The New Zealand Chemistry Curriculum
Levels 7 & 8

Selected studies in teaching, learning, concept
development and assessment

A dissertation presented in part requirement
for the degree of
Master in Science Education
in the
University of Canterbury
by
B R Henley

University of Canterbury
2001
## Contents

**Abstract**

**Preface**

**Acknowledgements**

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
</tr>
<tr>
<td><strong>Introduction</strong></td>
<td></td>
</tr>
<tr>
<td>1.1 Brief description</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Overview</td>
<td>1</td>
</tr>
<tr>
<td>2.</td>
<td></td>
</tr>
<tr>
<td><strong>Chemistry Teaching and Learning: The Issues</strong></td>
<td></td>
</tr>
<tr>
<td>2.1 Barriers to learning chemistry</td>
<td>3</td>
</tr>
<tr>
<td>2.2 Concept development and use of language</td>
<td>4</td>
</tr>
<tr>
<td>2.3 Misconceptions</td>
<td>8</td>
</tr>
<tr>
<td>2.4 Teaching to counter misconceptions</td>
<td>11</td>
</tr>
<tr>
<td>2.5 The assessment of chemistry</td>
<td>15</td>
</tr>
<tr>
<td>2.6 Summary</td>
<td>15</td>
</tr>
<tr>
<td>3.</td>
<td></td>
</tr>
<tr>
<td><strong>Validity of the University Bursaries Examination</strong></td>
<td></td>
</tr>
<tr>
<td>3.1 Introduction</td>
<td>17</td>
</tr>
<tr>
<td>3.2 The study</td>
<td>18</td>
</tr>
<tr>
<td>3.3 Conclusions</td>
<td>26</td>
</tr>
<tr>
<td>4.</td>
<td></td>
</tr>
<tr>
<td><strong>Part One: Concept Development and Students Understanding</strong></td>
<td></td>
</tr>
<tr>
<td>4.1 Introduction</td>
<td>28</td>
</tr>
<tr>
<td>4.2 Method</td>
<td>29</td>
</tr>
<tr>
<td>4.3 Results and analysis</td>
<td>30</td>
</tr>
<tr>
<td>4.4 Conclusions</td>
<td>32</td>
</tr>
<tr>
<td><strong>Part Two: Students Understanding of Precipitation Reactions</strong></td>
<td></td>
</tr>
<tr>
<td>4.5 Introduction</td>
<td>33</td>
</tr>
<tr>
<td>4.6 Method</td>
<td>33</td>
</tr>
<tr>
<td>4.7 Results</td>
<td>37</td>
</tr>
<tr>
<td>4.8 Discussion</td>
<td>38</td>
</tr>
</tbody>
</table>
5. An Evaluation of the New Chemistry Curriculum
   5.1 Introduction 40
   5.2 Method 40
   5.3 The questionnaire results 42
   5.4 The application test results 51
   5.5 Conclusions 59

6. Overall Conclusions
   6.1 General conclusions of the studies 62
   6.2 Implications and further study 64

References 66
Appendices 72
Abstract

This dissertation looks at questions relating to the New Zealand chemistry curriculum. The main findings relate to chemical misconceptions, concept development, pupils’ views of their learning environment, problem-solving ability and assessment of chemistry at year 13 level. Moreover, it shows how each is related to the current state of chemistry teaching, learning and assessment in the New Zealand curriculum. Relationships between pupils’ ideas of their own learning, their ability to understand important chemical concepts and to problem-solve, are described. These relationships give an indication of the strengths and weaknesses inherent in teaching and assessing chemistry, as well as identifying barriers to understanding that need to be addressed. Concept development is shown to be hindered by misconceptions, even though these alternative conceptions have been well documented here and overseas. Serious misconceptions are described regarding physical/chemical change, aspects of the kinetic theory of gases, chemical reactions and the mole concept. An intervention study of concept development using a discovery constructivist method is described that indicates this type of approach has real value for some aspects of chemistry. The approach may lend itself to student investigations in classification of matter, chemical analysis, equilibrium reactions, polarity of molecules and yield of an organic product. The ability of students to problem-solve and apply their knowledge and skills to new situations is strongly correlated with factors such as attitude to experimental work. There are, however, important skills detailed in the curriculum that are not covered by the current University Bursaries examination. These centre on problem-solving and include focusing, planning, information gathering, experimenting and reporting. There are aspects of some classroom environments, such as perceptions students have of the best way to learn and teacher controlled lessons, that encourage a passive role in learning (particularly for female students).
Preface

The author has been teaching chemistry and science for 20 years and has concerns about the level of understanding of important chemical concepts by senior science pupils. These concerns have prompted the research described in this dissertation, in an attempt to shed light on the best ways students learn and to discover where the difficulties in understanding lie. This is a large field and much research has already been undertaken, as evidenced in chapter 2, but the author remains concerned at the paucity of research results that have filtered down to the teaching level. Many teachers are simply not aware of what the researchers are doing, while for others the new information is not presented in a practical manner. It is hoped that the research described in this dissertation will be of benefit to chemistry teachers.

While it is acknowledged that many factors influence learning, this research has not taken account of socio-economic factors or cultural differences. It is also noted that students live in a media-saturated society and are constantly bombarded by computer images and television advertising. Consequently their ability or desire to learn science may be diminished in favour of more immediate goals. Perhaps for many students a limited understanding of science and chemistry is all that teachers can hope for. Having said this, chemistry teachers will always strive to improve ways of learning for their students.
Chapter 1 Introduction

1.1 Brief description

This study is centred on the New Zealand chemistry curriculum. In 1994 the curriculum was changed in line with the new curriculum achievement initiative affecting all subjects in New Zealand. Chemistry knowledge gained is cumulative and is intended primarily to prepare students for first year chemistry studies at tertiary institutions. Oughton (1999) provided a thorough review of these curriculum changes and in particular the development of ‘Chemistry in the New Zealand Curriculum, 1994’ (CINZC) before its distribution to schools in late 1994. Previous attempts during 1995-1998 at a new science syllabus with a heavy constructivist ‘flavour’ were abandoned with a change of government. The final document, heavily modified by submissions to the draft, was considered to be ‘moving away from a constructivist philosophy and was welcomed by many chemistry teachers’ (Oughton 1999).

In the introduction to the CINZC document, it is stated ‘study in chemistry enables students to……develop their understanding of the nature and behaviour of matter and… develop an understanding of the interaction between chemistry and technology’ (p6). One of the main aims of CINZC is to develop students’ understanding of chemistry concepts. The CINZC document clearly details aims, objectives, sample learning concepts, possible learning experiences and assessment examples. This new document however has only been of limited use to teachers during the last five years (Oughton 1999) with less than 20% of respondents to a survey reporting 'very successful' implementation in their schools.

1.2 Overview

Chemistry is a very complex subject and this has important implications on the way it is taught and learned. For most science students in New Zealand the first real introduction to the study of chemistry comes in year 11 (level 6), but intensive teaching does not begin until year 12 (level 7) and continues at year 13 (level 8). There has been considerable concern shown by extensive studies overseas (Heron 1999) in the way students bring alternate understandings of important concepts to their study of chemistry. Research by Metcalfe (1996) showed that at this time students in Christchurch also had these misconceptions. Other studies overseas showed that while some students may understand some concepts, they have difficulty in applying them to new or real-life situations (Bodner 1992). In New Zealand the new chemistry syllabus was
designed to have a new approach to learning that clearly identified the content and made suggestions of suitable contexts to improve understanding of basic concepts. This new syllabus has been taught since the start of 1997. The following important questions need to be answered before the value and impact of the new curriculum can be ascertained. Has the change signalled an improvement in the teaching and learning of chemistry? (in particular has there been any improvement in the understanding of basic concepts?). Do the pupils themselves feel that they ‘understand’ chemistry? Can they apply their knowledge? Is the new chemistry curriculum being properly assessed? The overall aim of this study was to determine the effectiveness of the chemistry teaching and learning programme designed to implement the New Zealand chemistry curriculum levels 7 & 8. The specific objectives were achieved by undertaking four separate studies:

1. Look at the validity of the University Bursaries chemistry examination.
2. Study students’ understanding of the particle nature of matter at three age levels.
3. Compare a discovery method of chemistry teaching with the more traditional approach.
4. Find out what students think about their chemistry learning and problem-solving ability.

Chapter 2 provides a literature review of relevant research dealing with barriers to learning, misconceptions, teaching methods and learning strategies shown to be effective. It also reviews the research on the effect of the new curriculum on the teaching of chemistry levels 7 & 8 in New Zealand. Chapter 3 examines the assessment of levels 7 & 8 chemistry at the University Bursaries level and investigates whether this examination is a valid assessment of the chemistry curriculum levels. Chapter 4 is in two parts. Part 1 is a study concerned with chemical concept understanding among pupils of different ages. The aim is to evaluate the development with age of an understanding of the particle nature of matter. Part 2 describes an intervention study that shows the effect of a new discovery method of learning on students’ understanding of precipitation and ionic reactions. Chapter 5 describes a larger study involving 60 year 13 chemistry students. This study seeks information about students’ understanding of their learning environment, their understanding of some important concepts and their ability to solve problems. It also looks at the relationship between students’ ways of learning and their ability to apply knowledge and skills to new situations. Final conclusions and the main summary are included in chapter 6.
Chapter 2  Chemistry Teaching and Learning: The Issues

This chapter examines the main issues relevant to today’s teaching and learning of chemistry at secondary level and describes the work done in identifying specific barriers to learning. Teaching strategies that may assist students to overcome misconceptions are presented and analysed and the relevance of such strategies to New Zealand chemistry teaching is considered. The issues identified in this dissertation as being the most important for teaching and learning chemistry in the New Zealand context are; (1) the development of important concepts; (2) the influence of misconceptions on learning; (3) the ability of students to posttest; (4) teaching strategies shown to be effective and (5) the assessment of chemistry as a guide for teachers.

2.1  Barriers to learning

Chemistry is complex by its nature and the implications of this for teaching and learning have been, and remain, far-reaching. Since the revolution in curriculum change in the 1960s, there have been great developments in teaching and learning programmes. (Johnston 1993). The main emphasis on experimental discovery and concept development appeared to the educators of the time to be full of promise, revolutionising the learning of chemistry. However, continued dissatisfaction at all learning levels, falling rolls in chemistry classes globally and a perceived view that chemistry is ‘difficult’ have led to a growing sense of crisis. Research in chemistry education, particularly over the past twenty years, has led educators to realise there are major problems to be addressed. Gabel (1999) summarises the ‘barriers to learning chemistry’. She lists these as:

* Abstract concepts that are inexplicable to students
* Having to understand and work simultaneously in three levels (macro, symbolic and sub-micro)
* The difficulties associated with experimental work
* Use of unfamiliar materials
* Use of strange language and terms
* The structure of chemistry

The research has shown that such barriers to learning are widespread and significant for most learners and even for some teachers. The existence of barriers needs to be acknowledged and
understood by teachers so that the design of chemistry programmes can take account of them. Some of these barriers are described in the succeeding sections.

2.2 Concept development and use of language

Many of the concepts traditionally taught require a thorough understanding of the particulate theory of matter and cannot be fully understood without resort to models. Physical/chemical change and element/compound distinctions are two examples mentioned by Gabel (1999) as giving particular difficulty. In New Zealand, Metcalfe (1996) has shown similar problems for learning atomic structure and bonding. In addition, long held incorrect concepts have proven difficult to change, even after extensive teaching, because students of chemistry have to make personal sense of new concepts before they are accepted. This resistance to change is, however, understandable because some of the scientific explanations appear to defy common logic in the sense of improving the quality of chemistry teaching.

2.2.1 Representation of matter

The three-fold representation of matter explained by Johnston (1993) is a well received model, used to explain the difficulties students have with learning chemistry. Experienced teachers can move easily within this triangle and slide from the macroscopic (what can be seen, smelt, heard or felt) to the sub-microscopic (particulate - ions, atoms and molecules) and to the symbolic.

![Diagram of representation of matter]

It is hard to disagree with both Johnston and Gabel that this complex representation of matter is fraught with difficulty for students and remains a significant barrier for many to understand chemistry. Research (Johnston 1997) shows much of the time spent on experimental work is wasted because many students cannot make connections between practical work and theory. Procedures in standard laboratory manuals contain many instructions that perhaps mask the true intent of the exercise. This ‘noise’ confuses the students and much time is spent on figuring out how to do the experiment rather than understanding the science behind it. Often there is the added complication of a time constraint and this unfortunately creates the main driving force.
Learning appears secondary to ‘getting it finished’. Work by Johnston and his research team at Glasgow University (1997) has shown that pre-labs (together with post-labs) have greatly enhanced both the understanding and relevance of experimental work.

Many of the words and expressions used in everyday life have different usage and meaning in chemistry. Some are noted by Gabel (1999) - words such as ‘element’, ‘compound’ and ‘pure’, together with expressions such as ‘the solution is weak’ cause confusion for some students. Careful definition and use by teachers is necessary to overcome these problems. There are also concerns from educators about the way chemistry is taught. No clear consensus of the most effective structural approach has been achieved (Metcalfe 1996). The traditional approach in which more theoretical aspects of atomic structure and bonding is taught is now being challenged and alternative methods focusing on a real-life contextual approach are encouraging for teachers (Beasley 1996).

2.2.2 Testing for conceptual understanding

A test of conceptual understanding is to be able to transfer that understanding to a new situation. Real-life situations often involve a challenge for students because they find it hard to link what they have learned to the new context. Consequently, testing for understanding of basic concepts should involve problems students have not seen before.

In the United Arab Emirates, Haidar (1996) tested prospective chemistry teachers for their understanding of the concepts of conservation, mole, atomic mass and chemical reactions. The results showed that understanding ranged from partial to zero. However, he reported that balancing of equations was an area that showed good understanding or algorithmic application. Most teachers relied on memorisation of concepts without understanding. What was understood was also fragmented. The effect of experience on retention and elimination of misconceptions about molecular structure and bonding was studied by Birk and Kurtz (1999). Their research shows that changing misconceptions is slow and difficult but fortunately has mainly disappeared by the time students enter university.

In Turkey, Ayers and Demirbas (1997) worked with a standardised test on five concepts administered to 556 students at secondary schools throughout the country. The test had two parts - knowledge of concepts and application of concepts to everyday situations. Results showed that not only were introductory concepts not well learned by secondary students but that a great number were not able to apply their knowledge in practical situations.
In New Zealand assessment of chemistry occurs at level 7 (6th Form Certificate) and level 8 (University Bursaries). While this assessment provides information about general levels of understanding, the application of learned concepts is not well tested. The development and use of the application test, described in chapter five, is in line with the work done by Ayers and Demirbas. This application test is needed to illustrate how well students apply conceptual understanding to new situations outside the classroom such as in the home or the workplace. The test also provides evidence of how well New Zealand students compare internationally.

2.2.3 How do concepts develop?

Nakhleh (1992) identifies two misconceptions centred on the particle nature of matter and the kinetic theory. Studies show that students have a continuous, rather than a discontinuous, view of matter, and a static, rather than a kinetic, view. There were also many problems with students’ understanding and explanation of chemical equations. Nakhleh’s research is based on a cognitive model in which students construct their own concepts and generate their own meaning. However, many students are not doing this at a fundamental level and consequently cannot build more advanced concepts at a later date. The author contends that educators need to:

* Make clear the difference between atom, molecule and ion
* Ensure there is adequate understanding of the kinetic behaviour of these particles and
* Clarify confusion in chemistry language by emphasising difference between the ‘everyday’ meaning and the ‘scientific’ meaning of terms used.

Ben Zvi (1988) echoes this problem with chemistry language in a study of children’s understanding in Israel. Apart from the language difficulty the concepts taught were abstract and non intuitive. Students who already have their own ideas of atoms and molecules will retain their views for a long time with modification coming only slowly. A feature of Ben Zvi’s work shows that children often transfer the macroscopic properties of the substance to the atom or molecule of the substance.

In the Netherlands, Vos and Verdonk (1996) examine differing views on the particulate nature of matter. There were not only differences in understanding between students and their teachers but also between teachers and scientists. An attempt was made to standardise the current thinking on the particulate model of matter and to achieve consensus on what is a valid description of this model of matter which can be acceptable to all educators.
In an attempt to establish levels of understanding of five chemistry concepts with age and reasoning ability, Abraham and Williamson (1994), in the United States of America, worked with 300 students at junior high school, high school and college. They found that concepts of chemical change, dissolution, conservation of atoms and periodicity were significantly affected by both the age level and reasoning ability of the students. Not surprisingly, the reasoning ability of the younger students was a limiting factor. These researchers believe that the central instructional problem of beginning chemistry is ‘helping students link experience-based observations of chemical phenomena, discovered in the laboratory, with the chemists’ abstract atomic and molecular models which explain those phenomena’. This is an important statement which best illustrates the problems for teachers of chemistry. However, Abraham and Williamson also caution that long-held misconceptions are difficult to shift because the new explanations may well be incomprehensible to students, even in the face of apparently overwhelming evidence.

De Jong, Aampo and Verdonk (1995) studied the learning of redox reactions among grade 11 students in the Netherlands. Electrochemistry was ranked by both students and teachers as one of the most difficult topics in the chemistry curriculum. From a constructivist point of view they agree with a conceptual change model elaborated by Posner et al (1982). In the study they use this model to illustrate the problems associated with the normal learning of the concept of oxidation and reduction. The main problem seems to be an instructional flaw that many teachers are simply not aware of and, as a result, these teachers do not appreciate the learning problems students have with the concepts. The application to industrial and real-life situations is not well done and would appear to reinforce the genuine difficulty students have with transferring their understanding to new situations.

2.2.4 Models of learning

How do students actually process information so that it enters and stays in long-term memory? This is an important question that needs an answer. While this research is highly theoretical and, at first glance, might not seem practical to classroom teachers, it is useful in giving a possible mechanism for how students process and store information. It may point to how chemical concepts are formed and modified. According to Gabel (1999) there are two vital models:

The Information Processing Model (Johnston 1993, 1997) explains how the two areas in
the brain process and store information. The short-term working space has limited volume and new information will only be stored in permanent (long-term) memory if suitable linkages are found and information is correctly filed. New information about a chemistry concept must be linked to previous knowledge or it is not fully understood. Too much chemical or other information at once will cause overload of the brain's working space, will not make sense and consequently reconstruction of a concept cannot take place. This model, which is gaining international recognition, would appear to give us a valid understanding of how concepts are learned. The model is similar to one proposed by Nuthall (1997) that focuses on important connections being made between existing knowledge and new information before being lodged in permanent memory.

The Social Constructivist model (Krajcik 1994) sees students constructing new meaning for a concept only after they have considered their current understanding through social interaction with their teachers or other students. Gabel (1999) further states that both these models are important to research in the 21st century and that they will give understanding of how students learn concepts in chemistry. Students do appear to learn in several different ways and the research in this area by Johnston, Nuthall and Krajcik is also valuable for teachers to understand how their students learn most effectively. However, this information must be presented in a form that is practical and of use to teachers if the benefits are to flow to the students.

Students have difficulty with the language of chemistry and development of concepts. This problem is antagonised by the alternate understandings they invent to rationalise their interactions with the world. In many cases this leads to serious misconceptions. Such misconceptions are discussed in the next section.

2.3 Misconceptions

Considerable research has been conducted on misconceptions in chemistry. A misconception here is defined as an understanding of a chemistry concept that is different from the accepted scientific view. These misconceptions abound in all areas of chemistry and global research has been conducted on these in depth for the past twenty years. They are not delocalised, but are commonly held views and understandings that transcend international boundaries. Major reviews of the research have been conducted by Gabel (1996, 1999), Metcalfe (1996), Mintzes, Wandersee and Novak (1996) et al. A review by Heron (1999) has
noted over 100 references.

2.3.1 Development of misconceptions

Research shows these misconceptions develop from a very early age according to the experiences a child has. As the child grows, more evidence is available which serves to either reinforce beliefs or to challenge them. By the time he/she reaches high school it is very difficult to shift such conceptions. Mintzes, Wandersee and Novak list what they call ‘emergent knowledge claims’ that seem to be the consensus of much research.

1. Learners come to formal science instruction with a diverse set of alternative conceptions concerning natural objects and events.

2. The alternative conceptions learners bring to formal science instruction cut across age, ability, gender and cultural boundaries.

3. Alternative conceptions are tenacious and resistant to extinction by conventional teaching strategies.

4. Alternative conceptions often parallel explanations of natural phenomena offered by previous generations of scientists and philosophers.

5. Alternative conceptions have their origin in a diverse set of personal experiences including direct observation and perception, peer culture and language, as well as in teachers’ explanations and instructional materials.

6. Teachers often subscribe to the same alternative conceptions as their students.

7. Learners prior knowledge interacts with knowledge presented in formal instruction, resulting in a diverse set of unintended learning outcomes.

8. Instructional approaches that facilitate conceptual change can be effective classroom tools.

These specific claims illustrate just how difficult it is for scientific concepts to replace ideas/explanations that appear worthy. In particular the symbolic and sub-microscopic nature of chemistry increases this difficulty. Even with this extensive list some relevant aspects are not addressed. For example, claim #2 ignores socio-economic factors that should be included and the use of the word ‘alternative’ in claim #6 needs clarifying.

There is very little relevant research on misconceptions being conducted in New Zealand. Metcalfe (1996) has presented a dissertation in part for her MScEd degree which focuses on
Form 6 (year 12) students' misconceptions in their understanding of atomic structure and bonding. Her results clearly show the same common misunderstandings that have been well documented elsewhere. In her review of current literature she summarises in part the historical development of the New Zealand chemistry curriculum and justifies the strong constructivist approach to it. She notes that the six main concepts listed have all been difficult to comprehend and understand by students because of the sub-micro nature of the particles involved and the language that is required for adequate description. Her review illustrates the many studies carried out on misconceptions particularly relevant to the understanding of atomic structure and bonding, including metallic bonding. Her research work concentrates on these misconceptions among Christchurch year 12 students and compliments the work done overseas. She found the main areas of confusion related to the concept of a molecule, the bonding of atoms and molecules, ionic bonding and changes of state. Teachers she interviewed all agreed that these concepts posed many problems for their students. Misconceptions, therefore, are possibly widespread in New Zealand and need to be identified at an early age.

2.3.2 Identification of specific misconceptions

Gabel and Samuels' (1987) study revealed serious misunderstandings of the particulate nature of matter and also showed that, although students could write formulae and balance equations correctly, their understanding was limited. This is in line with other similar studies and reinforces the often stated claim that real problems do exist for most students of chemistry. Further studies by Smith and Metz (1996) confirm that these misconceptions are widespread. They studied students' understanding of important concepts which included particulate and discontinuous views of matter, states of matter, chemical reactions and solution chemistry. Microscopic representation diagrams were used to illustrate the concepts and they clearly reveal the students' understanding. Boo (1997) presents an excellent review of misconceptions in a study of grade 12 students' understanding of the nature of chemical bonds and energetics across five reactions. Results show a range of chemistry conceptions at variance with the scientific view. Only 15% of students in the study could predict that each of the reactions studied was exothermic and at the same time give an explanation in terms of the energy in chemical bonds. Most seemed to hold the misconception that bond-making requires energy and bond-breaking releases it. For nearly 50% of students this notion seemed to be linked to the everyday observation that building a structure requires an energy input and destroying a building.
releases energy. There was also confusion evident among these students about the nature of ionic bonds and the driving force of reactions. This work by Boo gives an excellent platform for identifying misconceptions and points to the need for continual research into the revision of curriculum materials and teaching strategies.

Earlier workers, Abraham (1992), Griffiths and Preston (1992) and Lee et. al.(1993) also concentrated on the identification of specific misconceptions in chemical change, particle nature of matter and chemical bonding. The study by Boo however, is extensive and demonstrates that various methods for testing for misconceptions are being made available. The focus must now shift onto ways of teaching to counter these misconceptions. Several of these strategies/approaches are described in the next section.

2.4 Teaching to counter misconceptions

The prevalence of misconceptions is worldwide and has been well documented. Ways of countering the development of misconceptions are now being recognised and several new teaching strategies/approaches are discussed in this section. The role of the teacher is crucial in using and linking many different teaching strategies, allowing students many opportunities to make their concepts more scientifically acceptable. Gabel states that social interaction, use of analogy, models and concept maps, use of technology and sound laboratory instruction are all seen as important. Misconceptions in chemistry have been well identified and the focus must now shift to more effective teaching methods.

An extensive research study done by Laverty and McGarvey (1991) established a constructivist approach to learning that showed gains in the way students developed and used accepted ideas. This study involved active learning strategies such as small group discussion, class discussion, practical work and reporting back. Several posttests and other assessments showed sound learning gains and up to 82% had acquired the accepted scientific explanation.

Bodner (1992) also focuses on the constructivist approach and emphasises active learning which minimises these misconceptions. He states ‘students often held knowledge without understanding’. He also cites clear evidence that students were virtually unable to apply their chemical knowledge to the world in which they live (p 187). Heron and Nurrenbern (1999) compared the two main perspectives - behaviourist and constructivist - which have shaped chemical education research. Their study illustrates the shift over the past 50 years from one to the other and describes several constructivist models that appear to have been successful in improving understanding. Given the common misconceptions outlined above, it is appropriate to
reflect on the concepts that should be inculcated. Gillespie (1997) illustrates what he calls the
great ideas of chemistry: atoms molecules and ions; chemical bonds; molecular shapes; kinetic
theory; chemical reactions and energy and entropy. He contends that, in the past, these ideas
have been presented initially in too much detail and that a substantial amount of time was
required to make sure they were understood. Testing students’ understanding of these basic
concepts required a large number and variety of qualitative questions.

A new philosophical basis for teaching chemistry is described by Spencer (1999), who
compares traditional and student focused approaches to learning chemistry. This model is based
on developments in the learning process of the last twenty years and emphasises the gains to be
made in such an approach to learning. However this constructivist approach may be only useful
in certain topics that lend themselves to student investigation. Shiland (1999) also studied the
value of this philosophy in redesigning many aspects of laboratory work. This shows much
promise for making laboratory activities more meaningful thus creating a better learning
environment. Part two of chapter 4 illustrates such an approach as advocated by Shiland.

2.4.1 The value of an experimental approach

Several studies have concentrated on ways to improve understanding and generate
greater interest in chemistry. Bent (1984) emphasises the importance of good demonstrations
involving the use of chemical models: ‘Indeed, to be useful, a model must be wrong in some
respects - else it would be the thing itself. The trick is to see with the help of a teacher - where
it’s right.’ For example the properties of sulphur are soundly and vividly shown by heating the
solid in a test-tube and pouring the contents into water. Descriptive chemistry is seen as an
important and powerful tool for capturing the imagination. Swim (1999) describes an outreach
program in the United States of America, where high school chemistry students presented
chemistry demonstrations to the junior highs. This successful approach had several advantages
for the young demonstrators in that they began to understand the concepts involved and their
interest was awakened. Teachers in elementary schools were very enthusiastic about the impact
on their students. They reported many students who were now looking forward to studying
chemistry upon entering high school.

The experimental approach is also seen as valuable by Henderson and Mirafzal (1999)
who designed an experimental tour for the first day of chemistry class. The four experiments
described allowed students to discover principles related to states of matter, classification of
matter, density and chemical change. It is the author’s contention that students taught through
this experimental style achieved greater understanding of concepts. The experiments were set in
everyday contexts and a constructivist approach adopted.

In the United States of America, Hilosky, Sutman and Schmuckler (1998) looked at the
worth of laboratory work. They found, generally, that it was too self-contained and did not
correlate well with future instructional sessions. This study has made its own recommendations
such as reducing the number of investigations, linking labs more with future instructions,
training lab instructors more as facilitators and including laboratory work as part of the overall
assessment of courses. A recommended format is included in the article and may prove useful
for teachers; it gives details of the roles of instructor and student, the type and duration of
laboratory tasks, the assessment of learning, environment concerns and outcomes.

Experimental work is a valuable way to learn chemistry but it must be set up in a similar
fashion to that advocated by Hilosky and be seen as a worthwhile approach to understanding.

2.4.2 Innovative contexts

There have been many new contexts used by teachers in an attempt to increase students’
interest in learning chemistry and to improve their conceptual understanding. These have been
successful to different degrees and useful for their particular purposes.

In Israel, Stavey (1991) used analogy to change misconceptions. She found this
approach can help students to discard previous ideas and learn new information if their existing
conception is challenged and found to be unsatisfactory in some way. This was an
interventionist method using control and experimental groups with pre and post-test instruments
to measure learning gains. Epstein (1998) investigates the use of ‘bad’ science to teach ‘good’
chemistry. The author describes teaching chemical principles in the context of historically bad
science and then explaining why it was so. This approach seemed to be more palatable for the
students and it provided a classroom atmosphere where students were required to think about
approaching a scientific problem in a critical and open-ended manner. Some interesting
examples were given that could be used as starters for discussion in chemistry classrooms. An
intervention study was undertaken by Lin (1998) that compared two approaches to the study of
chemistry. The more traditional method of learning some basic concepts such as atomic theory,
formulae and Avogadro’s hypothesis, was contrasted with an historical approach. This
innovative method showed some gains in understanding of these concepts. The author contends
it is valuable to incorporate historical aspects into the teaching of chemistry. Interesting
anecdotes from the past may well serve to increase students’ interest and enthusiasm for
learning because it gives a human aspect to the knowledge.

Anthony et. al.(1998) describes a modular approach to learning chemistry. A real-life problem question is posed and students are given some background information. They then design their own activities to investigate the problem more fully, in a co-operative team approach. Presentation of results is through posters, debate or experimental report. This research is an evaluation of the program which has been in place for some years. Many different modules have been designed and more are planned. This approach may have some benefit for learning but it is the author's opinion that this method is too time consuming and there is too much variation in the quality of information.

A study by Nicoll and Trantman (1998) investigated four teaching formats which included normal lectures, concept maps, class discussion and co-operative learning. In comparing the effectiveness of each, student responses were used and these showed the different value each method had for different aspects of learning. Conclusions were that multiple methods of learning are valuable in that they enhance student participation. Ebenezer (1992) worked with students and concept maps, which he says can be used to examine their understanding of important concepts before an instructional unit begins. This approach has revealed alternate ideas and thus it becomes easier to plan activities either to modify students' thinking or elaborate on their ideas. The concept map helps students to recognise that they already know something about the topic. Regis and Albertazzi (1996) also describe concept maps as an aid to show the change in concept development over time. Towns (1998) describes how co-operative learning is instituted at a university first year chemistry course and how benefits accrue from this. Outcomes are described such as a feeling of community, a better classroom climate, more meaningful learning strategies and greater realisation of the students' own potential for achievement.

2.4.3 Use of models

In a study related to chemical models, Williamson and Abraham (1995) showed that many students lack the sub-microscopic understanding of phenomena because they cannot build a complete mental model that visualises particulate behaviour. Greater conceptual understanding occurred when students were exposed to computer animation because there is greater prompting of the formation of dynamic mental models. With the advent of more powerful computers and graphics programmes, the potential for effective interactive animation is vast. The importance of this technology to aid chemical concept understanding should not be understated. However, in
New Zealand schools little use is made of effective computer modeling due to a lack of suitable programmes. This is an area of need, and research needs to be focused on the best ways to make use of this technology.

The various teaching strategies and contexts outlined above have value for teachers because they are novel and increase students’ interest level. These have had demonstrated learning benefits for the students involved and illustrate the usefulness of models, historical connections, co-operative learning, modular approaches and experimental demonstrations. The development of new and innovative curriculum materials, including modelling of the particle nature of matter and chemical reactions, now needs to be a priority for curriculum planners.

2.5 The assessment of chemistry

The assessment of chemistry dominates and influences the teaching. As such it can be a highly influential motivating factor in the minds of students. Written examinations are the most common method of assessment, particularly at the higher levels such as year 13 chemistry in New Zealand. Because of the important status of such examinations, the teaching to a large extent is driven by them as a response to students having ‘success’. It is a sound programme that manages to assess all aspects of a curriculum. Often the more practical aspects such as experimental work and application of skills are tested in a minor way or ignored. Interesting contexts in which examination questions are based are now finding favour at the University Bursaries level and these are helping to make chemistry more relevant to the students. Amato-Wierda (1999) used theme-based exams to illustrate several important concepts. An example is given of the whole exam being based on the chemistry of the Galileo orbiter on its journey to Jupiter. Student reaction seemed positive and the results showed a small improvement in their examination results over the traditional approach. New and innovative approaches such as this may be more effective if they were extended to the whole year’s work and not be restricted to final examinations at the end of a course.

2.6 Summary

2.6.1 Issues addressed in this dissertation

There are important issues outlined in this chapter that point to a need for further investigation in the sense of improving the quality of chemistry teaching. It is the aim of this dissertation to address some of these in the context of the New Zealand chemistry curriculum. Creation and understanding of concepts, different learning approaches, identifying where
difficulties lie with the language of chemistry and the ability to problem-solve are issues that are of primary importance. Assessment issues such as coverage of the syllabus are also of concern because of their impact on student learning and these are analysed in chapter 3. The development of concepts by children to explain everyday occurrences and the modification of such concepts with age is a study that is described in part one of chapter four. The ability of a constructivist/discovery approach such as that advocated by Shiland and Spencer - to increase conceptual understanding of chemistry topics - may demonstrate a more effective way for students to learn. Such an approach to countering misconceptions is described in part two of chapter 4. The ability of our senior chemistry students to understand and apply concepts and to deal with the language of chemistry in a meaningful way is of continuing concern. A major part of chapter 5 addresses this important issue and describes how year 13 students approach problem-solving. The importance of experimental work and implementation problems are also vital issues identified in this section; these are also addressed in chapter 5.

2.6.2 Research questions

Research described in section 2.1 - 2.5 of this chapter illustrates the extensive work being undertaken to improve the teaching and learning of chemistry and it has provided the stimulus for this research dissertation. The concern, (with barriers to learning including concept-development, misconceptions, learning approaches and doubts about the implementation and assessment of the New Zealand chemistry curriculum), has led to the following fundamental questions:

* How well does the University Bursaries chemistry examination assess the new chemistry curriculum?

* How do students' understanding of specific chemical concepts develop over time?

* Will a new teaching approach make a significant difference to students' understanding of a chemical concept?

* What are students' perceptions of their chemistry learning and understanding, and how does this affect their confidence and learning?

* How well can students solve problems and how well can they apply their skills and chemical knowledge to new situations?

These questions are the focus of the four studies undertaken on the broad general aim stated at the end of chapter 1. These studies are described in the following chapters as outlined in 2.6.1.
Chapter 3

The Validity of the University Bursaries Chemistry Examination

3.1 Introduction

The culminating assessment of chemistry levels 7 & 8 is the University Bursaries chemistry examination. This chapter evaluates the validity of the examination in terms of content and context and also addresses two issues of current debate: curriculum changes and teacher concern. The following research questions are addressed:

*Does the UB chemistry exam adequately cover the syllabus in terms of the content and process skills?*

*Does the new contextual/thematic approach disadvantage students?*

3.1.1 Changes to curriculum

The chemistry syllabus changed in 1997 and a new examination prescription was prepared by NZQA ready for 1998. This prescription has been in force for two years of the examination: 1998 & 1999. The Chemistry in NZ Curriculum document (1994) clearly outlines the new approach to be taken by teachers and examiners and points to methods of assessment.

3.1.2 Contemporary debate

The validity of the University Bursaries examination is a relevant issue because there has been recent criticism from a group of Canterbury chemistry teachers (Rendle 2000). Such dissatisfaction with papers is not new. For example, Professor JE Packer (1996) writing about the 1995 paper says “The 1995 UB Chem paper contains a number of deficiencies, factual, symbolic and conceptual. The seriousness of these forces one to ask the question ‘Was this paper moderated by people of sufficient expertise?’” Professor Packer went on to detail criticism of 12 separate areas/questions. He concluded “This paper falls well below the standard that NZIC would expect of a national examination”. The chief examiner replied that there was no evidence for widespread concern. Nath Pritchard (1996), president of NZIC, criticised the marking schedule as inconsistent and recommended the use of practising scientists as moderators for the exam.

The criticism levelled at the 1999 paper was more substantial because of the large numbers of teachers involved. Neil McKeegan (2000), in a strong criticism of the 1999 paper, indicated concern in three main areas: The syllabus was not adequately covered, the contextual
nature of the questions disadvantaged students and the questions tested exceptions to the
knowledge rather than foundation knowledge. He said; ‘The examiner has little appreciation of
either the task of teaching at this level and of the learning capacity of a student’. Richard
Rendle (2000), representing 20 teachers, detailed 11 specific negative comments ranging from
the nature of the paper to the content and difficulty level of the questions. He summarised:
‘Only a few of the substances used by students throughout the year were referred to in the
questions’ and ‘The exam was conceptually too demanding for today’s year 13 students’. He
went on to give details of the major concerns in each question.

These claims were refuted by another chemistry teacher, Dr Jan Giffrey (2000) who
provided evidence to show that, in her opinion, much of the criticism was unfounded. She
contended her analysis showed that the 1999 paper extensively covered the prescription. She
says ‘The contextual questions provided all the extra information the students needed and her
analysis of such questions from the examiner’s report indicated that the candidates did not find
these questions particularly difficult’.

With such a debate raging it is prudent to undertake an in-depth study of the validity of
the UB exam.

3.2 The Study

3.2.1 Method

The content validity of the 1998 & 1999 exam papers was checked using a specially
designed curriculum profile. This profile (appendices 1 & 2) was based on the current
chemistry syllabus outlined in the Ministry of Education document ‘Chemistry in the New
Zealand Curriculum’ (1994), and on the NZQA UB chemistry prescription (2000). It included
the process skills that each student should achieve at levels 7 & 8, the basic concepts and
understandings of chemistry, and linked these skills with all subject topics. Setting up the
profile necessitated some subjectiveness in deciding what process skills would fit with topics.
The suitability of the profile was checked by an experienced chemistry teacher and adopted with
a few modifications.

The curriculum profile was used to check the 1998 and 1999 papers. The 1997 paper
was also included for comparison as the content of the new syllabus had changed only a little
from the previous one. Blank profiles were used for exams and the questions checked for:

* Topics covered

* Marks awarded for each part of a question

* Process skills assessed in each question
These examination profiles were then compared to the curriculum profile and areas underrepresented, over-represented or not represented were noted and summarised. In addition the total marks awarded for each of the 6 general content areas listed in Table 1 were calculated and compared to the exam topic coverage detailed in the prescription. From these comparisons it was possible to make some judgements on the content validity of the examination.

The contextual/thematic questions were examined to see if they adhered to the guidelines set out in the prescription and if they indeed provided all the information students needed to answer the questions without penalty.

3.2.2 Results
The results are reported as content coverage, process coverage and issues relating to contextual questions for the past three UB chemistry examinations. (Table 1 & 2)

3.2.3 Content coverage
The topics for chemistry are split into 6 general content areas (Table 1). All of the questions in the papers were classified into these areas and the allocated marks for each part, combined.

Table 1 General coverage of content areas

<table>
<thead>
<tr>
<th>Content area</th>
<th>Marks awarded %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Atomic structure &amp; bonding</td>
<td>15</td>
</tr>
<tr>
<td>2. Inorganic chemistry</td>
<td>15</td>
</tr>
<tr>
<td>3. Energetics of processes</td>
<td>15</td>
</tr>
<tr>
<td>4. Equilibrium</td>
<td>20</td>
</tr>
<tr>
<td>5. Oxidation &amp; reduction</td>
<td>15</td>
</tr>
<tr>
<td>6. Organic chemistry</td>
<td>20</td>
</tr>
</tbody>
</table>

These results showed that coverage varied from that recommended in the prescription:

<table>
<thead>
<tr>
<th>Areas under-represented</th>
<th>Areas over-represented</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>1999</td>
</tr>
<tr>
<td>Energetics</td>
<td>Inorganic chemistry</td>
</tr>
<tr>
<td>Equilibrium</td>
<td>Organic chemistry</td>
</tr>
<tr>
<td>1998</td>
<td>1998</td>
</tr>
<tr>
<td>Inorganic chemistry</td>
<td>Atomic structure</td>
</tr>
<tr>
<td>Energetics</td>
<td>Equilibrium</td>
</tr>
<tr>
<td>1997</td>
<td>1997</td>
</tr>
<tr>
<td>Energetics</td>
<td>Atomic structure</td>
</tr>
<tr>
<td>Inorganic</td>
<td>Equilibrium</td>
</tr>
</tbody>
</table>
Each year the content area of energetics of processes has been under-represented, and in two of the three years, atomic structure and equilibrium have been over-represented. Areas within 1.5% of the recommended marks were deemed acceptable. Every question was then looked at in detail and marks were identified in each of the topic areas. These results again illustrate wide variability (Table 2). For 1999, six of the topics were very under-represented (less than 5 marks) and three were not represented at all (0 marks).

### Table 2 Marks awarded per individual topic

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Electron configuration</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Chemical bonding</td>
<td>3</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Lewis structures</td>
<td>2</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Periodic trends</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Radioactivity</td>
<td>8</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>2. Group 17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transition elements</td>
<td>21</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>3. Energy in processes</td>
<td>11</td>
<td>17</td>
<td>11</td>
</tr>
<tr>
<td>4. Equilibrium</td>
<td>3</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Precipitation</td>
<td>10</td>
<td>12</td>
<td>27</td>
</tr>
<tr>
<td>Acid/base</td>
<td>13</td>
<td>27</td>
<td>18</td>
</tr>
<tr>
<td>Buffers</td>
<td>2</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>5. Oxidising &amp; reducing</td>
<td>12</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>agents</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volumetric analysis</td>
<td>10</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>Cells &amp; electrode potentials</td>
<td>6</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>6. Isomerisation</td>
<td>7</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Hydrocarbons/haloalkanes</td>
<td>3</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Alcohols</td>
<td>9</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Aldehydes/ketones</td>
<td>0</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Amines</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Acids &amp; derivatives</td>
<td>19</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>Polymers</td>
<td>0</td>
<td>7</td>
<td>11</td>
</tr>
</tbody>
</table>

**Examination profile**


<table>
<thead>
<tr>
<th>Topics covered</th>
<th>19/22</th>
<th>21/22</th>
<th>18/22</th>
</tr>
</thead>
</table>

20
The topics which were highly represented were acids & derivatives in organic chemistry (19 marks) and group 17 elements in inorganic chemistry (21 marks). There was a more even coverage in 1998 with only the buffers topic not represented although five other topics had less than 5 marks. However, the acid/base topic in the equilibrium content area took 27 marks. For 1997, acids & derivatives and precipitation reactions were over-represented.

3.2.4 Process skills

The CINZC document (p 8-9) lists eight general essential skills associated with the New Zealand Curriculum framework and applicable to the development of chemistry process skills. The following eleven process skills were selected as those most appropriate for demonstrating achievement at levels 7 & 8 of the chemistry curriculum:

1. Memory recall of chemical facts
2. Demonstration of understanding and explanation of concepts
3. Interpretation of patterns
4. Use of chemical terms/description
5. Writing formulae/equations
6. Using models/drawing structures
7. Numeracy including problems
8. Identification
9. Focusing/planning
10. Information gathering
11. Experimental/reporting

The UB exam clearly measure only the first 8 process skills. The last 3 are all part of the wider essential skill ‘problem-solving’ that is a very important part of achievement at level 7 & 8 of the curriculum. ‘The chemistry curriculum offers rich context for problem solving’ (CINZC 1994). The examination is a single 3-hour written paper. No provision has been made for assessment of skills 9, 10 and 11 which means that at this level about 70% of the curriculum skills are assessed and the other 30% are ignored.

3.2.5 Process skills coverage

Every question was examined in detail and process skills were identified in each of the topic areas. These are presented in Table 3:

21
Table 3  **Types of process skill covered per individual topic**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Examination profile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1999</td>
</tr>
<tr>
<td><strong>Atomic Structure and Bonding</strong></td>
<td></td>
</tr>
<tr>
<td>Electron configuration</td>
<td>1,2</td>
</tr>
<tr>
<td>Chemical bonding</td>
<td>2</td>
</tr>
<tr>
<td>Lewis structures</td>
<td>2</td>
</tr>
<tr>
<td>Periodic trends</td>
<td>2</td>
</tr>
<tr>
<td>Radioactivity</td>
<td>1,4,5,7</td>
</tr>
<tr>
<td><strong>Inorganic Chemistry</strong></td>
<td></td>
</tr>
<tr>
<td>Group 17</td>
<td>1,2,5,6,8</td>
</tr>
<tr>
<td>Transition elements</td>
<td>1,5,8</td>
</tr>
<tr>
<td><strong>Energetics</strong></td>
<td></td>
</tr>
<tr>
<td>Energy in processes</td>
<td>2,5,8</td>
</tr>
<tr>
<td><strong>Equilibria</strong></td>
<td></td>
</tr>
<tr>
<td>Equilibrium constants</td>
<td>2,8</td>
</tr>
<tr>
<td>Precipitation</td>
<td>1,2,5,6,8</td>
</tr>
<tr>
<td>Acid/base</td>
<td>5,7,8</td>
</tr>
<tr>
<td>Buffers</td>
<td>7</td>
</tr>
<tr>
<td><strong>Oxidation and Reduction</strong></td>
<td></td>
</tr>
<tr>
<td>Oxidising &amp; reducing agents</td>
<td>1,2,5,7,8</td>
</tr>
<tr>
<td>Volumetric analysis</td>
<td>1,7,8</td>
</tr>
<tr>
<td>Cells &amp; electrode potentials</td>
<td>2,7</td>
</tr>
<tr>
<td><strong>Organic chemistry</strong></td>
<td></td>
</tr>
<tr>
<td>Isomerisation</td>
<td>1,4</td>
</tr>
<tr>
<td>Hydrocarbons/haloalkanes</td>
<td>6,8</td>
</tr>
<tr>
<td>Alcohols</td>
<td>1,4,6,8</td>
</tr>
<tr>
<td>Aldehydes/ketones</td>
<td>-</td>
</tr>
<tr>
<td>Amines</td>
<td>-</td>
</tr>
<tr>
<td>Acids &amp; derivatives</td>
<td>1,2,5,6,8</td>
</tr>
<tr>
<td>Polymers</td>
<td>-</td>
</tr>
</tbody>
</table>

These results illustrate wide variability in the use of curriculum skills across all years investigated. Recall of chemical facts (1) has a major focus in atomic structure and bonding,
inorganic chemistry, oxidation/reduction and organic chemistry. Skill (2) - understanding and explanation of chemical concepts - is widely tested in atomic structure and bonding and equilibria. Other skills commonly assessed among the topic areas are writing formula/equations (5) and identification (8). Process skills 3 and 4 are rare. However the process skills of focusing/planning (9), information gathering (10) and experimental/reporting (11) are absent in all years. In summary, there is a prevalence of process skills 1, 2, 5 and 8 and an absence of process skills 9-11: an over-emphasis on facts and explanations and a lack of experimental problem solving.

3.2.6 Contextual/thematic issues.

Contextual and thematic questions were gradually introduced during the mid 90’s and this trend has continued. The new prescription (NZQA 2000) states:

'Candidates may be required to apply knowledge, understanding and acquired skills to unfamiliar situations. Where required information lies outside the prescribed content areas, this information will be provided as resource material in the examination paper. This applies particularly to questions that address the third objective in this prescription - analyse the interaction of chemical processes with people and the environment'

In view of these statements each of the exam papers was looked in detail to determine the effect this approach had on the performance of candidates.

For the 1997 UB paper, the examiner’s initial comments (Examiner’s Report 1997) included the comment: ‘Included are more contextual questions, and applications of chemistry to situations candidates were not expected to have encountered before’. In this paper seven questions could be regarded as contextual and each contained an introductory statement that linked the question to ‘interaction with people or the environment’ These included:

* The Chernobyl explosion
* Killing cancerous cells by ‘buttons’ of radiation
* Using household bleach
* Use of salts in melting of the ice on roads in winter
* Lead in paint on school buildings
* High temperature combustion of fuels in car engines
* Oxidation of glucose in muscles
* Chemical smells in barbeque cooking.

Each of these statements clearly established the context of the questions but they were not
necessary to answer the chemistry. Their use was to establish a familiar or new situation where the *relevance* of the chemistry involved is important. These contexts were unlikely to have any negative effect on candidates ability to answer the questions and indeed were not mentioned in any of the detailed analyses of the answers. Any such inability was due rather to the candidates lack of knowledge or understanding of concepts. An NZQA survey conducted after this exam showed high satisfaction with the coverage (Examiner’s Report 1997). Difficulties with the conceptual nature of the questions in this exam were not mentioned at any stage of this report. The overall mean mark for this paper was 50.3%; similar to the previous two years.

1998 was the first year of the new syllabus. In the introductory examiner’s comments it was noted *The use of a thematic approach, where the concepts were applied to situations which were possibly unfamiliar, may have caused some difficulties*. A close look at the questions revealed the following contextual references:

* The absorption of iron by rhododendron plants
* The effect of clay and peat soils on absorption rates
* The % iron in soil
* Methane as a fuel in car engines- high temperature combustion
* Sourcing of ethanol in wine by oxidation
* Self-dissolving surgical stitches
* Housefly sex attractant
* Fruit juice & vinegar preservatives
* Composition of garden fertiliser
* Yellow pigments used in oil painting changing colour
* Starch polymers

As in the 1997 paper, these references were given mainly as introductory sentences and these served primarily to put the question in an interesting context. In the marker’s comments for each question there was not one mention of confusion relating to this contextual and thematic approach. Table 4 shows the mean marks for each question.

**Table 4**

<table>
<thead>
<tr>
<th>Question</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean mark</td>
<td>51</td>
<td>63.3</td>
<td>55.4</td>
<td>55.5</td>
<td>47.4</td>
<td>45.4</td>
<td>57.6</td>
</tr>
</tbody>
</table>

These marks are within the range obtained in previous years and it would seem that the new approach had little influence. The examiner’s comments on each question indicated that it was the understanding and application of chemistry that determined marks and variation in the mean.
scores. Introductory comments by the examiner in his report may well have been over-stated.

The 1999 paper, included approximately the same number of contextual and thematic questions as the 1998 paper. The raw mean mark for 1999 was 54.5, slightly higher than in previous years. The following contexts were used in the eight questions:

* Ammonia gas & CFCs as refrigerants
* CFC stability in the ozone layer
* Swimming pools and chlorine
* Thyroid gland & iodine
* Radioactive iodine
* Animal fat, lard & hydrogenation
* Rusting in a droplet of water
* Car bodies and galvanised steel
* Vitamin C occurrence & antioxidant properties
* Apple juice & orange juice pH
* Shellfish & protective shells
* Solubility of shells

Once again these contexts were used as introductory sentences showing how chemistry was relevant to people and the environment. Considering all the examiner’s comments (Examiner’s Report 2000), very few related to the contextual or thematic approach having an adverse affect on the candidates’ ability to answer the questions. Only two questions contained parts that caused some difficulty: (worth 3 marks in total)

Q7 The word ‘synthetic’- explaining if synthetic and natural vitamin C were the same.
Q3 Hydrolysis of ‘lard’ & saturation caused by ‘hardening’

The mean scores for the the 8 questions were:

<table>
<thead>
<tr>
<th>Question</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean mark</td>
<td>65.3</td>
<td>54.8</td>
<td>41.4</td>
<td>60</td>
<td>46.2</td>
<td>51.3</td>
<td>55.6</td>
<td>41.3</td>
</tr>
</tbody>
</table>

A detailed knowledge of the contexts used in the questions was not necessary to answer them. All the necessary information needed to answer the questions was given and the variation in the means was again due to the inability of candidates to understand and apply concepts. Indeed for the most heavily criticised question (Q7-Vit C) the mean mark was the third highest confirming the contextual/thematic approach had no detrimental effect. Overall, the examiner’s report
shows that low marks in some questions are a result of the candidates lack of chemistry ability rather than confusion over contexts or themes.

3.3 Conclusions

3.3.1 Content validity

The results indicated that the three examinations considered all had content validity. There was some variation between years, as expected in a single 3 hour exam, but each year 85-95% of the prescription content was tested (Table 2). However, the content area of energetics of chemical & physical processes had been under-represented each year. Within content areas, several individual topics had been given greater emphasis, such as acid/base chemistry, group 17 elements and organic acids/derivatives. Topics of equilibrium and buffers had been under-represented. These comments aside, content validity existed in all these examinations, because of the strong relationship between the prescription and the content of the questions.

3.3.2 Process skills

A variety of process skills were required to be demonstrated by the candidates in answering the questions. These were reasonably well distributed throughout the topics and show a commitment on the part of the examiners to make the examination as wide-ranging and relevant as possible. However, the examination does not adhere to the curriculum requirement of testing all essential skills as the problem solving experimental component of the curriculum is absent. In addition, there is still a tendency for a reliance on questions that test recall of chemical facts; an important issue that is also significant in the research reported in chapter 5.

3.3.3 Contextual/thematic questions.

The examination mean marks indicate candidates did as well in the last two years as in previous years. No comments (apart from some introductory cautions) on individual questions were related to the contextual/thematic approach as having any adverse effect on candidates’ ability to answer questions: The variation in the mean mark of the questions was due to lack of knowledge or application. The introductory sentence at the beginning of a question gave an interesting context, in-line with achievement aim 1 (CINZC 1994). All information to answer the questions was given as stated in the prescription with the exception of isolated facts such as the meaning of terms ‘fatty acid’, ‘saturation’ and ‘lard’.
In summary, these examinations had content validity, required a limited range of process skills to be demonstrated and asked questions in interesting contexts that did not disadvantage candidates in any way. This study has shown that much of the criticism of the 1999 paper is unfounded, although there are concerns about the lack of evaluation of some process skills. The fact that very important skills could not be assessed by the University Bursaries examination is still of concern. Developing scientific skills and attitudes through investigative and practical work is an important part of the new chemistry curriculum (Achievement aim 2) and until some form of internal national assessment covers this, full assessment is not possible. Consequently, there is low motivation among students to develop these skills and little guidance from teachers who are mainly focused on their students passing the examination.
Chapter 4
Part One: Concept Development and Students Understanding

4.1 Introduction.
This chapter describes a small study into the nature of concepts that students may hold concerning some important aspects of the particulate state of matter. Through a series of demonstrations and interviews data was gathered and analysed for comparisons between the students’ observations. Misconceptions about scientific concepts abound. Generally, people construct suitable viewpoints which they feel comfortable with and many make use of today’s advanced technology without needing to understand the scientific principles behind it; indeed, most do not need to. Chapter 2 was concerned with misconceptions students bring to their study of understanding natural phenomena. In the discussion it was shown that misconceptions which have been personally constructed through life experiences and interpretations tend to be deep-seated and difficult to shift or change. Many different teaching strategies have been employed in an attempt to provide a coherent approach to concept development.

4.1.1 The basic concepts of chemistry
As far as chemistry is concerned, several key conceptual areas have been identified by researchers and some of these form the basis of this study. The most important concepts for beginning students of chemistry are those involved with the particulate nature of matter. These include the kinetic molecular theory, atoms, ions and molecules, chemical reactions and energy. A correct scientific understanding of these is so important that it is critical these ideas are exposed and explained to the students at the earliest opportunity. A great difficulty with this is that these explanations for natural phenomena are not obvious, and indeed may even conflict with a student’s macroscopic view of the world. This sub-micro representation of matter is new and strange to many students and it is acknowledged that, for some, learning will be difficult. The situation in New Zealand would appear similar but more research is needed to confirm this among our students, particularly those going on to study at the tertiary level.
4.1.2 Purpose/rationale

This investigation is centred on the concept 'The particle nature of matter', which in simple terms can be explained as follows:

* All matter is made up of sub-microscopic particles.
* These particles are atoms, ions or molecules.
* These particles are in continuous random motion.
* All matter exists in either solid, liquid or gas phase.

The main purpose of this investigation was to ascertain students' understanding of these concepts and to show how these develop with age. Students of various ages were shown three simple demonstrations and answered interview questions designed to probe their understanding of the phenomena. They were then asked to complete a diagram to reinforce their response.

4.2 Method

A room at the school was set aside for the interviews. These were conducted individually for about twenty minutes. Students were individually asked to look at three demonstrations and their answers to the questions were then recorded. They were given a few extra minutes to complete the diagrams.

Three different year levels were chosen and three students from each level were randomly selected by the class teacher. No allowance was made for differences in ethnicity, intelligence level or other factors and so the results must be treated with caution. There was no time limit and pupils were encouraged to give full and frank answers by rephrasing of the questions.

The selections were made as follows:

<table>
<thead>
<tr>
<th>Level</th>
<th>Year</th>
<th>Students</th>
<th>Selected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full primary</td>
<td>2</td>
<td>28 pupils</td>
<td>3 selected (2 boys, 1 girl)</td>
</tr>
<tr>
<td>Secondary school</td>
<td>8 science</td>
<td>32 pupils</td>
<td>3 selected (2 boys, 1 girl)</td>
</tr>
<tr>
<td></td>
<td>Year 13 chemistry</td>
<td>9 pupils</td>
<td>3 selected (1 boy, 2 girls)</td>
</tr>
</tbody>
</table>

Each of the pupils' responses were recorded on three separate sheets and these were not analysed until all the interviews were completed. The details of the demonstrations are:

**Demo #1** Some ethyl acetate was in a closed bottle in front of the students. After a couple of minutes the top was removed and a little of the substance poured onto some filter
paper. It was possible for the fragrance to be detected at a distance of one metre after 20-30 seconds. The students were asked a series of questions relating to what the smell was, what it was made up of and why it took some time to be detected. They were also asked to draw how they thought the smell reached the person's nose.

**Demo #2** A few drops of blue food colouring were placed at the top of a large deep bottle completely filled with still, cold water. After observing the colour for a few moments the students were asked to explain what was happening and also to complete diagrams about how the blue colour spread.

**Demo #3.** Two balloons were shown to the students. One had just been fully inflated and the other had been inflated two weeks previously and was now half inflated. This was explained to the students. They were also told that air could not get out of the top of the balloons because they were tied securely. The students were asked to explain what was happening inside the balloon and why one was half inflated. They completed a diagram representing the inside of the balloon.

4.3. **Results and analysis**

Samples of the students' sheets are included in appendix 3.

There are clear delineated beliefs, dependent on age, about the phenomena observed. Some of the year 2 students talked about germs, even oxygen, and the gas being strong. One had the possible idea that the gas was alive like the germs. One mentioned 'bits' of the chemical being small and that these could push. To explain their movement in the air they all said these bits must be very small. They are small enough to go through the balloon. None of these students mentioned particles, atoms or molecules. For the movement of the smell through the air they all drew a continuous line or lines from the paper to the nose. They all had difficulty explaining the movement and mixing of the colour. Most said the colour was 'heavy' and tried to explain it with vivid metaphoric descriptions like volcano and eggbeater.

For these young five and six year old students, their explanations make sense to them. It is their view of the world based on their experiences and constructed by them. Observed phenomena such as these demonstrations are explained in terms which are compatible with their view. What is this view? Generally some may picture smells and air as being made up of living entities (germs and oxygens that may have wings?) and can fly from place to place just as familiar animals do such as flies, bees and butterflies. However they picture these living things
as very small. *As small as germs* which cannot be seen. This notion of being alive may also be why the characteristics of *being strong* or *can push down* are included in their explanations. Some of the respondents drew a single zigzag line possibly because they would have observed the flight of bees and flies as not being straight. Others who drew a double line may have the understanding that one or two living entities move through the air and are responsible for the smell. These explanations are consistent across all three demonstrations and are entirely in line with this view.

Year 8 students were quite uniform in their explanations with all using the word *particles* and one boy even mentioned *molecules*. Most described the smell as a cloud of gas and drew it as such a continuum thing. These same students drew many individual particles and one could even explain how these particles crashed into each other and into the walls of the balloon. They mainly drew the solution as fully spread out and one said stirring would allow the particles to mix faster. They have had the benefit of several years of science teaching and this showed in their greater understanding and sophistication of concept development. They are beginning to abandon or modify the view of the year 2 students in excluding the living or alive characteristic although one student mentioned the air *dying*. Their view is of many small particles moving *floating* about in a cloud perhaps linked to their experience of steam from a kettle or of smoke from a fire. Their use of language such as *expanding* and *evaporate* allow more sophisticated explanations. Some have the added concept of many different things in the air such as *gases* and *pollution*.

Year 13 students predictably had the most developed concepts and it was pleasing to observe how they were confident to provide explanations in an acceptable scientific manner. All mentioned molecules of substances - air, chemicals - and some mentioned diffusion. All mentioned random particle motion that involved collisions and could describe sub-microscopic behaviour. Their diagrams showed great sophistication and often included other concepts such as density, pressure and diffusion. They also had a good knowledge of the composition of the air. For the colour mixing two of the students gave outstanding explanations mentioning concentration and evenness of distribution of the particles. One student mentioned energy of the particles and random movement. Their diagrams clearly showed the discontinuous nature of matter.
4.4 Conclusions

This small study of only nine pupils does show that there are alternative views about phenomena especially among the very young. The scientific concept of small particles constantly moving (the discontinuous view) has not been developed at year 2, but by year 8 some of the pupils are beginning to think in this manner. Provided teachers are aware of possible misconceptions pupils may hold, then such alternative views can be challenged and modified by careful and good teaching combined with a natural maturation.

<table>
<thead>
<tr>
<th>Year 2</th>
<th>Year 8</th>
<th>Year 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous view</td>
<td>Discontinuous view</td>
<td></td>
</tr>
<tr>
<td>Alive with wings</td>
<td>Inanimate</td>
<td></td>
</tr>
<tr>
<td>Strong and can push</td>
<td>submicroscopic</td>
<td></td>
</tr>
<tr>
<td>Kinetic (movement)</td>
<td>Kinetic</td>
<td></td>
</tr>
</tbody>
</table>

Young children clearly have a continuous view of matter and tend to describe it with human characteristics such as being strong, can push down or is alive. This is not surprising as they have been exposed to the everyday language and descriptions of things by their parents, teachers and family friends. After another five or so years of experience their views are changing and they are developing a more scientific conceptual understanding of matter. However, the results indicate that there is a wide range of understanding at this level and some students are clearly well ahead of others. At the year 13 level, students’ understanding of the particle nature of matter is generally excellent and concept development is sophisticated and mature. There is also confidence about the way the students express themselves and in using scientific language correctly. The author could not detect any serious misconceptions about the particle nature of matter among these students. Their view is the generally accepted scientific one of molecules constantly moving and colliding with other molecules and they are therefore able to explain their observations of macroscopic phenomena.
Chapter 4

Part Two: Students Understanding of Precipitation Reactions:
A New Learning Approach to Promote Conceptual Understanding

4.5 Introduction

There have been several intervention studies done in chemistry. One of these studies was described by Lim (1998) where an experimental group was taught using an historical approach to chemistry concepts. This group was compared with a control group and the results indicated the historical intervention had a significant effect for the new instructional approach. In New Zealand the same concern about failure to learn chemical concepts is shared by chemistry teachers (Metcalfe 1996), but little research has been carried out. It is hoped that this intervention study, although small and confined to only one school, may help to focus attention on (1) this area of need and (2) a possible new teaching approach. One of the areas known to cause difficulties for students is precipitation chemistry which involves using a set of rules to predict the outcome of ionic reactions.

The research question addressed in this section is:

Does the new discovery method make a significant difference to the learning and understanding of precipitation reactions?

4.6 Method

This study looked at a constructivist discovery approach to the learning of the rules for solubility and precipitation. This involved comparing two methods of intervention: The new approach that allowed for discovery learning and student led instruction and the more conventional approach which involved rules and teacher-controlled instruction.

4.6.1 Participants

The students involved in the study were from a year 12 chemistry class at a local high school. This was their first full year of the study of chemistry but some of the topics had been studied at very basic level in the previous year. There were eight students involved including two overseas students, one of whom had not studied chemistry before. An initial pretest was given on the first day to determine prior knowledge that test covered the naming of compounds, writing of formulae, ionic equations, colour of ions and prediction of precipitates. A special
coding system was devised to identify correct answers and errors in the skills listed above. From these results (Table 1) a detailed picture was drawn up of the knowledge base and skill level of each student. Their total scores were used to divide the class into two equal groups so that each had a similar mean score (Table 2).

**Table 1  Pretest**

<table>
<thead>
<tr>
<th>Student code</th>
<th>Mark (max = 47)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>1</td>
</tr>
<tr>
<td>S2</td>
<td>15</td>
</tr>
<tr>
<td>S3</td>
<td>13</td>
</tr>
<tr>
<td>S4</td>
<td>11</td>
</tr>
<tr>
<td>S5</td>
<td>19</td>
</tr>
<tr>
<td>S6</td>
<td>6</td>
</tr>
<tr>
<td>S7</td>
<td>11</td>
</tr>
<tr>
<td>S8</td>
<td>11</td>
</tr>
</tbody>
</table>

**Table 2 Equal Grouping**

<table>
<thead>
<tr>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>Mark</td>
</tr>
<tr>
<td>S2</td>
<td>15</td>
</tr>
<tr>
<td>S4</td>
<td>11</td>
</tr>
<tr>
<td>S6</td>
<td>6</td>
</tr>
<tr>
<td>S7</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td>43</td>
</tr>
<tr>
<td>Mean mark</td>
<td>10.8</td>
</tr>
</tbody>
</table>
4.6.2 Experimental design

The instruction took place at the school in the chemistry laboratory, providing a familiar setting for the students. The (normal) classroom teacher was present in the room throughout the sessions. Group A was then assigned the conventional method and group B the new discovery approach. The groups were kept apart in the laboratory and asked not to discuss their results out of class. Each group followed the general scheme detailed here. The instruction sheets given to the students are in appendix 4.

**Group A**
Conventional method: Rules and teacher-controlled instruction

The teacher defined ionic reactions, cation and anion and demonstrated these by test-tube reactions and writing examples on the board. Students’ attention was drawn to the existence of rules for precipitation and the students then proceeded to follow a set of prepared experiments. At various times during the experiments the teacher stopped the students and went over their results. Rules were constantly reinforced by extra exercises and questions based on the experiments. A summary of rules for precipitation was prepared with the assistance of the teacher. A final worksheet was given to the students.

**Group B**
Constructivist method: Discovery and student-led instruction

The teacher defined ionic reactions, cation and anion and demonstrated these by test-tube reactions and writing examples on the board. The students were then free to work with the chemicals to try to discover some precipitation rules. No other guidelines were given. Students constructed their own concepts and rules by sharing experiences. As a group they came up with their own summary for the prediction of precipitates. A final worksheet was given to the students.

At the end of the experimental session both groups were given the posttest.

4.6.3 Assessment details

The written test (appendix 5) included questions designed to show understanding and knowledge of solubility and precipitation. Specifically the following were tested:

* The correct naming and writing of reactant and product ions: questions 5 - 16
* The correct identification of reagent to use: questions 13 - 16
* The correct identification of the precipitate formed: questions 1 - 4
* The correct formula of the precipitate formed: questions 1 - 16
* Using an ionic equation to represent the precipitation reaction: questions 5 - 12
* The balancing of these equations: questions 5 - 12
* The rules for precipitation and using them for prediction: questions 13 - 16

The test contained four types of questions each testing a different concept or skill. There was some overlap in questions which could not be avoided (such as formulae).

### 4.6.4 Procedures

**Day 1**

Initially the students involved were given information about the study and they then sat the pretest. This took about 25 minutes and was marked according to the coding system described above.

**Day 2**

The next day, on the basis of this test, the class was equally divided into two groups, given the relevant instruction sheet and asked to spend some time preparing their resources. Some definitions were then given to the class as a whole after which they worked separately in their groups. Students worked for the remainder of the lesson investigating the reactions.

**Day 3**

Students continued with investigations. Discussion took place within groups about possible trends.

**Day 4**

Students continued with investigations. Some time was set aside for possible forming of rules (student-led group) and answering questions (teacher-led group). A worksheet was given to all students to assist with the learning of the concepts.

**Day 5**

A posttest was given that took about 25 minutes. This was marked using the same coding system as for the pretest. Both tests were independently marked by the two teachers.
4.7 Results

This chapter describes the results of the tests and presents them in table form. The tests and instruction went as planned, attendance was 100% over the 5 days and there were no interruptions. Precautions were taken to ensure there was no impact on the study from extraneous sources such as collaboration.

4.7.1 Test scores

Table 3 The test scores for pre and posttest.

<table>
<thead>
<tr>
<th>Teacher-led</th>
<th>Student-led</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>Posttest</td>
</tr>
<tr>
<td>Student 2</td>
<td>15</td>
</tr>
<tr>
<td>Student 4</td>
<td>11</td>
</tr>
<tr>
<td>Student 6</td>
<td>6</td>
</tr>
<tr>
<td>Student 7</td>
<td>11</td>
</tr>
<tr>
<td>Mean</td>
<td>10.8</td>
</tr>
<tr>
<td>SD</td>
<td>3.2</td>
</tr>
<tr>
<td>Mean Gain</td>
<td>10.0</td>
</tr>
</tbody>
</table>

The results show that while every student increased their total score, students involved in the student-led intervention achieved a greater overall increase. (This is shown in Table 3). The mean scores increased for both groups; From 10.8 – 20.8 for the teacher-led group and from 11.0 - 26.3 for the student-led group.
4.7.2 Effect size

One way of assessing the relative effectiveness of the two types of teaching is to examine the effect size. This is based on the difference in mean scores (pre and posttest) of students in each of the two methods. If this difference is greater than 0.5 then it points to a significant learning advantage of the intervention method over the usual one.

The calculation is presented below.

\[
\text{Effect size} = \frac{(X_1 - X_2)}{SD_2}
\]

where

\[
X_1 = \text{Student-led post mean score}
\]

\[
X_2 = \text{Teacher-led post mean score}
\]

\[
SD_2 = \text{Teacher-led post test standard deviation}
\]

\[
= \frac{(26.3 - 20.8)}{2.4}
\]

\[
= 2.3
\]

The effect size value of 2.3 represents a meaningful effect in the direction of the student-led intervention.

4.8 Discussion

This section presents the analysis of the results and interprets them in terms of the research question. The limitations of this study are discussed and the implications of this intervention research are outlined. Finally, recommendations for future study/research directions are made.

4.8.1 Interpretation

The results indicate that a significant difference exists between the effectiveness of the two methods of instruction. The composition of the two groups was based on the results of the pretest. Both groups had a similar average mean score. After the instruction both groups had improved their mean scores but the student-led group had a higher posttest mean (26.3) compared to the teacher-led group (20.8). This has resulted in a mean gain of 15.3 for the student-led group compared to a mean gain of 10.0 for the teacher-led group. This significant difference in favour of the student-led group is also quantified by the effect size calculation. The value of 2.3 indicates that the discovery method for this type of investigation can give students a significant advantage.

There were also differences in the correct responses between the two groups. Analysis shows that while the teacher-led group improved their response rate from 6 to 7 (for identifying the correct reagent to use), the student-led group increased theirs from 2 to 9 for the same skill.
All students in both groups reduced their errors. For writing formulae the student-led group reduced their errors from 16 to 3 but the teacher-led group reduced theirs from 14 to just 11. Overall it is a similar picture; the student-led group reduced their errors by 50% (from 44 to 22) while the errors of the teacher-led group were reduced by 28% (from 54 to 39).

4.8.2 Limitations

This small study was limited to only eight students and so the results must be interpreted with care. Issues of teacher bias and consistency of the lessons (kept as standard as possible) were unlikely to have affected the results. The tests were administered in an identical fashion with the same questions and check marked by the two teachers.

4.8.3 Research question and implications

The new student-led discovery method has made a significant difference to learning and understanding of precipitation reactions thus providing a positive answer to the research question. Students involved in this group achieved significantly higher scores in the posttest and this indicates greater understanding of important concepts, writing of formulae and using the rules of solubility to make predictions.

This study, although small in scope, has shown that serious attention should be focused on the constructivist approach to chemistry learning in areas where practical investigation is appropriate as there is educational value in such an approach. Opportunities for peer group interaction, discussion and concept development are important for allowing students to learn and develop understanding of important chemical concepts.
Chapter 5  An Evaluation of the New Chemistry Curriculum

5.1  Introduction

5.1.1  Brief description
This evaluation was conducted to establish the effectiveness and worth of the teaching
and learning programme designed to implement the New Zealand chemistry curriculum. Data
was gathered via a questionnaire and applications test designed to indicate how students relate to
their study of chemistry, their level of understanding of selected important concepts and their
ability to problem-solve.

5.1.2  Key evaluation questions
The main question was:
* To what extent does the year 12 and year 13 chemistry programme prepare students
to understand and apply chemistry concepts?
The specific questions were:
* What is the students’ attitude to their study of chemistry?
* Is the classroom environment conducive to learning?
* Do the students see some topics/concepts as more difficult than others?
* Can the students understand and apply some basic chemical concepts?

5.2  Method
5.2.1  Sample
Sampling was necessary for this study. As chemistry is taught in groups within schools
it was convenient to employ a form of cluster sampling (where a school was randomly selected
from the pool of 21 Christchurch schools.) There were about 600 students studying chemistry
at year 13 level in these schools. An approximate 10% sample was achieved through a two-stage
sampling procedure. The 21 schools were placed into three groups A,B and C based on their
decile rating. (Decile rating of 1 = bottom 10% of schools based on average parental income; decile rating of
10 = top 10% of schools based on average parental income)
A - Schools with decile rating 1, 2 and 3.
B - Schools with decile rating 4, 5 and 6.
C - Schools with decile rating 7, 8, 9 and 10.
To more accurately reflect the local schools' decile distribution in Christchurch, three schools were each randomly selected from decile groups A & B and four from group C. From each of these ten clusters, six students were randomly selected by their class teacher, giving a total of sixty students.

5.2.2 Data collection/analysis
Information was gathered from two sources using the following instruments:
* A questionnaire for students
* A small applications test for students based on concepts
This allowed for the collection of both quantitative and qualitative data. The questionnaire asked for students' opinions about how they regard their learning of chemistry in relation to their understanding of important concepts. In addition, students were asked to identify key teaching and learning strategies that they have found effective. The applications test consisted of five questions designed to show:
* How well a concept is understood
* How well that concept is applied to an unfamiliar situation.
The test concentrated on the important concepts of:
  (a) The particulate nature of matter and kinetic theory.
  (b) Chemical reactions and conservation of matter
  (c) Moles and stoichiometry
  (d) Polarity of molecules.
  (e) Chemical & physical change
Copies of these instruments are included in appendices 6 & 7.

The responses to the questionnaire and applications test were coded on a 1–3 scale and comments from students were categorised into broad classes of response and summarised. These coded responses were collated onto a database using 'Statview' and the statistically analysed results imported to a word processor from where they were presented graphically and in table form. Gender subgroup analysis was undertaken on all results and only those that showed a significance difference are reported: for example, in the questions on preferred ways of learning, class environment and in the applications test total scores.
5.2.3 Procedure

These instruments were developed in early June and desk reviewed by two experienced chemistry teachers after which they were extensively trialled and piloted by several year 13 students. Some changes were made to improve the wording and remove ambiguity. The questionnaire and applications test were administered at the school by the author during Term 3, 2000. The class teacher had broadly classified the class into top, middle and bottom academic groups before the random selection had been made. The selected students were removed to another room and the questionnaire and applications test done in a quiet and consistent manner.

5.3 The questionnaire results

Thirty-five female and twenty-five male students completed the questionnaire. Twenty-four students were in the upper decile group (C), twenty in the medium (B) and sixteen in the lower group (A). The students were placed by their teachers into three academic groups: twenty students in the top, twenty-four in the middle and sixteen in the bottom group.

5.3.1 Background information and students’ attitude

The first three questions were concerned with the students’ attitude towards chemistry: Why they undertook the study of chemistry at this level, what was their general level of interest and whether they would carry on with their chemistry studies at university or other tertiary institution. The results are displayed in Figures 1, 2 and 3.

Fig 1 Students’ Reasons for choosing chemistry in year 13.
The results shown in figures 1, 2 and 3 indicate that the students selected chemistry for a variety of reasons but the most common factor (for about 50%) was as part of their career plans. A similar number indicated they intended to study chemistry at the tertiary level, however, this number could increase because a substantial proportion were ‘not sure’. Interest in chemistry at the University Bursary level was high although twice as many indicated it was ‘just interesting’ rather than ‘very interesting’.

Analysis of these questions on the basis of gender indicated no differences in response between the male and female students.

5.3.2 Previous study

The next figure relates to the background knowledge students may have gained from year 11 study in science and maths, that may have helped them with better understanding of concepts and problem solving in year 13 chemistry.
Nearly 70% of the students said that their earlier study in year 11 had been of some help to better understand and solve problems in year 13 chemistry while over 20% reported it had been a great help. Just over 50% of the students said the chemical principles they learned in year 11 had helped them better understand year 13 chemistry. 30% were not sure. Over 60% of the students said that learning chemical facts in year 11 had helped them to understand and learn year 13 chemistry.

The great majority of students indicated that the background knowledge they acquired as a result of year 11 study in science and maths helped them understand concepts and solve problems in year 13 chemistry. However, there were some students who were not sure if the earlier study had been of any help. A sound background in science is important because it gives the student information that can be built on in later years. There is evidence presented in part 5.4 that indicates students with such backgrounds show superior problem-solving skills.

5.3.3 Preferred ways of learning

The next figure relates to preferred ways of learning chemistry. The students were asked to rate the value of the five suggested ways of learning: doing experiments, having discussions, making notes, watching teacher demonstrations and individual work.
A variety of ways of learning were seen as important to the students. Experimental work, individual and group work, discussion and note-taking from the teacher were all rated as important: 88 - 95% of all students rated these ways of learning chemistry as either very valuable or quite valuable. However note-taking from the teacher was rated the highest at 62%, followed by individual work (42%), discussions and demonstrations at 40% and doing experiments rated the lowest at 32%. On closer examination the statistics reveal substantial gender differences; Over 75% of female students (including 82% of the ‘top’ ones) regarded note-taking as their most valuable way of learning. For male students the figure was much lower at 44%. Only 30% of all students rated doing experiments as a ‘very valuable’ way of learning. For the top students the gender difference was even greater; 56% of males and 27% of female students rated this way of learning as very valuable.

Further analysis of the students who selected the very valuable response in these questions, produced the following statistics:

<table>
<thead>
<tr>
<th></th>
<th>Experiments</th>
<th>Discussion</th>
<th>Note taking</th>
<th>Demonstration</th>
<th>Individual work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>36</td>
<td>44</td>
<td>44</td>
<td>41</td>
<td>28</td>
</tr>
<tr>
<td>Female</td>
<td>26</td>
<td>41</td>
<td>75</td>
<td>40</td>
<td>50</td>
</tr>
</tbody>
</table>

45
This showed an even greater disparity in gender difference. Female students rated note-taking and individual work much more highly than the male students; however, male students rated experimental work higher than the female students.

5.3.4 Students working environment

The following results refer to the class working conditions influenced by the amount of work needing to be done, the influence of other students on a particular student’s ability to learn, and the influence and ability of the teacher (Q6). Students were asked five questions relating to workload, class environment, explanations by the teacher, teacher availability and exam revision time.

Fig 6 Workload in Chemistry

![Workload Graph](image.png)

Over 75% of students rated their workload as just about right with just over 10% reporting that it was too high.

Fig 7 Class Working Environment

![Class Environment Graph](image.png)

All the students rated their class working environment as either fantastic (23%) or OK (77%). None of the students viewed their learning environment as poor.
Fig 8  Explanations by Teacher

All of the students rated their teacher’s explanations as either exceptional (28%) or good (72%).

Fig 9  Teacher Availability

Over 80% of the students said the teacher was always or mostly available to answer their questions.

Fig 10  Revision Time

Only 17% of students said not enough time was available for revision of work for exams.
Further analysis of the five parts of Q6 on the basis of gender revealed the following statistics:

**Class environment:**
- Males: 8% rate as fantastic
- Females: 36% rate as fantastic

**Teacher explanations:**
- Males: 32% rate as exceptional
- Females: 26% rate as exceptional

Clearly there was a substantial difference in the way female and male students viewed their class environment with a smaller difference noted in the explanations by their teacher. Over 36% of female students rated their class environment as fantastic compared to just 8% of male students. There was also a small difference in students’ opinions of teacher explanations with 32% of male students rating these as ‘exceptional’ compared to 26% for female students. There were no gender differences in workload, teacher availability or revision time. However, students generally showed great support for their teachers and felt as though they get much from them. The results also indicate that generally the students are positive about their learning environment in the classroom. There were no differences between students from different decile groupings, indicating that students from low socio-economic areas have the same attitude to their learning environment as do students from the high socio-economic areas.

### 5.3.5 Difficulty of topics

The following figure relates to the difficulty level of topics. The topics each contain many chemical concepts that the students may find hard to understand. Over 85% of students have said some of the topics/concepts are difficult. Only 8% of students found none difficult.

**Fig 11 How difficult are the topics of chemistry?**

The actual topics identified by the students is presented in Table 1. Ten different topics were identified, with 16 students stating acid/base the most difficult to understand.
Table 1  

<table>
<thead>
<tr>
<th>Topic</th>
<th>Student responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid/base/titration/buffers</td>
<td>16</td>
</tr>
<tr>
<td>Organic compounds</td>
<td>8</td>
</tr>
<tr>
<td>Atoms/molecules/bonding</td>
<td>6</td>
</tr>
<tr>
<td>Equilibrium</td>
<td>6</td>
</tr>
<tr>
<td>Oxidation/reduction</td>
<td>5</td>
</tr>
<tr>
<td>Quantitative</td>
<td>4</td>
</tr>
<tr>
<td>Energy</td>
<td>4</td>
</tr>
<tr>
<td>Analysis</td>
<td>2</td>
</tr>
<tr>
<td>Periodic trends</td>
<td>2</td>
</tr>
<tr>
<td>Electron configurations</td>
<td>1</td>
</tr>
</tbody>
</table>

It is clear from Table 1 that most students (80%) found some of the concepts/topics of chemistry difficult to understand. The topic of most concern to students was generally found to be aqueous solution chemistry. This topic contains several important concepts such as acid/base equilibria, functions of a buffer, definitions of strong and weak acids and dissociation constant. It is interesting to note that this topic contains the more difficult mathematical problems that students have to solve in year 13 chemistry.

5.3.6  Practical use of chemical knowledge

Over 68% of students were able to describe a situation where they had used their chemical knowledge. These are summarised in Table 2. However, further analysis of these 41 responses revealed that only 13 indicated a link between the students’ knowledge and a real-life situation. The other 28 responses were vague or general in nature and indicated an inability to apply knowledge and skills learned.
### Table 2  Application of knowledge

<table>
<thead>
<tr>
<th>Application Area</th>
<th>Student responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleaning (general)</td>
<td>11</td>
</tr>
<tr>
<td>Cooking</td>
<td>5</td>
</tr>
<tr>
<td>Engines (how they work)</td>
<td>4</td>
</tr>
<tr>
<td>Alcohol</td>
<td>3</td>
</tr>
<tr>
<td>Food (what’s in it)</td>
<td>3</td>
</tr>
<tr>
<td>Gardening</td>
<td>3</td>
</tr>
<tr>
<td>Chemist supplies</td>
<td>2</td>
</tr>
<tr>
<td>Swimming pools</td>
<td>2</td>
</tr>
<tr>
<td>Environment</td>
<td>2</td>
</tr>
<tr>
<td>Batteries</td>
<td>2</td>
</tr>
<tr>
<td>Making solutions</td>
<td>2</td>
</tr>
<tr>
<td>Embalming</td>
<td>1</td>
</tr>
<tr>
<td>Paints/solvents</td>
<td>1</td>
</tr>
</tbody>
</table>

41/60 responses

Some were clearly no different from what any lay person might say; eg ‘cleaning’, ‘cooking’ or ‘embalming’. Both males and females were equally represented in the best responses, among which were; ‘The effect of soil pH on plants’, ‘Understanding how the car battery works’ and ‘making up different concentrations of solutions’. Answers of this quality were in the minority. This may indicate that many students have not had the opportunity to observe and experience chemistry in a real-life context.
5.4 The application test results

5.4.1 Introduction

The applications test posed questions that contained the following basic concepts taught as part of year 12 chemistry and reinforced during year 13 chemistry. In some schools these may have been introduced in year 11 as part of science or chemistry:

* Chemical & physical change
* Kinetic theory of gases
* Chemical reactions and the conservation of matter
* Moles and stoichiometry
* Polarity of molecules.

5.4.2 Overall raw scores

The overall raw scores are presented in Figs 12, 13 & 14. The maximum score was 20.

Fig 12 Raw Scores Achieved by Male / Female students

This graph shows the spread of raw scores for female and male students. This data has generated the following statistics.
<table>
<thead>
<tr>
<th></th>
<th>Female</th>
<th>Male</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>11.6</td>
<td>12.4</td>
<td>11.9</td>
</tr>
<tr>
<td>SD</td>
<td>4.2</td>
<td>5.1</td>
<td>4.5</td>
</tr>
<tr>
<td>N</td>
<td>35</td>
<td>25</td>
<td>60</td>
</tr>
</tbody>
</table>

As there is no statistically significant difference between them, the sample of 60 students has been treated as one group for the purposes of analysis.

The next two graphs (Figs 13 & 14) show the spread of marks against school decile group and against academic group. The statistics are:

<table>
<thead>
<tr>
<th></th>
<th>Decile group</th>
<th>Academic Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upper</td>
<td>Medium</td>
</tr>
<tr>
<td>Mean</td>
<td>12.0</td>
<td>12.8</td>
</tr>
<tr>
<td>SD</td>
<td>4.6</td>
<td>4.2</td>
</tr>
<tr>
<td>N</td>
<td>24</td>
<td>20</td>
</tr>
</tbody>
</table>

The medium decile schools have achieved a slightly higher mean than the other two groups. The academic group performance is as expected (mean =14.9) with a significant difference between these top students and middle/bottom ones.

**Fig 13  Total Student Scores against School Decile Group**

There appears to have been no substantial difference in achievement between schools from different decile groupings.
The top group had a range of scores from 6-20 with six scoring below the mean (11.9) for all students. The range for the middle group was 3-18 and for the bottom group 2-17.

The following graphs (Fig 15 - 19) illustrate the student response to the individual questions in the applications test. Each of the questions was marked for evidence of student understanding and explanations given. Analysis of this data in terms of gender indicated no substantial differences between male and female students except in Q1 part A. Consequently the sample is treated as one group.
5.4.3 Physical and chemical change

This question asked students to identify each type of change from the two examples given. Students were asked to justify their choices.

**Fig 15 Physical & Chemical Change**

![Bar graph showing Q1: Physical and chemical change]

Most of the students (80-90%) were able to identify both changes but only 60-65% could explain the difference. Very few mentioned that the chemical change example involved the formation of new compounds. One common reason given was the misconception that the difference between the two is reversibility. These students have failed to understand that chemical changes may also be reversible.

5.4.4 Phase change and kinetic theory

This question was designed to test aspects of the kinetic theory of gases such as the random orientation and movement of molecules and their volume filling characteristics. Students were asked to consider what was happening at the molecular level during the sublimation of carbon dioxide. Retention of the chemical bonds within the carbon dioxide molecule and conservation of the number of atoms were aspects of the physical change also tested.
There was generally a high level of understanding of a phase change such as sublimation, although a lesser proportion of students (74%) were aware of the random nature of the gas particles; most sketched them with the same orientation ignoring their randomness. Other aspects such as retention of chemical bonds (83%) and conservation of atoms (85%) were well demonstrated by the students. Generally most students could show an adequate understanding of the kinetic theory of gases and were able to explain a phase change such as sublimation without too much difficulty.

5.4.5 Chemical reaction between hydrogen and iodine

In this next question students had to demonstrate their understanding of a gas phase reaction. Excess hydrogen had been mixed with solid iodine and students were asked to sketch in the molecules of gaseous hydrogen before the reaction took place. Columns 1, 2 and 3 of figure 17 show the students’ response to this in terms of the random orientation and volume filling characteristics of the molecules, as well as showing the correct number of reacting molecules.
The second part of Question 3 was concerned with the molecular species left after the reaction was completed. Students were asked to sketch in all the product molecules and their responses are shown as the last four columns in Figure 17. They needed to demonstrate the volume filling characteristic of the gaseous products, the correct number of hydrogen iodide molecules, the excess hydrogen molecule and also show that the total number of atoms was conserved.

In this more difficult question relating to a chemical reaction most students again showed good understanding of the properties of a gas and the Kinetic theory. However, less than 25% could indicate the random nature of the gas particles before the reaction. Over 65% drew in the correct number of hydrogen molecules (column 3) and between 50-60% showed how a gas filled the whole box or volume (column 2 - before the reaction and column 4 - after the reaction). But less than 36% (columns 5, 6 and 7 ) could show the conservation of atoms, draw the correct number of product HI molecules or could account for the excess hydrogen. The most common errors were to ‘lose’ some of the atoms and to ‘add’ another iodine molecule to account for the excess hydrogen.
5.4.6 Stoichiometry of a reaction

In this question students were asked about the reaction between iron atoms and oxygen gas. To answer correctly, students needed to show a sound understanding of the symbols and sub-scripts used in a reaction and to recognise the reacting mole ratio.

Fig 18 Stoichiometry

![Graph showing mole ratio](image)

Just under 60% of students were able to determine the correct number of oxygen atoms that were needed. Slightly more recognised the correct mole ratio between iron and oxygen but less than half the students realised the importance of each oxygen molecule containing two atoms of oxygen to the calculation. Stoichiometry and the mole concept appeared generally well understood although there appeared some careless explanations given by some students when attempting to show evidence for their answers. Once again the symbolism used was not sufficiently understood by many students.

5.4.7 Removal of an oil stain

Figure 19 shows the response to a practical problem of solvent selection. This question was testing students’ ability to identify a characteristic of the stain (oil is non-polar) and to associate this with one of four options of possible solvents. Students needed to give an explanation for their selection.
Over 70% of students recognised or selected the correct solvent to dissolve the oil stain but just over 25% were able to give a correct scientific reason or explanation. Application of the concept of polarity of molecules to a practical problem indicated that many were able to select (or guess) the correct solvent to use, but almost 75% were unable to explain the reasons for their choice.
5.5 Conclusions

5.5.1 Important correlations

There is a strong relationship between the students who said they found chemistry very interesting and their application test scores.

N=19  X=14.8

This is considerably above the mean for all students (X=11.9) and indicates students who are really interested in chemistry are best at problem-solving.

Those students who indicated that the earlier work done in year 11 had been of great help with their year 13 studies had higher mean scores in the applications test compared to the whole group.

Q4a Solving problems  N=14  X=13
Q4b Chemical principles  N=30  X=12.5
Q4c Chemical facts  N=36  X=12.3

These students considered that the earlier work had better prepared them to solve problems and understand concepts. This is borne out by the test results.

There is a strong positive correlation between students who regarded doing experiments as a very valuable way of learning and their ability to problem-solve. These students scored higher on the application test.

N=19  X=12.4

It is interesting to note that is a gender difference here;

X(male) =12.0
X(female) =12.8

Conversely there is a negative correlation between the female students who regard note-taking as a very valuable way of learning and their performance at problem-solving.

N=25  X=11.1

Some of the best performances in problem-solving have come from female students who regard experimentation as a very valuable way of learning and some of the poorest performances in problem-solving have come from female students who regard note-taking as a very valuable way of learning.

Further analysis of the performance of the teacher-selected top students revealed the following data:
Applications test results - % gaining full marks per question

<table>
<thead>
<tr>
<th>Question</th>
<th>% (female)</th>
<th>% (male)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>54.5</td>
<td>66.7</td>
</tr>
<tr>
<td>T2</td>
<td>81.8</td>
<td>100</td>
</tr>
<tr>
<td>T3</td>
<td>9.1</td>
<td>33.3</td>
</tr>
<tr>
<td>T4</td>
<td>36.4</td>
<td>66.7</td>
</tr>
<tr>
<td>T5</td>
<td>36.4</td>
<td>66.7</td>
</tr>
<tr>
<td>N</td>
<td>11</td>
<td>9</td>
</tr>
</tbody>
</table>

In every question of the applications test the top academic boys outperformed the top academic girls in terms of application of knowledge, skills and problem-solving.

There are important links indicated above between how students regard their learning and their ability to problem-solve. Students who say they like chemistry and find it very interesting are generally those who are more successful at problem-solving. In addition, students who feel they had been given a good background in earlier years also tended to be the best problem-solvers. However the strongest correlation with problem-solving involved those students who regarded doing experiments as a very valuable way of learning. Interestingly, in this category female students were shown to slightly out-perform the male students. Generally, however, the male students were better at problem-solving than the female students.

5.6.2 How students regard chemistry

Interest in chemistry at the University Bursary level is good although twice as many indicated it was 'just interesting' rather than 'very interesting'. This perhaps showed that the students think the course could be made more relevant and interesting to them. Almost 75% of the top academic group indicated they will continue their study of chemistry; an even distribution between male and female students.

5.5.3 Experimental approach to learning

It was pointed out in chapter 2 how the experimental approach to learning was gaining prominence and evidence was presented to illustrate the advantages of such an approach. However, the results of the questionnaire indicate that for many of the students surveyed, such a method of learning is not a high priority. These are disturbing results because chemistry is an
experimental science and the new syllabus has placed great emphasis on an investigative skill developing scientific methodology. Instead we have retention and acceptance of the teacher-centred model where over half of our chemistry students might have been 'conditioned' to a passive way of learning such as note-taking. As stated in chapter 4, creating opportunities for individual and collective experimentation is valuable for allowing students to learn important chemical concepts.

5.5.4 Understanding and application of concepts.

Chemical change is a concept not well understood. This concept involves the formation of new substances and the breaking and making of chemical bonds. As physical and chemical change is such a fundamental concept it is expected a very high proportion of students at the year 13 level would be able to explain the difference. There is concern here that some of our University Bursaries students are going into the examination with inadequate basic knowledge. Chemical and physical changes surround us in real life and more attention needs focusing on these concepts, perhaps presenting them in familiar contexts.

Chemical reactions and the language and symbolism used are basic concepts applicable to all areas of chemistry and evidence was presented in chapter 2 to show how understanding is limited. An analysis of Question 3 shows and confirms serious misunderstandings regarding chemical reactions remain. Many students had failed to take account of conservation of atoms and seemed unable to cope when one of the reagents was in excess. There seemed to be difficulty in interpreting the equation; i.e. in using the language of chemistry to fully understand what was going on at the molecular level. In spite of extensive research and many new teaching strategies, the situation is not really any better. One of the factors may be that there is too little communication between researchers and teachers.
Chapter 6  Overall Conclusions

This dissertation has looked at questions relating to the New Zealand chemistry curriculum. The main topics under scrutiny were related to chemical misconceptions, concept development, the students' views of their learning environment, problem-solving ability and the assessment of chemistry at year 13. This chapter links the findings from the four separate studies and shows how each is related to the current state of chemistry teaching, learning and assessment in the New Zealand curriculum. Relationships between students' ideas of their own learning, their ability to understand important chemical concepts and to problem-solve, are described. These relationships give an indication of some of the strengths and weaknesses inherent in teaching and assessing chemistry at levels 7 & 8, as well as identifying barriers to understanding that need to be addressed.

6.1  The general conclusions of the studies

The first study on development of the concept of the particle nature of matter showed that the path to a sound scientific understanding is arduous and long. This was a limited study of the level of understanding of nine pupils and while it demonstrated excellent understanding by the senior year 13 students of one concept, it would be unwise to extrapolate this result to all our senior chemistry students. The year 8 students retain simple ideas and explanations of phenomena that have been personally developed over previous years and in some cases these are very hard to shift. The alive or living characteristics attributed to inanimate objects linger with some students. Real effort on the part of the teacher is necessary to affect a change because in many cases scientific explanations are not obvious and may even cause confusion in the student's mind. However, a conflict is necessary if students are to realise the inadequacy of their own explanations. The NZ chemistry curriculum lists six important concepts central to the learning of chemistry and teachers must be aware of the need to introduce these to students even as early as year 7. Serious misconceptions by local students are described in chapter 5 regarding physical/chemical change, aspects of the kinetic theory of gases, chemical reactions and the mole concept.

The intervention study of concept development using a discovery constructivist method indicated that this type of approach has real value for some aspects of chemistry and substantiates the research described in international studies such as those reported by Stavey and
skills via students taking an open ended approach and with help from the teacher, being able to make sense of the data. Unfortunately this area is not part of formal assessment at UB level. This approach may also be of benefit to student investigations in classification of matter, chemical analysis, equilibrium reactions, polarity of molecules and yield of an organic product.

The learning environment in some classrooms indicates changes are necessary if the true intentions of the new curriculum are to be realised. The ‘system’ currently rewards those who regard note-taking and fact-gathering as the important way to learn. Many students, particularly high achieving girls, capitalise on this. This is perhaps at the expense of those whose skills lie predominantly in the areas of problem-solving and experimental approaches to learning. Problem-solving was strongly correlated with several desirable characteristics. In particular, evidence has been presented to show that students who are best at problem-solving:

* are really interested in chemistry
* recognise the relevance and help of earlier study
* regard doing experiments as the most valuable way of learning.

If the assessment at year 13 included aspects of an experimental approach, perhaps by internal assessment of an investigation, then the learning emphasis would have to change. This may even result in a more interesting and challenging course thereby improving students’ attitude and enthusiasm for further learning. A more relevant course could also address the broader issue of students seeing chemistry in a much wider context and decrease their reliance on teacher-centred methods of learning. As stated in chapter 3, developing scientific skills and attitudes through investigative and practical work is an important aim of the new chemistry curriculum. This problem-solving approach needs greater emphasis as a way of learning these essential skills.

NZQA make a valid assessment of the chemistry examination prescription chapter 3 based on the new chemistry curriculum level 7 & 8. The research described here showed that content validity existed in the 1997, 1998 and 1999 examination papers. During this time there has been a minor change with the introduction of contextual/thematic type questions. There is anecdotal evidence that for some students, these questions came as a surprise. However, it was found that the design of the questions ensured that students were not really disadvantaged. Thus the NZQA examiners have largely succeeded in incorporating this aspect of the curriculum into the examinations. The results in chapter 3 indicate that the relevance of chemistry to everyday things and understanding of how chemical knowledge is applied, is one area that should be emphasised more. Too many students are unable to apply their knowledge in a practical way. The situation will only improve when more teachers are willing to expose their
students to many different contexts and new situations.

There are, however, important skills detailed in the curriculum that are not covered by the examination. These centre on problem-solving and include focusing, planning, information gathering, experimenting and reporting. Owing to the need to cover a diverse content in preparation for the examination, it is doubtful if these other important skills are being developed at all. Evidence presented in chapter 5 indicates that many students have been conditioned to learn in a passive non-interactive manner and that learning for many has taken place without understanding of the central concepts of chemistry.

6.2 Implications and further study

The University Bursaries chemistry course needs to be made more relevant and interesting by providing everyday examples and contexts and by challenging students with problems to solve. Students need such opportunities and experiences so they can see chemistry as an integral part of a relevant and rewarding career choice. There needs to be a move away from teacher-centred learning to a situation where students take more responsibility for their own learning by investigating and problem-solving. Some students, including many female students, need to be encouraged to place greater value on doing experiments and problem-solving as ways of learning, and to place less reliance on note-taking. To be fair to teachers and students, the present University Bursaries chemistry assessment rewards the note-takers and fact-gatherers with a dominance of memory recall of chemical facts type questions as evidenced by the results of the study in chapter 3. Accordingly, assessment should be widened to encourage the development of other important chemistry curriculum skills. Teacher explanations should include more student input so that explanations in general are more relevant and understandable.

6.2.1 Difficulty of concepts.

Students continue to find the topic of aqueous solution chemistry and the concepts associated with this very difficult. Teachers need to put increased effort into students understanding of this topic. Greater emphasis must be made on correctly using the language of chemistry and making sure all students understand such basic concepts as physical & chemical change, the mole, conservation of matter and the meaning of chemical reactions. Students need greater opportunities for acquiring skills of providing sound scientific reasons for chemical phenomena. Development of scientific concepts should begin as early as year 7, with sound
teaching of basic chemical concepts such as the particle nature of matter. Interactive computer models may assist here. Other teaching methods, such as pupil-centred discovery learning, should be explored as valuable aids to learning.

6.2.2 Application of concepts and problem-solving skill.

There needs to be a much greater effort to provide real-life contexts for teaching concepts in and to provide many everyday examples. Teacher development days should be set aside so that guidelines for this can be written and material resources developed. Only when students have been exposed to such examples will they then have the confidence to apply their chemistry knowledge and skills to new situations and problems. The three chemistry achievement aims are:

1. Investigate and develop an understanding of the way materials and chemical processes interact with people and the environment;
2. Carry out a range of practical investigations and use this and other information to explore chemical behaviour;
3. Understand important concepts in chemistry and major patterns of chemical behaviour;

If these aims are to be realised, then the barriers to learning (outlined in chapter 2) must be minimised. Evidence has been presented to show that such barriers still exist for many students and that more attention has been focused on curriculum achievement aim 3. There are aspects of some classroom environments - such as students' perceptions of the best way of learning and teacher-controlled lessons - that encourage a passive role in learning. Concept development is also shown to be hindered by misconceptions, even though these alternate conceptions have been well documented here and overseas. Problems with language especially relating to chemical reactions and equations, lack of suitable contexts presented to students, too few opportunities for problem-solving and application of skills, are identified barriers preventing learning. Consequently, students' chances of attaining aim 1 are severely limited. Restricted assessment pertaining only to aim 3 encourages many teachers to concentrate mainly on this aim, thus creating a further barrier to the investigative planning and skill component of the curriculum.

Further research is needed to find out the extent to which an investigative problem-solving model of learning can assist the development of concepts, knowledge and skill. Given the three issues of teaching, curriculum demands and assessment, it is important that these are addressed simultaneously to provide a cohesive approach to chemistry teaching.

65
References:

*Journal of Research in Science Teaching* **29**: 2, 105-120

*Journal of Research in Science Teaching* **31**: 2 147-165

*Journal of Chemical Education* **76**: 795-797

*Journal of Chemical Education* **75**: 322-324.

*Journal of Chemical Research* **72**: 879-885

*Journal of Chemical Education* **61**: 774-777

*Education in Chemistry* **24**: 117-120.

*Journal of Chemical Education* **76**: 124-128

*Journal of Chemical Education* **69**: 186-190

*Journal of Research in Science Teaching* **35**: 569-581
*Journal of Chemical Research* 72: 578-579


*Journal of Chemical Education* 72: 715-716

*Journal of Research in Science Teaching* 31: 1102-1109

*Journal of Research in Science Teaching* 33: 657-664

*Journal of Chemical Education* 69: 464-467

*Journal of Chemical Education* 75: 1399-1403

Francisco J. and others. (1998). Integrating multiple teaching methods into a general chemistry classroom. *Journal of Chemical Education* 75: 210-213

Furio and Galatyud (1996) Beyond misconceptions 
*Journal of Chemical Research* 73: 36-39


Gabel D. (1999) Improved teaching and learning through chemistry education research: A look to the future. *Journal of Chemical Education* 76: 548-553

67
Journal of Chemical Education 64: 695-697


Giffrey J., NZChem (2000), 80, p4

Journal of Chemical Education 74: 862-864.


Journal of Chemical Education 76: 1221-1223.

Journal of Chemical Education 76: 1353-1359

Journal of Chemical Education 61: 847-849.

Journal of Chemical Education 70: 701-705

Journal of Chemical Education 74: 262-268.
*Journal of Chemical Education* 75: 425-435.

*Education in Chemistry*: July 1991 99-102


*Journal of Chemical Education* 75: 1326-1330


*Journal of Chemical Education* 69: 191-195.


NZQA (1997) *Marking Schedule & Examiner’s Commentary 1997*


NZQA (1997) UB Examination: Chemistry 1997


NZQA (1999) UB Examination: Chemistry 1999


Stavey R .(1991) Using analogy to overcome misconceptions about conservation of matter.


<table>
<thead>
<tr>
<th>Content</th>
<th>Recall chemical facts</th>
<th>Explaining concepts and understanding</th>
<th>Interpretation and patterns</th>
<th>Using chemical terms and description</th>
<th>Writing formulas and equations</th>
<th>Using models and structures</th>
<th>Problem-solving</th>
<th>Observing/planning</th>
<th>Inferring/gathering</th>
<th>Experimental and reporting</th>
<th>Identifying</th>
<th>Weighting for exam</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>e configurations</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical bonding and forces</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lewis structures</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Periodic trends</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radioactivity</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 17 elements</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transition elements</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reaction rate</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energetics of processes</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equilibrium, Kc</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precipitation, Ks</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid/base, pH, Kw, Ka, Kb</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buffers</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxidising &amp; reducing agents</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volumetric analysis</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cells &amp; electrode potentials/</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isomerisation</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrocarbons/Haloalkanes</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohols</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aldehydes/ketones</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amines</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid derivatives</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polymers</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>Recall chemical facts</td>
<td>Explaining concepts and understanding</td>
<td>Interpreting patterns</td>
<td>Using chemical terms/description</td>
<td>Writing formulae/equations</td>
<td>Using models/draw structures</td>
<td>Numeracy/problem solving</td>
<td>Focusing/planning</td>
<td>Information gathering</td>
<td>Experimentally reporting</td>
<td>Identifying</td>
<td>Weighting for exam</td>
<td>Total score</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-----------------------</td>
<td>----------------------------------------</td>
<td>-----------------------</td>
<td>----------------------------------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
<td>---------------------------</td>
<td>------------------</td>
<td>---------------------</td>
<td>-----------------------------</td>
<td>------------</td>
<td>-----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>a configurations</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td></td>
<td>5</td>
<td>1</td>
<td></td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Chemical bonding and forces</td>
<td>✅</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Lewis structures</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Periodic trends</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Radioactivity</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>14</td>
<td>5</td>
<td>8</td>
<td>22</td>
</tr>
<tr>
<td>Group 17 elements</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>5</td>
<td>1</td>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td>Transition elements</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>19</td>
<td>3</td>
<td>7</td>
<td>25</td>
</tr>
<tr>
<td>Energetics of processes</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>7</td>
<td>4</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>Equilibrium, Kc</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Precipitation, Ks</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>5</td>
<td>1</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>Acid/base, pH, Kw, Ka, Kb</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>3</td>
<td>3</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>Buffers</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>17</td>
<td>5</td>
<td>1</td>
<td>23</td>
</tr>
<tr>
<td>Oxidising &amp; reducing agents</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>4</td>
<td>4</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>Volumetric analysis</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>17</td>
<td>3</td>
<td>6</td>
<td>26</td>
</tr>
<tr>
<td>Cells &amp; electrode potentials</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>17</td>
<td>3</td>
<td>6</td>
<td>26</td>
</tr>
<tr>
<td>Isomerisation</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>4</td>
<td>7</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>Hydrocarbons/Haloalkanes</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Alcohols</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Aldehydes/ketones</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Amines</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Acid derivatives</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Polymers</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
<td>❌</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Record sheets</td>
<td>Student</td>
<td>year</td>
<td>Date</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>---------</td>
<td>------</td>
<td>------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starter Questions</td>
<td>Can you now smell the substance?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Can you explain why you can smell it?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Can you see the substance? Why not?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>What is the substance made of?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Why does it take some time before you can smell it?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Why could you not smell it when the top was on the bottle?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Complete this picture of how you can smell the substance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demo #1</td>
<td>Can you explain to me what is happening here?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demo #2</td>
<td>Why does it take some time for the blue colour to spread?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Complete these pictures about how the blue colour spreads.

now  

in 1 hour

next week

Demo #3  
Can you explain to me what has happened here?

Why has the second balloon gone down?

Complete these diagrams for the balloon

Today  

after 1 week

after 1 month

Can you draw what is happening inside the balloon?
Starter Questions

Demo #1 Can you now smell the substance?

Yes.

Can you explain why you can smell it?
The smell is smelly.

Can you see the substance? Why not?
No

What is the substance made of?
The smell...

Why does it take some time before you can smell it?
It flies - It takes a while. It has to push through the air and the

Why could you not smell it when the top was on the bottle?
The top was on tight - couldn't get oxygen and gas.

Complete this picture of how you can smell the substance
Demo #2

Can you explain to me what is happening here?

It's like fireworks going down from the sky.
The green colour is a little bit heavy.

Why does it take some time for the blue colour to spread?

Because the water is a little heavy also and it stops the green colour coming down. The green colour won't come to the bottom.

Complete these pictures about how the blue colour spreads.

now

in 1 hour

next week

Demo #3

Can you explain to me what has happened here?
Why has the second balloon gone down?

The air is coming out of the sides. The air is pushing out - what is pushing? The germs are pushing.

What are the germs? - The bugs.

Is there anything else in the air? - Oxygen.

Oxygen is really small - smaller than the germs.

Complete these diagrams for the balloon.

![Diagram of a balloon today, after 1 week, and after 1 month]

Can you draw what is happening inside the balloon?

![Diagram showing oxygen and a germ inside the balloon]
Appendix 4

Instruction sheet  Student led Group

Session 1  (Wednesday)

Demonstrations by teacher

Classifying ionic reactions. Anion and cation definition
Identifying ions present in a solution
Observing a precipitate
Writing ionic equations for the reactions observed.
Make short notes on the above.

Meet as a group. Gather equipment and set up in corner of room.
Begin experimenting by working with cations and then anions to discover any patterns.
**Sodium hydroxide** is a good chemical to add to cations!
You will be given limited assistance by one of the teachers.

Session 2  (Thursday)

Continue with experiments. Work together and discuss everything you find out.
Record all results. Identify cations and anions that combine to give precipitates.
Consider possible rules for solubility and precipitation: some for cations and some for anions.

Session 3  (Friday)

Finalise results with intensive discussion
Analyse results
Summarise the results together. Form a set of precipitation rules.
Start the worksheet and complete for homework
Learn the work over the weekend

Session 4  (Monday)

This will be a posttest on the work learned.

**Please do not converse with members of the other group about the results of your work. This is most important.**
Appendix 5

Predicting precipitation

Pretest / Posttest

Name

Answer all the questions on this sheet.

For questions 1 – 4 give the name or formula of the precipitate which would form when the following pairs of solutions are mixed.

1. Potassium chloride and silver nitrate
2. Iron II sulphate and sodium hydroxide
3. Sodium sulphate and barium chloride
4. Lead nitrate and magnesium sulphate

For questions 5 – 8 write the ion-equation for the formation of the following insoluble compounds.

5. Lead sulphate
6. Iron II hydroxide
7. Silver iodide
8. Calcium hydroxide

For questions 9 – 12 write an ion-equation for any precipitate which would form when the following solutions are mixed. If a precipitate does not form write ‘no reaction’.

9. sodium hydroxide and silver nitrate
10. Potassium nitrate and calcium chloride
11. Barium nitrate, potassium nitrate and sodium sulphate
12. Copper sulphate, potassium nitrate and sodium hydroxide

For Questions 13 – 16 name a chemical that could be used to distinguish between the following pairs of solutions. (You need to name the chemical and state what you expect to see happen when it is added to each solution).

13. KCl and CuSO₄
14. Na₂CO₃ and NaCl
15. FeCl₃ and CuCl₂
16. Al(NO₃)₂ and Mg(NO₃)₂
Appendix 6

Student Questionnaire

Year 13 Chemistry

Student Perceptions and Understandings

Dear Student

Please answer the questionnaire by ticking the brackets that apply, and/or writing in the spaces provided.

Please return the questionnaire to your teacher.

Thank you for your assistance in this research project.

Bruce Henley
University of Canterbury
Section 1

If you are an International student or English is NOT your first language tick here ( )

1. Gender: male ( ) female ( )

2. Why have you chosen to study chemistry in year 13? Please tick the main reason.
Career plans ( ) I've done well in the past ( ) I Need it for University Bursaries ( ) No specific reason ( )

3. How interesting do you find chemistry as a subject to study?
Very interesting ( ) Just interesting ( ) Not very interesting ( )

4. The following are questions about how your background knowledge may have helped your current studies in chemistry.

How much help have the year 11 maths and science courses been for solving chemistry problems in years 12 and 13?
Been a great help ( ) Been some help ( ) Been no help ( )

Has your understanding of chemical principles or concepts from year 11 helped your year 13 chemistry?
Yes ( ) No ( ) Not sure ( )

Have the chemical facts, that you remember from year 11, helped you in your year 13 Chemistry?
Yes ( ) No ( ) Not sure ( )

5. The following are questions about ways of learning. How valuable are they to your understanding and learning of chemistry?

Doing experiments Very valuable ( ) Quite valuable ( ) Not valuable ( )
Class discussions ( ) ( ) ( )
Note taking from teacher ( ) ( ) ( )
Watching practical demonstrations ( ) ( ) ( )
Individual work ( ) ( ) ( )
6. The following are questions about your current working environment in chemistry.

How do you find the workload in chemistry?

Pretty light ( ) Just about right ( ) Too high ( )

How do you rate the class environment?

Fantastic ( ) OK ( ) Poor ( )

What do you think of your teacher explanations?

Exceptional ( ) Good ( ) Poor ( )

How often is the teacher available to answer your questions?

Always ( ) Most of the time ( ) Sometimes ( ) Rarely ( )

How much time is made available during class-time for revision of content and examination practice questions?

A lot of time ( ) Some time ( ) Not enough time ( )

7. How difficult to understand do you find the concepts / topics of chemistry?

All very difficult ( ) Some are difficult ( ) None are difficult ( )

Can you please note here your most difficult concept / topic. __________________________

8. Would you please give an example of being able to apply your chemistry knowledge or skills in everyday life.

______________________________

9. Do you think you will carry on with your study of chemistry at tertiary level?

Yes ( ) No ( ) Not sure ( )

Section 2

Would you please now answer the following chemistry questions on the next sheet.
Appendix 7

Question 1

Consider these two situations:
A. Some salt is dissolving in water.
B. A match is burning down to a black stick.

Does A involve a chemical change?  yes ( ) no ( )
Please give a reason for your answer

Does B involve a chemical change?  yes ( ) no ( )
Please give a reason for your answer

Question 2

Solid carbon dioxide can sublime (turn directly into a gas). The left-hand box shows 6 molecules of solid carbon dioxide in a vessel. In the right-hand box draw how the carbon dioxide would appear after it has sublimed.

\[
\begin{array}{c}
\begin{array}{c}
O=O=C=O \quad O=O=C=O \\
O=O=C=O \quad O=O=C=O
\end{array}
\end{array}
\]
Question 3

Hydrogen and iodine react to form hydrogen iodide as shown by the following equation:

\[ \text{H (g) + I (s) \rightarrow 2HI (g)} \]

The boxes below represent a close up of a vessel in which 5 molecules of hydrogen are mixed with 4 molecules of iodine solid. The left hand box shows the situation before the reaction occurs. Complete this box by drawing in the 5 molecules of hydrogen (gas). The right-hand box represents the situation after the chemical reaction is complete. Draw an accurate representation of all the molecules present.

Question 4

Consider the reaction \(4\text{Fe} + 3\text{O} \rightarrow 2\text{Fe}_2\text{O}_3\)

If 4 million iron atoms reacted, how many million oxygen atoms reacted? ( )

Give a reason for your answer.

Question 5

A brown oil stain appears on a light coloured carpet. The best solvent to clean it off would be;

water ( ), alcohol ( ), tetrachloromethane ( ), salty water ( )

Give a reason why the solvent you have selected would work.
Appendix 8

Department of Education
University of Canterbury
Christchurch
New Zealand

29/07/2000

Dear student,

I am undertaking research into the teaching and learning of certain aspects of the year 12 and 13 chemistry course and in particular the effect of the new curriculum. The aim is to ascertain your understanding of selected chemical concepts and your opinion on aspects of the chemistry course.

I have randomly selected nine schools from throughout Christchurch and your school is one of those chosen. Your chemistry teacher has agreed to assist me in the administration of the tasks. You and five other students have been randomly selected from your year 13 chemistry class, and will sit a questionnaire and applications test. This would involve approximately 20 minutes only of your lunchtime. There is no risk involved to you, and neither you nor the school will be identified in the published results. To ensure anonymity and confidentiality all questionnaires and tests will be destroyed at the end of the study. You are not asked to give your name.

This project is being carried out under the supervision of John Longbottom (College of Education) and Andy Pratt (University of Canterbury). Permission for this project has been granted by the Human Ethics Committee.

I would like you to consider being part of this important project which would start early term 3 2000. Thank you for your assistance and giving up some of your valuable time.

If you agree to participate please complete the consent form below and return to your teacher.

Yours sincerely

Bruce Henley

Consent Form: Chemistry Concepts and The New Zealand Curriculum

I have read and understood the description of the above named project. On this basis I agree to participate as a subject and I consent to the publication of the results of the project with the understanding that anonymity will be preserved. I understand also that at any time I may withdraw from the subject including the withdrawal of any information I have provided.