Science Investigation in New Zealand Secondary Schools:

Exploring the Links between Learning, Motivation and Internal Assessment in Year 11

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Abstract

Science investigation is one of the three aspects of science learning, along with scientific knowledge and an understanding of the nature of science, within the constructivist science curriculum statement of the New Zealand Curriculum Framework. Year 11 students in New Zealand secondary schools who learn to investigate in science are assessed internally for National Certificate of Educational Achievement credits and grades. The purpose of this research was to gain an understanding of the phenomenon of student learning and motivation to learn in year 11 science investigation and how the recent systemic change to formal assessment in New Zealand secondary education is related to teaching and learning of science investigation in year 11. This research, which adopted a case study approach, investigated the phenomenon of science investigation at a regional level through a survey of all year 11 science teachers in the Wellington region and an in-depth study of science investigation in one coeducational, medium size, state, secondary school and one year 11 science class in that school. The data were collected through surveys, classroom observations, teacher and student interviews and document analysis. Findings suggest that the introduction of internal assessment of science investigation led to change in teacher practice. The narrow fair testing type of investigation required for internal assessment and experienced by the students encouraged a surface approach to learning rather than deep learning for understanding. Students set performance goals and were motivated to achieve credits and grades in the assessment.

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CHAPTER ONE
Introduction

Learning in science is complex and demanding if the aim of teaching science in schools is to develop conceptual understanding, procedural knowledge, and an understanding of the nature of science. Learning to investigate is a mandated requirement of *Science in the New Zealand Curriculum* (Ministry of Education, 1993a). *Science in the New Zealand Curriculum* was the first national curriculum statement written for science across all levels of schooling in New Zealand and there were great expectations that its implementation would lead to better teaching and learning of science in New Zealand primary and secondary schools.

There is considerable information internationally about teaching and learning of science investigation in secondary schools, but little is known about teaching and learning of science investigation in New Zealand. Secondary schools in New Zealand have undergone significant change in the assessment of science investigation since the introduction in 2002 of the National Certificate of Educational Achievement. The case study in this thesis explored the teaching, learning, and internal assessment of science investigation in year 11 from the perspective of teachers and students. At the time of data collection, the new assessment regime had been in place for five years allowing teachers time to gain experience in using it. This research was therefore timely to gain insight into any influence on teaching and learning of science investigation that this change in assessment practice might have had.

1.1 Locating Myself as an Educator and Researcher

I was born and educated in India and had a privileged education in an English medium school. My interest in science started when practical work in schools became compulsory and was externally assessed. I found practical work exciting and motivational and accepted assessment of practical work as a natural part of the learning experience. This fascination with learning science led to a Bachelor of Science, followed by training as a primary and secondary school science teacher and a Bachelor of Education. I completed a Master of Education specialising in methodology of science teaching. Subsequently, I worked as a lecturer at a College of Education in India for a year before coming to New Zealand. It was difficult to get a permanent teaching job, and my teaching career in this country started as a pool reliever. Over the following 27 years I trained as an early childhood educator, taught science in primary and intermediate schools and eventually science, biology, and horticulture in secondary schools before being appointed as a lecturer at the former Wellington College of Education, now the Faculty of Education at Victoria University of Wellington. Teaching science in New Zealand from early childhood to tertiary has been a privilege as it has given me an understanding of the science learner at different stages of formal education. Currently, I am a teacher educator and a member of a science teacher network in the region where I work.

During this journey of science teaching I have experienced significant changes in the approaches to science teaching from doing practical work in the 1970s to the emphasis on the teaching of process skills in the 1980s, and science investigations from 1990 onwards. My involvement in science fairs and CREST (Creativity in Science and Technology) over the last 20 years has been a worthwhile experience because of the enthusiasm shown by the participants for learning through carrying out investigations on topics of interest to them. Like other science teachers in New Zealand, I experienced the implementation of the first national science curriculum statement and the changes to the school qualification system and its associated assessment regime. As a teacher educator I have wondered how these changes have influenced the teaching and learning of science investigation and it is this interest which led to the research presented here.

1.2 The Research Rationale

Presently, there is little research on the impact of internal assessment of investigation in year 11 science on the teaching and learning of science investigation in New Zealand. Tension exists between teaching for learning and teaching for assessment. Research in the United Kingdom suggests that teaching of science investigation in year 11 (Sc1 in the UK) is narrowly focused on assessment. This prompted an urge to find out what was occurring in New Zealand secondary schools in year 11 science.

The problem investigated in this study is how science investigation is taught and assessed in year 11 science in New Zealand secondary schools. Teaching depends on teachers' understanding of science investigation, and how they teach students to investigate was an essential component of this research.

In recent times, teachers of senior science in New Zealand have had to adapt to two significant systemic policy changes that have impacted on their practice. The first change was the move to a single science curriculum statement for all levels that replaced the previous syllabi and prescriptions. *Science in the New Zealand Curriculum* is a substantive document that heralded a major change in philosophy and set a new direction for science teaching and learning. The curriculum statement regarding teaching of science investigation, made mandatory in 1993, is discussed in Chapter two. Briefly, the document sets achievement objectives for each level and indicates progression from one level to the next. Although there is evidence that New Zealand teachers have always done experiments and practicals in science classes, a progression in students' investigative skills is now an expected outcome.

No sooner had teachers come to grips with these curriculum changes when the second systemic change took place (New Zealand Qualifications Authority (NZQA), 2001). As part of the National Qualifications Framework there was a change to standards-based assessment. A new National Certificate of Educational Achievement for senior secondary education was put in place. In year 11 the National Certificate of Educational Achievement level 1 replaced School Certificate, in year 12, level 2 replaced Sixth Form Certificate and in year 13 level 3 replaced the University Bursaries Examination. These changes were implemented in three successive years from 2002.

With the introduction of the National Certificate of Educational Achievement level 1, internal assessment of science investigation was introduced in year 11 science. The practice of science investigation was not previously assessed and science was not assessed internally except in a few schools that offered modular science.

My interest in the teaching and learning of science and anecdotal evidence from my colleagues in teacher education suggested that teachers were putting considerable effort into teaching to investigate because students were to be assessed. This made me wonder – is the change in assessment policy affecting teaching and learning in secondary school? How do teachers teach their students to investigate and how do they assess their learning? Are our students learning to investigate or being taught to pass the examination as is happening in other parts of the world? Do students want to learn to investigate and what motivates them to learn to investigate? This study attempts to understand the interconnectedness of the multiple dimensions of learning to investigate, motivation to learn, and assessment of investigation for the National Certificate of Educational Achievement level 1.

The theoretical frame for science learning in this research is constructivism. *Science in the New Zealand Curriculum* is underpinned by a constructivist theory of learning, where learning is considered to be an active rather than passive process and each individual constructs their own understanding based on their experiences. According to this theory of learning, students link new learning with their existing knowledge and beliefs which they modify if necessary (Driver, Asko, Leach, Mortimer & Scott, 1994). Additionally, reconstruction of meaning requires effort from the learner. If the students are required to make an effort, then motivation is also required. Unless students are motivated they are unlikely to make an effort. Conceptual change is largely influenced by three factors – choosing to engage, engagement with the task, and willingness to persist with the task – all of which are behavioural indicators of motivation (Pintrich, Marx & Boyle, 1993). Constructivist theory implicates motivation as a necessary pre-requisite and co-requisite for learning (Palmer, 2005). Palmer adds that most research in science education has not focused on motivation to learn.

In this thesis school science investigation is understood as a:

> Practical activity in which students are not given a complete set of instructions to follow (a 'recipe'), but have some freedom to choose the procedures to follow, and to decide how to record, analyse and report the data collected. They may also (though this will not be taken as a defining characteristic) have some freedom to choose the question to be addressed and/or the final conclusion to be drawn. Like 'experiments', 'investigations' are a sub-set of 'practical work'. (Millar, in press, p. 2)

1.3 Outline of the Thesis

The thesis comprises nine chapters. Chapter two locates the place of this study in *Science in the New Zealand Curriculum* (Ministry of Education, 1993a) and describes the structure of both *The New Zealand Curriculum Framework* (Ministry of Education, 1993b) and *Science in the New Zealand Curriculum.* Chapter three presents the review of selected relevant literature for science investigation, constructivism as a theory of learning, motivation to learn, and assessment of learning to investigate.

The research design and methodology are described in Chapter four, supporting the choice of a case study as the appropriate approach to comprehend the phenomenon of school science investigation. The data were collected through a questionnaire survey of year 11 science teachers of the greater Wellington region to gain a broad overview of teachers' perspectives on science investigation. This was followed by a nested case study in one secondary school in the region through teacher interviews, classroom observations, student focus group interviews, and analysis of school and science department documents.

Results of the study are reported in Chapters five, six, and seven. Chapter five is devoted to the reporting of results from the teacher survey carried out to understand the phenomenon of interest from the perspective of the population of science teachers in the Wellington region. Chapter six describes the school and the structure of the science department, and provides an insight into the organisation of science teaching within the department. The chapter then presents results of the study school science teacher interviews. Chapter seven reports results of the study of science investigation within a single class in the study school. It includes data from classroom observations, teacher and student interviews, teacher reflections, student surveys, and document analysis. The discussion chapter, Chapter eight, presents the integrated results comparing and contrasting data from the multiple sources, identifying ten emerging themes, synthesising, and discussing these themes in light of existing literature. The findings of the research, answers to the research questions, implication of the findings for practice and policy as well as suggestions for future research are presented in Chapter nine.

CHAPTER TWO

The Curriculum Context of the Study

A curriculum statement is the founding policy document on which all teaching and learning is expected to take place within a given timeframe. The *New Zealand Curriculum Framework* (Ministry of Education, 1993b) and *Science in the New Zealand Curriculum statement* (Ministry of Education, 1993a) define the teaching and learning that is required to have taken place in classrooms during the course of this research and provides the context for this study. Relevant information from level 6 of the senior curricula, *Biology in the New Zealand Curriculum* (Ministry of Education,1994a), *Chemistry in the New Zealand Curriculum* (Ministry of Education, 1994b), and *Physics in the New Zealand Curriculum* (Ministry of Education, 1994c) is also presented.

2.1 *The New Zealand Curriculum Framework*

The New Zealand curriculum sets out the requirements for student learning, and schools develop their individual school curriculum according to the needs of their students and community. The Ministry of Education (1993b) states:

> **The New Zealand curriculum** comprises a set of national curriculum statements which define the learning principles and achievement aims and objectives which all New Zealand schools are required to follow. (p. 4, Emphasis is original)

The *New Zealand Curriculum Framework* (Ministry of Education, 1993b) includes seven curriculum statements, one for each essential learning area of language and languages, mathematics, science, technology, social sciences, the arts, and health and physical wellbeing. It sets out the essential skills and the place of attitudes and values in the school curriculum, and outlines the policy for assessment at school and at the national level. The individual curriculum statements provide details of the knowledge, skills and attitudes that students are required to develop.

The principles provide direction for learning and assessment, foster achievement and success for all students, define the achievement objectives against which student progress is measured, allow flexibility for designing the school curriculum, ensure that learning progresses coherently, and encourage students to become independent learners. The principles acknowledge the significance of the Treaty of Waitangi and the “unique position of Māori in New Zealand society” (p. 7), reflecting “the multicultural nature of New Zealand society” (p. 6), and relate learning to the wider world. The curriculum statements have English and Māori versions. The Māori version of the science curriculum statement, *Ngā Ahuatanga o te Putāiāo* (Ministry of Education, 1994e), is also available but has not been used as science in the present study is explored in English medium schools.

2.1.1 Development of essential skills

The *New Zealand Curriculum Framework* (Ministry of Education, 1993b) requires the development of eight essential skills across all subject areas. These skills are important for the learning of science and are listed below:

> Communication skills
> Numeracy skills
> Information skills
> Problem-solving skills
> Self management
> Social and co-operative skills
> Physical skills
> Work and study skills. (p. 17)

2.1.2 Attitudes and values

The curriculum considers the development of positive attitudes towards all areas of learning and states that "(a)ttitudes consist of the feelings or dispositions towards things, ideas, or people which incline a person to certain types of actions" and further that "(a)ttitudes strongly influence the process, quality, and outcomes for both learning and assessment" (p. 21). The curriculum defines values as "internalised sets of beliefs or principles of behaviour" (p. 21). The curriculum acknowledges that no schooling is "value-free" and expects schools to develop a curriculum that reflects the values of its community. Values of "honesty, reliability, respect for others, respect for the law, tolerance (rangimarie), fairness, caring or compassion (aroha), non-sexism, and non-racism" (p. 21) are the values of a democratic society to be promoted in the school curriculum.

2.1.3 Assessment

The "close relationship between learning and assessment" (p. 24) in the *New Zealand Curriculum Framework* is reflected in the learning outcomes required to be met by the curriculum. Learning is to be measured against the learning outcomes. School-based assessment would help in identifying the students' learning needs in order to improve learning, and for reporting progress to parents. "Diagnostic surveys, running records … formal and informal tests, observations, anecdotal records, and self-assessment by students" (p. 24) are promoted as sound assessment practices. It is also expected that assessment at “key transition points of school entry”, namely, year 7 and year 9, will be useful for further learning (p. 25). Primary schools will pass on to secondary schools the information collected in the form of student progress records. The records will be used as student profiles at the end of secondary schooling and will include information pertaining to the academic achievement as well as development of essential skills.

The curriculum and assessment for all years of schooling are the responsibility of the Ministry of Education. “Examinations and assessment for the purpose of awarding senior secondary school qualifications are the responsibility of the New Zealand Qualifications Authority” (p. 26) which ensures that the learning outcomes of the national curriculum statements are met.

2.1.4 Levels of achievement

The curriculum acknowledges that “In any one class, students may be working at a range of levels, both in different learning areas, and within a single learning area” (p. 23). Each curriculum statement organises learning into strands. Each strand is divided into eight levels which describe the progression from junior primary to senior secondary. Thirteen years of schooling from year 1 to year 13 are represented by the aforementioned levels. The curriculum is seamless, highlighting the overlapping nature of the achievement levels. In the context of this study, in year 11 most students would be at level 6 of the curriculum although there may be some students at levels 5 or 7.

2.1.5 Achievement aims and achievement objectives

Achievement aims and objectives are a common feature of all curriculum statements. These are identified for each level of every strand. The achievement aims state goals for the strand and provide thematic links between the achievement objectives of one level and those of the next within the same strand. The thematic structure of achievement objectives within achievement aims is intended to help teachers with planning school-wide teaching schemes. The seamless nature of the levels can facilitate the planning for teaching multiple levels within a class.

Achievement objectives in levels 1 to 5 are each linked to approximately two years' learning experience. Levels 6, 7, and 8 represent a one-year learning period. “Teachers are expected to derive specific learning outcomes from the achievement objectives and place these outcomes within contexts that are appropriate to the learning needs of their students” (Ministry of Education, 1993a, p. 17). The learning outcomes are used as criteria against which learning can be assessed. The curriculum, therefore, is intended to be both constructivist and outcomes based, but there is no evidence in Ministry curriculum documentation that recognises the inherent tension between these two philosophies. It is a curriculum expectation that assessment against intended learning outcomes is used to monitor student progress.

2.2 *Science in the New Zealand Curriculum*

Science in the New Zealand Curriculum statement (Ministry of Education, 1993a) has six learning strands, four are described as contextual and two as integrating. The contextual strands are:

- Making Sense of the Material World
- Making Sense of the Physical World
- Making Sense of the Living World
- Making Sense of Planet Earth and Beyond. (p. 14)

The two integrating strands are:

- Making Sense of the Nature of Science and its Relationship to Technology
- Developing Scientific Skills and Attitudes. (p. 14)

The expectation is that schools will develop schemes of teaching in which the contextual strands and the two integrating strands will be inter-woven to deliver a coherent learning programme that helps students to develop knowledge, skills, and an understanding of the nature of science. According to the science curriculum:

> Science is both a process of enquiry and a body of knowledge; it is an integrated discipline. The development of scientific skills and attitudes is inextricably linked to the development of ideas in science. (Ministry of Education, 1993a, p.14)

In each year of schooling, students are expected to have learning experiences relating to each of the six strands.

2.2.1 Contexts for learning

The science curriculum provides sample learning contexts at each level; for example at level 6 in the strand Making Sense of the Living World, plant breeding, farming, and medicine are some of the suggested learning contexts. Using learning contexts is expected to allow for an integrated approach to planning and teaching. Teachers are encouraged to use achievement objectives from different learning strands and it is suggested that achievement objectives from different learning areas could be used to plan and deliver an integrated unit of learning in a particular context.

2.2.2 Learning experiences

It is expected that students will participate in a number of learning activities "to ensure that they have opportunities to develop skills, knowledge, and attitudes in science that are described by the achievement objectives" (p. 18). The document provides a list of possible learning experiences for each level. These suggested experiences give "guidance about the science concepts, language, approaches, techniques, materials and equipment which are appropriate for each level. Learning experiences also suggest the scope and depth of expected learning" (p. 18). Teachers are encouraged to use these and other learning experiences that they choose to provide a balanced learning programme for the students based on student interest, community resources, and current events.

2.2.3 Assessment examples

According to the science curriculum, the purpose of assessment is "to improve students' learning and the quality of the learning programmes" (p. 18). It is suggested that the assessment is an integral part of the learning programme and that it is consistent with the general aims of science education as required by the curriculum. The statement provides examples of assessment tasks for five of the six strands. It does not provide these examples for the Developing Scientific Skills and Attitude strand as the achievement objectives for this strand are expected to be integrated with those of the contextual strands. An illustrative example of such assessment tasks is "designing a "fair test" on the insulating properties of neoprene material used in a wetsuit design" (p. 83). The curriculum highlights that the assessment examples suggested are not a complete list and that "Teachers will also need to locate and devise other assessment tasks for their own diagnostic, monitoring, and review purposes" (p. 19). The curriculum suggests that a range of assessment procedures and a variety of assessment tasks should be used to have a full picture of student achievement in all aspects of science learning.

2.2.4 Level 6

Science is taught in most schools up to year 11. As the focus of this study is on year 11, level 6 science will be referred to as year 11 science. Schools are also able to offer year 11 biology, chemistry, or physics. All senior science curriculum statements (*Biology in the New Zealand Curriculum, Chemistry in the New Zealand Curriculum,* and *Physics in the New Zealand Curriculum*) start at level 6. Some schools also offer human biology, horticulture, and alternative science courses. As there is no curriculum statement for human biology and horticulture, schools use achievement standards as a guide (achievement standards are designed by the New Zealand Qualifications Authority for assessment and are described in detail in Chapter three). Alternative science courses are mostly internally assessed and generally designed within schools for students who may find the year 11 science course challenging.

2.3 Science Investigation in *Science in the New Zealand Curriculum*

Relevant to this study is the place of science investigation in the science curriculum as it applies to year 11 (level 6 of the curriculum). According to the science curriculum, investigations provide key opportunities for students to extend their understanding in science (Ministry of Education, 1993a). Through investigating it is expected that students will develop skills and attitudes and background understanding of the nature of science. One of the aims of science education listed in the curriculum is to advance learning by:

> Encouraging students to develop skills for investigating the living, physical, material and technological components of their environment in scientific ways. (Ministry of Education, 1993a, p. 9)

The importance of science investigation is highlighted in the achievement objectives of both the contextual strands and the integrating strands.

2.3.1 Science investigation in the contextual strands at level 6

Science investigation is required to be taught in each of the contextual strands. To illustrate, in the Making Sense of the Physical World strand, achievement objective 1 at level 6 states:

> Students will be able to carry out practical investigations, with effective control of variables, into common physical phenomena, and relate their findings to scientific theories, *e.g. force and acceleration, insulation, heat capacity of different materials.* (p. 82)

Similarly, Making Sense of the Living World states, “Students can investigate and describe examples of different types of helpful and harmful micro-organisms” (p. 64). In the Making Sense of the Material World strand, all four achievement objectives require investigation. For example, “investigate and understand how familiar chemical substances can be grouped into families which have characteristic chemical properties” (p. 100). Likewise, in the Planet Earth and Beyond strand achievement objective 1 states that, students can "investigate and classify minerals and rocks according to their easily observed properties and relate to their common use" (p. 118).

2.3.2 Science investigation in the integrating strands

As already noted, the integrating strands comprise Making Sense of the Nature of Science and its Relationship to Technology and Developing Scientific Skills and Attitudes.

Making Sense of the Nature of Science and its Relationship to Technology

The achievement objectives of this strand do not mention investigation; however, at level 6 students are expected to "understand the characteristics of scientific experiment...(and)... investigate how knowledge of science and technology is used by society when making decisions about environmental issues" (p. 36).

Developing Scientific Skills and Attitudes

The achievement aim of this strand is for students to "use their developing scientific knowledge, skills, and attitudes to further develop their investigative skills" (p. 42). Investigation is not always practical in nature. *Science in the New Zealand Curriculum* states:

> Carrying out an investigation in science involves an interaction of many complex skills. These include focusing, planning, information gathering, processing, interpreting, and reporting. Students may be investigating by carrying out a practical investigation of the "real world", by carrying out an investigation of appropriate reference material, or by integrating these approaches. (p. 43) (The emphasis is original)

Additionally, focusing and planning, information gathering, processing and interpreting, and reporting constitute the four achievement objectives. In relation to science investigation the notes at the end of the table of achievement objectives of this strand state:

> 1 The ability to carry out a complete investigation is the key expected outcome of this achievement aim.
>
> 2 It is expected that the students will develop any specific investigative skills they need when they are carrying out a complete investigation.
>
> 3 The processes of investigation are not sequential. The process may begin at any point in the table above and will tend to move backwards and forwards. Students should be reflecting on their decisions, actions, and findings and modifying their plans and actions as they are proceeding. (p. 47)

Problem solving is identified in the curriculum as a vital part of scientific investigation defined in the science curriculum as:

> …identifying and analysing the problem, gathering relevant information, designing alternative solutions, testing the method or device, evaluating the method or device, modifying the method or device, and reaching a decision regarding the merit of the chosen method or device. (p. 43)

It has been signalled that the student needs to develop the skills to critically evaluate their plan and alter it if required. The emphasis is not only on the development of the individual skills of planning, information gathering, processing and interpreting, and reporting but also on using these skills to carry out investigation and to solve real problems.

Furthermore, as students learn science they need to develop the underlying attitudes upon which science investigation depends. “These attitudes include curiosity, honesty in recording and validation of data, flexibility, persistence, critical-mindedness, open-mindedness, willingness to suspend judgement, willingness to tolerate uncertainty, and an acceptance of the provisional nature of scientific explanation” (p. 43).

The connectedness between science skills, investigation, and essential skills required by the *New Zealand Curriculum Framework* is shown in figure 2.1.

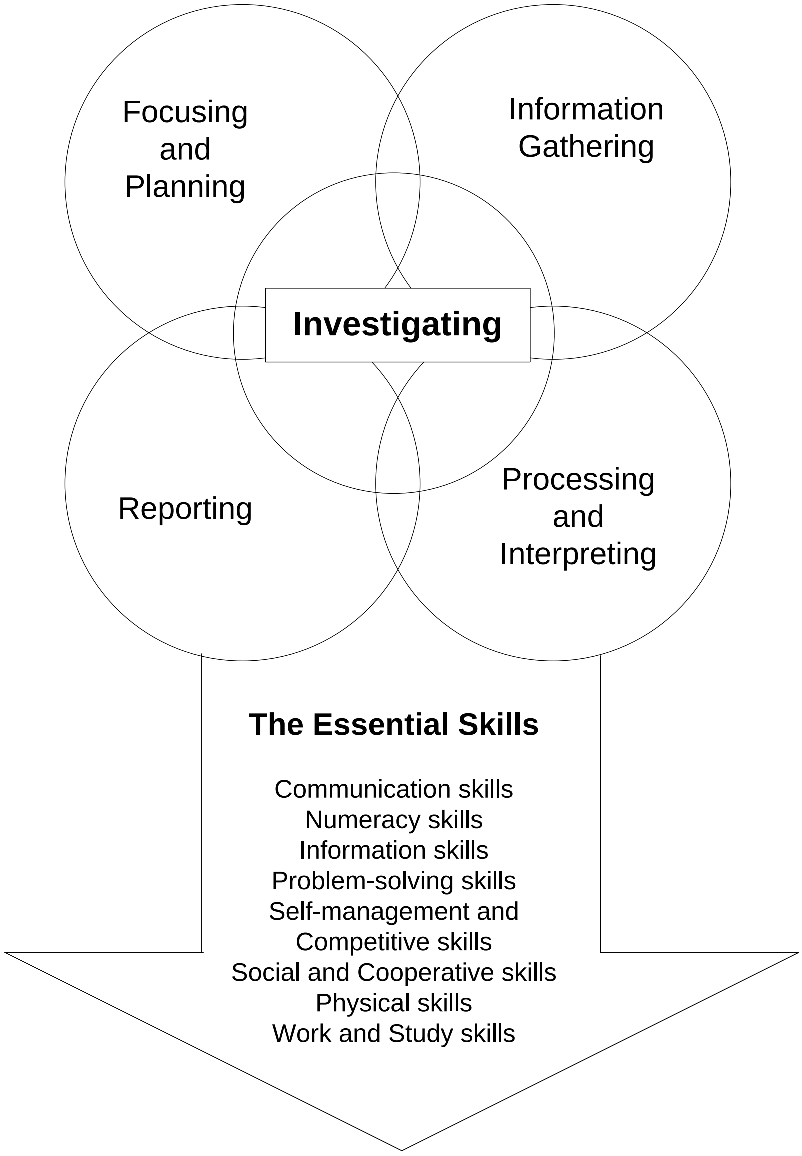

Figure 2.1: Relationship between science skills, investigation and essential skills required by the *New Zealand Curriculum Framework*

Overall, it can be said that science investigation, along with developing knowledge of content and an understanding of the nature of science, is fundamental to learning science in year 11.

The science curriculum uses the terms fair testing, investigation, and experiment. For example, in the nature of science strand of the curriculum, achievement objective one states that students can "understand the characteristics of a scientific experiment" (p. 36). In the possible learning experiences for the same achievement objective it is suggested that students could be learning by "carrying out a fair test on the insulating properties of thicknesses of polystyrene" (p. 37). The first two assessment examples for this strand at level 6 state:

- awareness of the need for replication of results, when students carry out their own experiments on selected aspects of living, physical and material worlds;
- ability to design and carry out an experimental investigation, when the students analyze a range of consumer products. (p. 37)

The science curriculum does not provide definitions for the terminology used in the document. This lack of definition could have implications for teacher understandings of the nature and purpose of experiments, fair testing, and investigation.

2.4 Assessment Policy and Practice in Schools

The implementation of *Science in the New Zealand Curriculum* required a change in direction for assessment policies. Following the implementation of the *New Zealand Curriculum Framework*, the Ministry of Education published a handbook, *Assessment Policy and Practice* (Ministry of Education, 1994d) to enable schools to develop school-wide assessment policies.

> Assessment is an integral part of the curriculum. The New Zealand Curriculum builds on the close relationship between learning and assessment. It provides clear learning outcomes against which students' progress can be measured. (p. 24)

The handbook suggested that schools develop policies for gathering assessment information for five purposes:

1. For teachers to use assessment information to identify student prior knowledge and experiences and plan the learning programmes accordingly.
2. For monitoring student progress, and to ascertain that learning objectives were being met.
3. To provide useful feedback that leads to increased student confidence.
4. To contribute towards the development of student profiles and for reporting student achievement when the student leaves secondary school.
5. To evaluate the effectiveness of teaching programmes and deciding how these programmes may be improved.

According to the handbook, schools were expected to develop assessment policy based on the principles of assessment outlined in the handbook. The principles suggested that assessment should be an "integral" part of the learning process and that the "purpose of assessment should always be made explicit". Assessment information was to be shared with the students and it would be as objective as possible. Multiple methods were to be used for assessment which would take place in several contexts and the form of assessment was to be carefully selected so that it was "appropriate for the knowledge, skills, or attitudes to be assessed". The guidelines recommended that various "learning styles and cultural expectations" were to be considered especially for students for whom English was their second language. Assessment activity was expected to be age appropriate, and at the right developmental level for the student. Finally, it was expected that assessment would have "credibility" for all involved and results should be "capable of being communicated clearly" (Ministry of Education, 1994d, p. 8).

These principles demonstrated that the intention of assessment processes was to be learner centred and focused on determining what learning was taking place. In addition to the above principles, the handbook also described three types of assessments:

1. Diagnostic assessment is for the teacher to find out what the student can and cannot do. This would enable the teacher to identify the learning difficulties that students may be having and to design learning experiences that address those difficulties. Diagnostic assessment could be carried out through well-designed tests or through questioning individual students.

2. Formative assessment is an essential element in the teaching and learning process. Its purpose is to provide the student with feedback to enhance learning. Formative assessment could take many forms. It could be asking questions and clarifying, commenting on student presentations, interviews or going over test results.

3. Summative assessment would take place at the end of a learning sequence to gauge student achievement. This formal assessment would be a more structured activity compared to formative assessment.

2.5 National Certificate of Educational Achievement

New Zealand has a National Qualifications Framework administered by the New Zealand Qualifications Authority. The secondary school qualifications are the National Certificate of Educational Achievement and New Zealand Scholarships which are available from levels 1 to 4 (levels of the National Qualifications Framework are different to those of the *New Zealand Curriculum Framework*). The National Certificate of Educational Achievement levels 1, 2, and 3 have replaced the former School Certificate, Sixth Form Certificate, and the University Bursaries examination, respectively. Level 4 replaced Scholarship. The National Certificate of Educational Achievement level 4 was introduced in 2004. Most students studying in year 11 are at level 6 of the curriculum and would be assessed for the National Certificate of Educational Achievement level 1. However, students in year 11 are able to sit the examination for National Certificate of Educational Achievement levels 1 to 4 provided they have completed the pre-requisites of the previous level. Table 2.1 shows the current levels of curriculum and levels of achievement within the National Qualifications Framework.

Table 2.1: Years of schooling, curriculum levels and levels of achievement

Years of schooling	Curriculum levels	Qualification levels
1 and 2	1	
3 and 4	2	
5 and 6	3	
7 and 8	4	
9 and 10	5	
11	6	National Certificate of Educational Achievement level 1
12	7	National Certificate of Educational Achievement level 2
13	8	National Certificate of Educational Achievement level 3
		New Zealand Scholarship

NZQA (2010)

New Zealand moved from a norm-referenced mode of assessment in schools to standards-based assessment. In a norm-referenced system, students are ranked against each other. In a standards-based system student performance is assessed against standards. Phillips (2006) defines a standard as a “shorthand description of the learning or behaviours that need to be demonstrated, and the assessment criteria that will be applied to make this judgement, in order to gain credits towards a national qualification” (p. 183).

The National Certificate of Educational Achievement offers two types of standards that can be used to assess student performance: achievement standards and unit standards. Both achievement standards and unit standards credits count towards National Certificate of Educational Achievement qualifications. Achievement standards are largely used for academic secondary school qualifications. Achievement standards allow the student to gain a Not Achieved, Achieved, Merit, or Excellence grade, as well as credits. Competency-based unit standards were developed in the 1990s, initially for vocational qualifications and later for all school subjects. These are internally assessed in secondary schools and each standard is worth a specific number of credits. In both achievement and unit standards students accumulate the credits that count towards the qualification. While achievement standards allow for Not Achieved, Achieved, Merit, and Excellence grades, unit standards only allow either an Achieved or a Not Achieved grade. Unit standards are perceived by some students to be inferior to achievement standards because the students gaining unit standards tend to be among lower performing students (NZQA, 2006b). Some teachers expressed reservations about assessing the lower performing students through unit standards (Alison, 2005; Hipkins, Vaughan, Beals & Ferral, 2004; Phillips, 2006). The debate about standards-based assessment and assessment for learning is included in a literature review of the National Certificate of Educational Achievement (Zepke et al., 2005) and is addressed in Chapter three. Relevant to this study, the provisions for assessment in science and assessment of science investigation are discussed below.

2.5.1 Assessment in science for year 11

Since the staged introduction of the National Certificate of Educational Achievement in 2002, students have been assessed through a combination of internal and external assessment, and on successful achievement of 80 credits at level 1 qualify with a certificate at National Certificate of Educational Achievement level 1. Students then build on levels 1 and 2 to achieve National Certificate of Educational Achievement level 3, which is designed to acknowledge achievement across a range of learning areas and provide an advanced foundation for further study or employment (NZQA 2010; Phillips, 2006). In year 11 science, these include two internally assessed achievement standards, one each for carrying out a practical investigation and the other researching an aspect of science. The external achievement standards offered in year 11 can be in physics, chemistry, biology, geology, and astronomy. In Hipkin et al.'s (2004) view, the National Certificate of Educational Achievement allows schools the flexibility to design courses that address the needs of their students using a combination of internal and external assessment units and achievement standards.

2.5.2 Assessment of investigation in year 11

While the science curriculum emphasised the teaching of science investigation and practical skills to carry out science investigation, the written School Certificate examination of science investigation prior to 2002 included questions that assessed students' ability to plan investigation, process and interpret data, and write a report. The National Certificate of Educational Achievement standards-based assessment introduced mainly holistic assessment of the skill of gathering information (performance).

Relevant to this study, Science Achievement Standard 1.1 (AS1.1) is currently offered by the schools to assess students' ability to carry out a science investigation. AS1.1 requires students to "Carry out a practical science investigation, with direction, by planning the investigation, collecting and processing the data, and interpreting and reporting the findings". The AS1.1 explanatory notes describe an investigation as:

> …an activity covering the complete process: planning, collecting and processing data, interpreting, and reporting on the investigation. It will involve the student in collecting the primary data. (New Zealand Qualifications Authority, 2005, p.3)

There is a fundamental difference between *Science in the New Zealand Curriculum's* and the New Zealand Qualifications Authority's definitions of science investigation. The curriculum uses the word "focussing" and expects evaluation of the process as the investigation progresses and emphasises the non-sequential element of investigation (see section 2.3.2), but the assessment does not mention focussing as recommended in the curriculum and promotes a linear approach.

The standard defines what is meant by direction and suggests that a template is provided for student use (NZQA, 2005, p. 2). The standard also specifies what the practical activity will involve, how a quality investigation leads to collection of valid data and what is meant by evaluate (Appendix 1). This standard is worth four credits and the students gain an Achieved, Achieved with Merit, or Achieved with Excellence grade. To gain Achieved, students should be able to "carry out a practical investigation", for Merit they should be able to "carry out a quality practical investigation" and for an Excellence grade they should be able to "carry out and evaluate a quality practical investigation" (NZQA, 2005, p. 2). Since 2007, the accumulated grade, Achieved, Merit, or Excellence is endorsed on students' National Certificate of Educational Achievement certificates.

2.6 Summary

The *New Zealand Curriculum Framework* sets out the expected learning in New Zealand schools and describes the principles of teaching and learning, identifying seven learning areas each with a separate curriculum statement. It outlines the essential skills, values, and attitudes all students should develop during their schooling.

Science in the New Zealand Curriculum is an outcomes-based curriculum statement. It provides achievement objectives for each level which are translated into learning outcomes that are measurable and achievable. This curriculum has six strands – four contextual and two integrating. The contextual strands provide broader disciplinary contexts for learning, learning experiences, examples of assessment for learning, and guidance about the content to be learnt. The integrating strands outline the skills to be learnt, attitudes to be developed and an understanding about the nature of science and its relationship to technology. Teachers are encouraged to develop learning programmes in specific contexts that are meaningful to their students, and to use the examples but add other learning experiences to deliver a balanced learning programme. Eight levels of learning are identified that represent 13 years of schooling. The curriculum is seamless and requires progression of learning, suggesting that in any year of schooling students can be working at different levels.

Science in year 11 is assessed by both internal and external achievement standards for the National Certificate of Educational Achievement level 1 qualification administered by the New Zealand Qualifications Authority. Most schools offer 20 to 22 credits in science in a combination of internal and external standards (NZQA, 2006a). Science investigation is assessed through AS1.1, an internally assessed achievement standard worth four credits. Direction is provided in the form of a template, equipment and written instructions. Successful completion leads to the National Certificate of Educational Achievement level 1 science achievement standard AS1.1 with an Achieved, Merit or Excellence grade.

Central to this study is the curriculum expectation that students will learn to investigate through carrying out practical investigations using skills of focussing, planning, gathering information, processing, interpreting, and reporting. Students are to learn to carry out investigation and become skilful in solving problems and critically evaluating both the process and outcome of their investigation.

Chapter two described the *New Zealand Curriculum Framework, Science in the New Zealand Curriculum* statement and the National Certificate of Educational Achievement, and located the phenomenon of science investigation as required to be learnt by the curriculum and assessed through the internally assessed achievement standard science AS1.1. Chapter three presents the review of selected relevant literature on science investigation, constructivism as the theoretical frame for the study, motivation, and assessment.

CHAPTER THREE
Literature Review

Internationally, teaching students to practise science investigation and the assessment of learning in science investigation has been an enduring issue. In the United Kingdom, Australia, and United States, the science curricula of the 1990s required the teaching and assessment of science investigation. As the curriculum and assessment requirements for New Zealand are similar, selected literature related to the learning and assessment of science investigation from these countries was reviewed. The review encompasses: (1) the issues related to the nature of science investigation, (2) learning of science investigation where constructivism is taken as the theoretical frame for learning because the science curriculum is underpinned by constructivist philosophy, (3) the motivation to learn science investigation, and (4) the assessment of science investigation. Finally, the theoretical frame for this study is summarised.

3.1 The Nature of School Science Investigation

Learning in scientific investigation is an important goal of science education, alongside the acquisition of scientific knowledge, understanding, and practice (Kanari & Millar, 2004). The practical aspect of the subject has had a distinct and central role in the science curriculum internationally. Science educators have argued that many benefits accrue from engaging students in practical activities in science (Hofstein, 2004; Hofstein, Kipnis & Kind, 2008; Lunetta, 1998; Woolnough, 1991). To have an understanding of the context in which science investigation fits into the bigger picture of teaching and learning of science, the review includes historical perspectives on the development of the practical component of what it is to learn from doing science in schools.

Research in science education can be categorised into three broad dimensions – knowing of science, doing of science, and learning about the nature of science (Hodson, 1998; Monk, 2006). There is considerable agreement amongst educational researchers that all three aspects are essential for the learning of science in secondary school. The concerns, doubts, and relative importance of each of these aspects in relation to students' learning are debated in literature (Abrahams & Millar, 2008; Hart, Mulhall, Berry, Loughran & Gunstone, 2000; Millar, 2004; Monk, 2006; Wellington, 1998; Woolnough & Allsop, 1985). The teaching of all three aspects is required by *Science in the New Zealand Curriculum*.

Research findings suggest that properly developed investigative skills and meaningful learning from these activities are less frequent than can be hoped for (Hodson, 1990; Hofstein et al., 2008; Roberts & Gott, 2004a). For this research, the doing of science, and in particular why and how students should investigate and what they learn from it, are the key foci.

3.1.1 Development of practical component of school science

According to Millar (2004), generally the practical component of school science, practical work is "any science teaching and learning activity in which the students, working individually or in small groups, observe and/or manipulate the objects or materials they are studying" (p. 1). Millar preferred the term "practical work" rather than "laboratory work" as observations and manipulation of objects can be done both in and outside the laboratory. When these activities happen outside the laboratory they are referred to as practical, practicals, or fieldtrips. In a related vein, Wellington (1998) says that teachers often use the word experiments instead of practicals:

> In fact many practical activities done in school science are plainly not experiments at all; they may simply be illustrations of phenomenon (either done in small groups or on the front bench); they may simply be providing experiences or getting a feel for a phenomenon for pupils: they may simply be exercises or routines for pupils to follow by giving students an opportunity to experience a phenomenon, or it may be exercises or routines for students to follow aimed at developing a particular skill. (p. 11)

Woolnough and Allsop (1985) classified school practical work as exercises, investigations, and experiences. According to Woolnough and Allsop, exercises were about skills development, including correct use of laboratory equipment. In their view, investigations involved problem solving in open-ended tasks, and experiments were used to give the students a "feel for phenomena" (p. 4). Lunetta, Hofstein and Clough (2007) offer a broader definition of practical work in science as laboratory activities or practical activities that are "learning experiences in which students interact with materials or with secondary sources of data to observe and understand the natural world" (p. 394). Practical skills are sometimes referred to as "process skills". Laboratory experiments and inquiry learning are terms used in the United States and practical activities and investigation in the United Kingdom (Lunetta, 2003). In Millar's (in press) view "experiments and investigation are a sub-set of practical work" (p. 1). For this study, practical work includes all hands-on practical activities, experiments and investigations.

Learning science by “doing” has been a key element of science education in New Zealand and internationally (Hipkins et al., 2002). Doing science is described as a pedagogical approach to science learning and is not always a scientific investigation (Millar, 1998; J. Osborne, 2000). Hodson (1996) argues that if the goal was for students to gain an understanding of the power of scientific investigation, then learning about science has to be linked with doing science.

In New Zealand, according to Hipkins et al. (2002), the first substantive government funded research about learning in science was the Learning in Science Projects (LISP) carried out at Waikato University. This research comprised five projects between 1979 and 1996 and investigated learning of science in primary and junior secondary school, research into students’ understanding of energy as a concept, teacher development, and assessment of learning. The first LISP reported that “there were problems with the notion of evidence and experiments in promoting conceptual development in science classrooms” (Hipkins et al., 2002, p. 76). Some of these problems children faced in learning science were:

- the existing knowledge students bring to the classroom-“children’s science”
- a personal constructivist view of learning
- the importance of context
- children’s classroom experiences and
- children’s outlook on science. (p.76)

International research focused on children’s “alternative conceptions”. Extensive research in the United Kingdom by Driver and Easley (1978) and Driver (1989) found that children have different views about science ideas to adults. In New Zealand, research by R. Osborne (1982) and others claimed that children had integrated theories of science and called it “children’s science”.

According to Hipkins et al. (2002), to address the issue of the learning problems faced by students in science an interactive teaching framework was developed which involved students participating in a focussing task followed by exploration and reflection. It is reported that the use of the interactive framework led to increased student interest, engagement and involvement in the investigation along with other positive outcomes. One issue that arose for some teachers using the interactive approach was that “the ‘science’ became lost in the sea of language activities in the context of a topic such as spider, rocks and metals” (p. 83). A consideration in the use of the interactive framework for senior secondary school was the perceived time taken up by this pedagogical approach and teacher concerns about covering the examination prescription.

Practical work was first introduced in schools in the nineteenth century in Britain (Atkin & Black, 2007) and in New Zealand (Fry, 1985; McLaren, 1987). The purpose was not just to do experiments to confirm a theory that was already known but to find out something that had not been known previously (Armstrong, 1903, cited in Atkin & Black, 2007; Woolnough & Allsop, 1985). According to Atkin and Black (2007), the pendulum swung between inclusion of practical work and more effort in learning scientific facts and theories. In the period between the first and second world wars, a "cookbook" approach to school laboratory work developed with an emphasis on practical skills, following instructions and confirming well-established results as reported earlier. Practical work was about "learning by doing" and would confirm the theory presented in the textbooks. This approach lasted for several decades.

Wellington (1998) described three phases of practical work in science education in the United Kingdom in the last 50 years; these are the discovery approach, the process approach, and investigation. All three approaches were also followed in science education in New Zealand. The discovery approach originated in the United States and was followed up in the United Kingdom through the development of the Nuffield programmes of the 1960s. These United States and United Kingdom programmes were also used in New Zealand in the 1960s. The Nuffield projects worked well for some schools over a period of about 15 years. This discovery approach was criticised for representing scientists as men in white coats acting as Sherlock Holmes promoting observations as theory-free, and for the leap from experimental data to theory through an inductive process (Hodson, 1996; Wellington, 1998). Hodson (1996) summed it up as "philosophically unsound and pedagogically unworkable" (p.18).

The second phase, the process approach, implied that processes of science (observing, predicting, inferring etc.) could be learnt out of context. The skills were taught separately and it was expected that they were transferable from one context to another. It was also promoted that the less able learners could learn the skills even if they could not understand the content. By implication, science was being made accessible to all (Wellington, 1998). Locke and Foster (1987) believed that cognitive and psychomotor skills were enhanced through practical work; they emphasised that students should be able to transfer these skills to contexts in other areas of the curriculum and indeed to their everyday activities. Hodson (1991) disagreed and asserted that the transfer of these skills to another context is not achieved by most students. Woolnough and Allsop (1985) suggest that a case against practical work was the inefficient use of time and supported the thinking that "what could be learnt by practical work could be learnt through demonstrations" (p. 8). Others insisted that conceptual understanding and skills could not be separated (Adey, 2001; Driver et al., 1994).

Investigation, the third phase, was introduced in England and Wales in 1989. It was to be taught in schools and assessed through internal assessment (Sc1) for General Certificate of Secondary Education. Wellington (1998) asserts that this caused a lot of damage because it reduced investigative work to a template model of teaching followed by assessment. Students were required to plan a science investigation, carry it out, and write a report of their findings. According to Roberts and Gott (2004a), it caused much concern among researchers and teachers and:

> In some schools, Sc 1 investigations seem to have become synonymous with practical work in science and in some textbooks any activity that uses apparatus seems to be called an investigation. (p. 113)

Due to resentment and bitterness demonstrated by teachers to this approach, changes have been made so it is now called "Experimental and Investigative Science." It has less emphasis on controlling variables which means less emphasis on "fair testing", and it stresses evidence and evaluation although it still "promotes one model or template for science and scientific enquiry" (Wellington, 1998, p. 5).

For the present research, science investigation as taught and assessed for Sc1 is significant as the New Zealand model for teaching investigation has similarity with that of England and Wales. The assessment requirement of science investigation for the New Zealand National Certificate of Educational Achievement level 1, AS1.1, is similar to Sc1 for General Certificate of Secondary Education in England and Wales. However, the later revision to Sc1, which removes the assessment of performance part of the investigation, does not apply to the New Zealand system.

According to Carin, Bass and Contant (2005), towards the end of the 1990s the American Association for Advancement of Science established Project 2061 to establish what children in the United States should know and be able to do in science in the 21st century. As a result, the National Science Education Standards were written by educationists and coordinated by the National Research Council. There are six standards altogether; among them are the Science Teaching Standards (Carin et al., 2005). According to these standards, the students were to learn through inquiry that parallels the methods used by scientists, and learn how knowledge is produced. They would also learn how scientists investigate, sometimes on their own and at other times cooperatively with others. It was expected that students would be able to construct meaningful knowledge. The key strategy was for “students to investigate authentic questions of interest to them” (p. 31).

Until the middle of 1900s science education in Australia followed the British model. In the 1950s, with continuing issues of low uptake of science courses in Australian universities the use of the scientific method in a “distilled-essence” was proposed so school children could understand it and apply it to other fields as well as science. According to Bradley (2005), Australian science teachers embraced the “scientific method”. In some Australian states scientific method was listed among the objectives of the course. Bradley adds that the scientific method was described as a series of steps and included observing, defining the problem, gathering of reliable data, selection of an appropriate hypothesis to explain the data, planning, carrying out of experiments or observations to test the hypothesis, drawing a conclusion in support or otherwise of the tested hypothesis, and publication of the procedure in such a way that anyone who follows the steps could reach the same conclusion.

Scientists carry out investigations in a variety of ways. They do not follow a particular method but many different methods depending on the nature of the investigation. Drawing upon the work of Knorr-Cetina (1999) in comparing two different scientific laboratory cultures of high energy physics and molecular biology, Davies (2005) argues that there are differences “in practice between science disciplines, and between individual topics within disciplines” (p.3). Davies attributes these differences to the nature of the questions asked, and the theories, methods and equipment used. It is concluded that there is no one “scientific method” and is in agreement with science education researchers including Hodson (1990), Wellington (1998) and Tytler (2007).

3.1.2 Place of practical work in school science

The curriculum in England and Wales and *Science in the New Zealand Curriculum* require the teaching of science skills and investigation. The research reported in this section is focused on the reasons for doing practical work and investigation in secondary schools and what students learn from it.

Gott and Duggan (1996) point out that practical work in school science in the first half of the 20th century was largely concerned with “recipe practical” that illustrated science theory in action. During the first Learning in Science Project in New Zealand Tasker and Freyberg (1985) observed practical work of this kind and found that it was misinterpreted by the students. These misinterpretations included mistaking the purpose of the experiment by attending to aspects that were other than what the teacher intended, not recognising the significance of particular aspects of the task even though they were using correct terminology, and making procedural mistakes that affected the results but not recognising these (Hipkins et al., 2002). In this type of practical work students follow structured worksheets to get the right answer. Such practical work did not lead to the development of understanding of the underlying theory (Woolnough, 1991). Despite evidence of limited learning that comes from such practical work, recipe practicals are common in New Zealand schools (Hipkins et al., 2002). Internationally many reasons are offered for the inclusion of practical work in school science.

Wellington (1998) put forward cognitive, affective, and skills arguments for and against including practical work to promote pupil learning in science. Cognitive reasons for practical work included that practical work improves students' understanding of science and may help to confirm the theory they had learnt. Affective reasons included "students finding practical work interesting and exciting which helps to promote positive attitudes towards science" (p. 7). Skills reasons were about developing skills for using apparatus, measuring and manipulating objects, "learning processes such as predicting, inferring and evaluating, learning to work with others and developing an understanding of scientific enquiry" (p. 7). The cognitive arguments against practical work were "the noise that can cause confusion; sometimes the practical goes wrong, leaving students with mixed messages" (p. 7). Affective reasons against practical work include some students not liking practical work while others like it because they see practical work as a social occasion requiring little intellectual input. Wellington's argument against practical skills is that there is little evidence that the skills learnt are transferable as they are context specific. Effective group work frequently does not happen as pupils talk about non-science issues or individuals carry out the work and others watch, or become confused about approaches to scientific enquiry if the nature of the practical activity is not clearly explained.

Gott and Duggan (1996) classified science practical work into five types: "skills, observations, enquiry, illustration, and investigation" (p. 26). Sequentially, this included students learning particular skills, applying their conceptual frameworks to scientific ideas, discovering and acquisition of "concepts, laws and principles", verification of science ideas, laws and principles, and the aim of the investigation was to "provide opportunities for students to use concepts, cognitive processes, and skills to solve problems" (p. 26).

Previously, Millar and Driver (1987) identified three types of processes involved in investigating. These were skills processes, cognitive processes, and pedagogical processes. “The skills processes include observing, classifying, and hypothesising as well as gathering information, processing this information, and drawing conclusions” (p. 35). Millar and Driver argue that all the skills processes listed here, other than hypothesising, are not unique to science, in fact “these are characteristics of many human endeavours” (p. 35). It is also clear that transferability of skills learnt out of context may be a claim but does not have evidence to justify it (Hodson, 1990, 1996). Millar (2004) asserts that “cognitive learning outcomes are not likely to be achieved as a result of engagement in a single practical activity... (and) ... whilst practical work may contribute towards this it will only be part of a broader teaching strategy” Millar (p. 9). The third kinds of processes, pedagogical processes which are not discussed by Gott and Duggan (1996), are aimed at shifting from teacher-centred learning through transmission of facts to student-centred learning through doing. Millar adds that the idea that simply through doing science students can develop “understanding of concepts and skills used by scientists has no theoretical underpinning” (p. 9). Abrahams and Millar (2008) found that “teachers assumed that explanatory ideas ‘emerge’ from observations and add that this does not happen no matter how carefully these are guided or constrained” (p. 1965). There is some agreement that skills and concepts could be learnt through practical work with varying degrees of success. While Millar argues that conceptual understanding is not a direct outcome of practical work, Hodson questions the claim that skills learnt in one context are transferable to another context.

Woolnough and Allsop (1985) have identified three fundamental aims for practical work: developing practical skills and techniques, being a problem solving scientist, and getting a feel for the phenomena. Millar (1998) describes the purpose of practical work as a means of developing students’ scientific knowledge and students’ knowledge about science. Millar (2004) suggests that much of the learning from practical activity takes place in the discussion that follows the practical activity and that the two are so closely related that it does not make sense to separate them. He suggests that the “whole activity” has to be seen as: “the data collection phase <u>and</u> the data interpretation phase” (p. 8) (Emphasis is original). For Millar the role of practical work in the teaching and learning of science content is to help the students to make links between two “domains” of knowledge as shown in Figure 3.1.

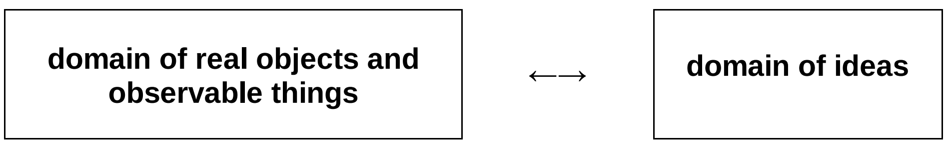

Figure 3.1: Practical work: linking two domains of knowledge (Millar, 2004, p. 8)

Millar points out that for linking the two domains through practical work, the latter needs to be scaffolded by the teacher. In a similar vein, Wellington (2005) refers to building the bridge between "knowledge that" (observed phenomenon), "knowledge what" (remembering facts) and "knowing why" (understanding the reason for phenomenon occurring) (p. 107) and asserts that the bridge between "*knowledge that and knowledge why* will not be built by unguided "discovery" or unsupported and unscaffolded activity amongst groups of children" (p. 107).

For Millar (2004) the success of any practical work depends on the intended learning objectives of the task. He proposes five objectives for learning through practical work which include: learning to identify objects and phenomena and become familiar with them; learning of facts; learning a concept; learning a relationship; and, learning a theory or model. Of these, Millar argues that the first two are achievable through practical work; although practical work may contribute towards the other three, a single practical experience is unlikely to achieve these. Millar's objective of learning about phenomena and becoming familiar with it is in congruence with Woolnough and Allsop's (1985) notion of getting a feel for the phenomena. Lunetta et al. (2007) define practical work in science as:

> Laboratory activities or practical activities are learning experiences in which students interact with materials or with secondary sources of data to observe and understand the natural world. (p. 394)

In Australia, Hart et al. (2000) in their study found that although teachers share the aims of the laboratory task with their students, they often do not share the learning expected as a result of the laboratory task. They reported that:

> While much laboratory work has a common purpose of seeking to develop students' understanding of science content knowledge, we have found that students also need to have sufficient relevant content knowledge prior to the activity if they are to meaningfully engage with it. (p. 672)

Hart et al. investigated student learning through practical work where the teacher focused on the importance of communication, publication and verification of results. They suggest, for students to make links between tasks and a holistic view of their science learning experiences, their teachers need to make the pedagogical purpose of laboratory work explicit to their students.

Rennie, Goodrum and Hackling (2001) conducted a national study into the teaching and learning of science in Australian schools. Their brief was to describe ideal practice, investigate the actual practice and make recommendations to close the gaps between the ideal and actual. One theme of the ideal practice relevant to the current study was that “The teaching and learning of science is centred on inquiry. Students investigate, construct and test ideas and explanations about the natural world” (p. 467). Rennie et al.’s findings indicated that teaching and learning occurred in two kinds of lessons: practical activities where teachers gave instructions on how to carry out the experiment and teacher talk. Of the secondary students who participated in their research, 61% reported copying notes from the teacher in almost all lessons. Of particular interest was the finding that 59% of students said that they were never allowed to choose their own topic to investigate and 33% said that they were never allowed to plan and do their own experiments. The authors of the report recommended that teachers be given support and professional development to refine their pedagogical skills and knowledge so that they can effectively facilitate “inquiry-oriented, student-centred activities and formative assessment” (p. 490).

The critics of practical work identify the issues they have about the benefits of practical work. Hodson (1990) argues that at best through practical work children re-discover what the teacher already knows. Millar (2004) does not dispute that learning by doing has affective advantage as it motivates students to want to learn science but he says “we must say that this is the purpose of practical work” (p. 39). Hart et al. (2000) point out that students can learn something from doing practical work but “by claiming too much for laboratory work, we diminish what we can achieve” (p. 672).

Millar (1998) analysed a range of practical activities used at different levels in schools. He does not advocate that teachers give up familiar and well-tried practical activities as they can be memorable events and add to interest and learning. Millar (2004) reminds that there are significant differences between research laboratories and the school science laboratory and that “scientists explore the boundaries of the known and believe that they are capable of doing so” whereas students are only trying to come to terms with already accepted knowledge (p. 15).

The place and purpose of practical work has been the focus of research and debate for the past three decades and researchers’ thinking and views about this aspect of science continues to evolve.

3.1.3 Experiments

In relation to practical work in school science, the term experiment is often used by teachers and researchers alike. Over the past three decades it has been suggested and contested that experiments involve replication of a piece of practical work already done, either recently or in the more distant past. In the 1980s, Finch and Coyle (1988) recommended that the term “experiment” should be “reserved…. for true Popper-type experiments where an abstract high level theory, model of law is put to a cleverly devised check” (p. 45). A decade later, Wellington (1998) cautioned that, “Replication is an important part of learning to do science but it does not need to be set up as an activity in which students follow steps provided by the teacher to ‘confirm’ a theory” (p. 11). More recently, Abrahams and Millar (2008) described an experiment as “a planned intervention in the material world to test a prediction derived from a theory, hypothesis” (p. 1947).

Thus an experiment in school science is an intervention or manipulation of objects that helps in understanding the material world. It may involve replication of an activity to confirm a theory learnt and therefore be a standalone activity, for example if a metal rod is heated, it expands. Through doing this experiment, a student can confirm the theory that metals expand when heated. It can also be said that that the intervention of heating the metal can prove the prediction that metals expand when heated.

Alternatively, an experiment can be carried out within or as part of an investigation. If the student is to carry out an investigation, this would involve trying out their plan to see if it “works”, to evaluate and make decisions about proceeding with the investigation. This “experiment” could lead to altering the method. In this case the experiment would be within an investigation.

3.1.4 Science investigation

According to Woolnough (1991), scientific investigation is a holistic approach to learning science through practical work. Gott and Duggan (1996) state that “the aim of science investigation is to provide students opportunities to use concepts and cognitive processes and skills to solve problems” (p. 26). They explain that to carry out a science investigation, the student starts with a question, comes up with a hypothesis or defines a problem, plans what and how they will find out the answer, carries out the investigation, gathers and processes information, comes up with a conclusion, and discusses the results.

Patrick and Yoon (2004) suggest that students gain most from science investigation when they “discuss expectations, observations, conclusions, theories, and explanations before, during, and after conducting the activity” (p. 319) and Millar (2004) agrees with the importance of discussion before and after the investigation.

Learning investigation needs to be seen as a recursive process rather than a constrained procedure. This recursive process is promoted in *Science in the New Zealand Curriculum* (p. 47). The degree to which the student has control over defining the problem, choosing the methods, and arriving at solutions dictates whether a practical activity is an open investigation or a closed practical activity (Simon, Jones, Fairbrother, Watson & Black, 1992).

Open-ended investigation differs from other kinds of practical work in that the student is given few instructions about data collection, processing, and analysis when they are required to solve a problem. The student looks at the problem presented to them, then uses their existing contextual and procedural understanding to first come up with a hypothesis. This hypothesis is not a random guess but based on thought and current understanding. They plan and carry out the investigation. As the investigation proceeds the student evaluates the procedure and makes changes as required. The decision making, evaluation and modification are essential to the process of investigating and make the principal difference between an investigation and a practical task (Gott & Duggan, 1996).

Focussing on using science investigation to develop conceptual understanding, science educators propose that carrying out a complete investigation of this kind enables students not just to do science but also to learn the science concepts and understand the nature of science (Hodson, 1990; Roberts & Gott, 2006).

Drawing from Gott and Mashiter's (1991) knowledge-based problem solving model of science investigation, Roberts and Gott (2003) proposed an example describing investigation. They used the ecological study of shrimps to demonstrate an open-ended investigation. However, they make two points: one that this would not be a suitable example for Sc1 (the internally assessed investigation for 15 year olds in science education in the United Kingdom) due to the time taken for such investigations and the number of students involved; and the other that "opportunities to carry out this sort of extended task which incorporates all the elements from the problem-solving model, are unfortunately rare" (p. 117). Roberts and Gott suggest that even if it is unrealistic to enable all pupils to carry out extended explorations, it is still possible to teach all aspects of the model through using smaller, manageable practical tasks. According to this model, students need both understanding of science concepts (substantive knowledge) and skills (understanding of science procedures) to successfully carry out a science investigation. The model emphasises the thinking behind the doing aspect of investigation. The requirement of both substantive and procedural knowledge to carry out an investigation is supported by Abrahams and Millar (2008).

In New Zealand, this kind of open-ended investigation is required in senior biology (Ministry of Education, 1994a, p. 28). Haigh (1998), in her research in senior biology, reported that open-ended investigation supported by expert mentors can help to extend gifted students. More recently Roberts (2009), in an empirical study using Gott and Mashiter's (1991) model, concluded that having the procedural knowledge is essential for students to carry out open-ended science investigation. Roberts (2009) says:

> Genuine open-ended investigations .... are those in which pupils are unaware of any correct answer, where there are many different routes to a valid solution, where choices have to be made about equipment selection, where different sources of uncertainty lead to variation in the data and where students reflect and modify their practice in the light of the evidence they have collected. The evidence produced, then, is messy rather than the laundered version common in practical work contrived to illustrate ideas to students. (p. 31)

Such investigation, she argues, allows the student to be creative in their problem solving. In a class where such creativity is allowed, no two investigations would be the same as all students would have the licence to come up with their own approach.

Recently, in Australia, in response to a loss of interest in taking science in secondary schools, Tytler (2007) suggested *“Re-imagining science education”* and presented what in his view were strands of a re-imagined curriculum. Relevant to this study was what he considers investigative science should look like:

> Science investigations should be more varied, with explicit attention paid to investigative principles. Investigative design should encompass a wide range of methods and principles of evidence including sampling, modelling, field-based methods, and the use of evidence in socio-scientific issues. Investigations should frequently flow from students' own questions. Investigations should exemplify the way ideas and evidence interact in science. (p. 64)

In the 1990s Watson, Goldsworthy and Wood-Robinson (1999) proposed six different types of investigations for school science which cover a range of skills and give students the opportunity to gain an understanding of science ideas and how science works. Along with the list of types of investigations they explained what students will be doing when carrying out these investigations, and provided examples.

1. Classifying and identifying: this involves grouping things and looking for patterns either through experimenting or from information from databases. The students could look at a collection of shellfish and group them as having one or two shells.
2. Fair testing: these apply to situations where the students observe the relationships between two variables. One variable is changed (independent variable) and the other factors are controlled. Examples here could be investigating the need for both water and oxygen for iron to rust.
3. Pattern seeking: considering large amounts of data where variables cannot be easily controlled. They recognise the importance of having a large sample to ensure that any conclusions that are drawn are significant. They are also looking for cause and effect. Examples would include biological surveys where there will be variations within a population.
4. Investigating models: testing to see if the models explain certain phenomena. Students have to look at the explanations presented by one scientist to another and on the basis of the evidence presented put forth their own ideas.
5. Exploring: students make a study of a change over a period of time. This could include observations of life present in rock pools in high, mid, and low tide areas. Students raise questions from their observations.
6. Making things or developing systems: students apply the knowledge and procedures they have learnt in science to develop artefacts for specific use.

These six types of investigations are promoted in New Zealand through the use of textbooks and workbooks that set out tasks students can carry out (Abbott, Cooper & Hume, 2005). Some of the examples listed above are also used in the list of learning experiences in *Science in the New Zealand Curriculum* (Ministry of Education, 1993a, p. 83).

Fair testing is important in this research as it is emphasised as a type of investigation in *Science in the New Zealand Curriculum* and it is the type of investigation assessed through Achievement Standard AS1.1 (NZQA, 2005). Fair testing types of investigation have been criticised as linear and sequential (Hume & Coll 2008). The Education Review Office (1996) reported that the fair testing approach is common in primary schools where many schools choose to involve all students to participate in science fairs and most investigations carried out by the students are of fair testing types. The Education Review Office reported that in some cases this was the only science taught (science fairs are competitions for New Zealand students from year 7 to 13 where students investigate a question of their choice and present their results). Watson et al.

(1999) found that in the United Kingdom the national curricula have an “over-heavy” emphasis on fair testing and that this is detrimental to other kinds of investigation such as “classifying, identifying, pattern seeking, exploring, investigating and making things and developing systems” (p. 85).

Following a study of four classes of year 12 and 13 biology students in a New Zealand secondary school undertaking open-ended investigation “with guidance”, Haigh (1998) recommended that students investigate the problems set in contexts that have some links to their everyday life and that they have the opportunity to share their thinking in every stage of investigation. She found that some students require more support from the teacher than others. If this support is available, students are able to develop both conceptual understanding and procedural knowledge, and she suggests that it is likely that they will develop more positive attitudes towards science. Her research showed that some procedural knowledge could be transferred to new contexts.

In a case study of science investigation “with direction” in New Zealand, Hume and Coll (2008) concluded that students in year 11 were acquiring a narrow view of science investigation as “fair testing”, and that although learning was taking place students’ responses demonstrated rote learning and low level thinking. They have attributed their findings to the narrow curriculum experienced by students due to schools’ science teaching programmes which were influenced by the requirements of national assessment policy.

Open-ended investigation is, however, undertaken by students in New Zealand through CREST, a programme that originated in the United Kingdom in which students from year 7 to year 13 can participate in science and technology outside the classroom. The CREST programme enables students to develop their own investigation with support from the wider scientific community. Davies and France (2001), in their evaluative study of the effectiveness of CREST and Olympiads, found that this kind of investigation had significant benefits for both teachers and students. In particular, it confirmed an interest in science and extended the ability of exceptional students.

According to Millar (2004), “there are very few examples of successful implementation of extended investigation as part of the science curriculum in the context of ‘mass education’ where large numbers of teachers and students are involved” (p. 16). He argues that teachers find it difficult to come up with enough projects that students could do and so the investigations become routinised and no longer what the curriculum intended. In some cases the "assessed investigation becomes almost the only investigation done" (p. 16).

Teachers cite challenges that include lack of time, lack of confidence in their own ability to assess, along with safety and management issues (Tamir, 1989). Over a decade later, in New Zealand, McGee et al. (2003), during the curriculum stocktake, found that teachers reported lack of resources, time restraints, inadequate facilities, and little technician support to repair and maintain equipment and set up laboratories as reasons for not using an investigative approach in their teaching.

Another issue was raised by Allen (2008) who found that an investigation needs to be challenging for the student. If the activity is too simple and the answer is already known, data collection becomes a chore as outcomes have been determined beforehand. There is little intellectual challenge left in the activity. The student then focuses on getting the right answer rather than carrying out a scientific investigation.

There have been significant developments in the field of school science investigation and assessment of science investigation over the last decade which included the identification of problems with validity and reliability of the assessment of investigation (Roberts & Gott, 2004a, 2006), evaluation of evidence provided by the data collected by students, role of argumentation (Roberts, 2009), and creativity in science investigation (Gott, Duggan & Hussain, 2009).

3.1.5 Summary

Science education researchers agree that practical work has a place in the learning of science. In over a century of "doing of science" in primary and secondary schools different types of practical work have been carried out including experiments to confirm theory and to get a feel for the phenomena, and doing recipe practicals that are easy to manage with large classes and have an easy-to-follow and secure framework for teachers to implement. Doing of science can be looked upon as a pedagogical approach that has motivational benefits but it may not be an appropriate pedagogy if it does not lead to the intended learning.

Internationally, three distinct phases for school practical work have been identified in the last 50 years. The first was the discovery approach where the notion of a student as a scientist was developed. This phase was followed by the "process approach" to doing science where it was believed that students could be taught science skills and once they had become skilful they would be able to transfer these skills to other contexts. However, research suggested that skills and context could not be separated and skills learnt in one context can rarely be transferred to another. The last phase was identified as investigation. This led to mostly fair testing types of investigation being taught in the United Kingdom and New Zealand.

Ideally, school science investigation would involve practical work in which the student seeks an answer to a question they have identified or a problem they are interested in solving. Students are given few instructions, and putting into practice their procedural and conceptual knowledge plan and carry out the investigation. They evaluate their procedure as the investigation progresses and make any changes required. Although the answer to the question they were asking may be known to scientists and the teacher, for the student it provides an opportunity to find out for themselves. In school science, with large classes of students, teachers find it difficult to manage such investigation and often the whole class carries out the same investigation. The fair testing type of investigation is most common in schools even though the learning from such investigation may be limited. Increasingly, there is a call in the science education community to get away from a "routinised" fair testing type of investigation and give the students the opportunity to carry out open-ended investigation that allows them to be creative in their problem solving.

3.2 Constructivism as a Theory of Learning in Science

In Chapter two it was noted that the *Science in the New Zealand Curriculum* statement that provides the learning context for this study is underpinned by constructivism. It is this curriculum that informed the teaching of science investigation in schools during the course of this study. The fundamental constructivist belief is that knowledge must be constructed by mental activity of the learner and cannot be transmitted (Driver et al., 1994). Much research into learning in science in New Zealand has been informed by constructivist views of learning since the 1980s. There are a large number of publications about teaching and learning science that draw upon social and personal constructivist views of learning. Understanding which pedagogical approaches are likely to help students to grasp concepts, develop skills or understand about the nature of science is likely to influence how we teach and improve student learning (Driver et al., 1994; J. Leach & Scott, 2003).

Before selecting a learning theory as a lens for this study it was considered important to understand where and how this learning of science investigation was to take place, which is the learning context. This study is about learning of science investigation in secondary schools. Typically, in New Zealand secondary schools science is taught in laboratories and a class can consist of one teacher and approximately 25 to 30 students. In most schools, students have between 45 to 55 minutes in one science lesson and there could be three or four lessons in a week. Students sit in groups of three or four. These groups are not always set up as cooperative learning groups, but in most cases, the students work in groups because of the limited amount of available equipment. This means that either the student learns as an individual or as a member of a group who may have input into each other's learning. As in other western countries, the teacher may often present the work in a didactic way and students carry out practical work following highly structured instructions (Berry, Mulhall, Loughran & Gunstone, 1999; Hume & Coll, 2008). The teacher has little chance to address the need of each individual; they may be able to manage practical work with students working in groups but "they have little possibility of responding to each individual student's cognitive processes over a sustained period of time" (J. Leach & Scott, 2003, p. 95). It is therefore important to consider how knowledge which is to be taught is introduced in the social environment of the laboratory and how the individual student learns and then applies their learning.

Constructivism as a theory of learning originated in the field of cognitive sciences and provides a basis for understanding how individuals incorporate new knowledge built from personal experiences into existing knowledge and then make sense of that knowledge (Ferguson, 2007; Tobin, 1990; von Glasersfeld, 1992). Constructivism provides a framework for thinking about the ways in which learners engage and make sense of the objects around them (Bodner, Klobuchar & Geelan, 2001; Ferguson, 2007).

There are several different kinds of constructivism that have been reviewed by Geelan (1997) and Ferguson (2007). Ferguson explains how each form varies from the other depending on the individual learner, the social milieu, the role of language and the balance of power during the process by which knowledge is constructed. He associated each of these forms with the individual with whom it is most closely associated:

- Personal constructivism: Driver and Easley (1978), R. Osborne and Wittrock (1985)
- Social constructivism: Solomon (1987)
- Radical constructivism: von Glasersfeld (2007)
- Critical constructivism: Taylor (1993)
- Contextual constructivism: Cobern (1993).

3.2.1 Personal constructivism

Personal constructivist (also called cognitive constructivist) theories focus on the individual's personal construction of meaning (Driver, 1989). According to O'Loughlin (1992), in this kind of constructivism the role of the social and cultural context of the learner is not acknowledged. Osborne and Wittrock (1985) described the assumptions on which personal constructivist theory is based. These are:

> a) The learner's existing ideas influence what use is made of the sense and in this way the brain can be said to actively select sensory input.
>
> b) The learner's existing ideas will influence what sensory input is attended to and what is ignored.
>
> c) The input selected or attended to by the learner, of itself, has no inherent meaning.
>
> d) The learner generates links between the input selected and attended to and parts of memory store.
>
> e) The learner uses the links generated and the sensory input to actively construct meaning.
>
> f) The learner may test the constructed meanings against other aspects of memory store and against meanings constructed as a result of other sensory input.
>
> g) The learner may subsume constructions into memory store.
>
> h) The need to generate links and to actively construct, test out and subsume meanings requires individuals to accept responsibility for their own learning. (pp. 65)

Personal constructivism acknowledges that children bring "prior knowledge", and "alternative frames" and highlights the importance of the teacher finding out what the child already knows and then focusing on developing the student's ideas. Driver and Easley (1978) posited that observations are theory laden, and students' prior learning is just as important as their cognitive development that determines understanding out of an experimental situation.

According to Solomon (1987), a huge number of research projects were carried out that confirmed the existence of children's alternative frames. Hewson (1981) reported that taught scientific ideas could live alongside the children's own ideas. R. Osborne (1985) questioned why those children's existing science ideas (children's science) were not being replaced by the science ideas (scientists' science). Tasker and Freyberg (1985) suggested that there were mismatches between the students' knowledge structures and teachers' beliefs about these structures. Students considered each lesson to be an isolated event where the teacher assumed linking of ideas in the present lesson to the concepts they had learnt previously, and students' understandings of the purpose of the lesson. The lack of student interest in the features of the investigation they were carrying out and most importantly the understandings that the teacher thought students had developed through the learning process were not the learning outcome teachers had planned (Tasker & Freyberg, 1985). They also argued that while investigating students made "executive decisions", talked about what they knew and which step they were up to. In Bell's (2005) words "the students were not engaging with the ideas of science; that is, minds-on science was not occurring" (p. 21).

The problem with this theory of learning is that it does not acknowledge the learner as part of a social setting. If we consider the reality of the classroom, there are social interactions between the teacher and the students and between students. Solomon (1987) says that although similar results were found by Gilbert, R. Osborne and Fensham (1982) and Driver and Erickson (1983), they did not look for an alternative frame for understanding students' conceptions which would have more successful outcomes for student learning (Solomon, 1987). This is explored in detail under social constructivism.

3.2.2 Social constructivism

Solomon (1987) suggested that the social setting "makes an essential difference to the learning situation, to how the task is perceived and even to the tools for thought that will be used" (p. 63). Learning is affected by our reflection on experiences we have, as well as from the reaction of others when we share our ideas. Solomon (1987) posits that we might not understand what we think until we can discuss it with others and get their views about our thoughts.

The social constructivist view acknowledges the intra-domain nature of learning with both the social setting and the individual's role in the construction of knowledge. Solomon (1987) made social interactions in the classroom the focus of her research on student learning and according to her:

> As students interact with one another, with teachers….they develop ideas that, because they are held in common, create a universal discourse, a common frame of reference in which communication can take place. (p. 68)

Bell (2005) criticised Soloman's social constructivist view of learning as "under-developed" and "vague" (p. 41). Earlier, Bell and Gilbert (1996) proposed a social constructivist view of learning that recognised that:

- Knowledge is constructed by people.
- The construction and reconstruction of knowledge is both personal and social.

- Personal construction of knowledge is socially mediated. Social construction of knowledge is personally mediated.
- Socially constructed knowledge is both the context for and outcome of human social interaction. The social context is an integral part of the learning activity.
- Social interaction with others is part of personal and social construction and reconstruction of knowledge. (pp. 50-51)

3.2.3 Other schools of thought

Three other schools of thought about constructivism are radical, critical and contextual constructivism. Von Glasersfeld (2007) is the leading proponent of radical constructivism. He emphasises that knowledge cannot be separated from knowing. Human connection to knowledge is through experience. It is through experience that we come to know the real world which is separate from, external to and independent of human consciousness (Tobin, 2007). Radical constructivism "does not deny the existence of reality in the presence of cognizing beings to think of it" (Tobin, 1993, p. 4). Von Glasersfeld's views have been criticised for a lack of acknowledgement of social context as well as views about reality (Matthews, 1995). Radical constructivists ignore the social and historical aspects of knowing, as do personal constructivists.

The term critical constructivism was introduced by Tobin (1992) who said that "beliefs about control became intertwined with constructivism. Critical constructivism includes the self-regulation that reveals the psychological, ethical, moral, and political beliefs intertwined with the construction of knowledge" (p. 20). Tobin (1992) suggested that children's knowledge construction goes beyond the personal and social and includes other aspects.

The idea of contextual constructivism was suggested by Bell (2005). Bell draws upon Bruner (1990), who posits that "it is culture that shapes the human life and human mind that gives meaning to action" (p. 34) and this happens through symbolic systems of the culture as well as "language and other modes of discourse that are part of the communal life" (p. 34). The emphasis on teaching in contexts that are meaningful to the learner comes from this line of thinking. *Science in the New Zealand Curriculum* emphasises the teaching of science in contexts that are meaningful to the learner and in particular, the use of contexts that would be meaningful to Māori students.

In the research presented here the classroom is considered a social setting in which the learning occurs and it is considered that students construct personal knowledge based on existing ideas and through interactions with the teacher and other students.

3.2.4 Constructivist pedagogy

Constructivism presupposes that all new learning is acquired in relation to prior knowledge (Windschitl, 2002). Baviskar, Hartle and Whitney (2008) described four features of a pedagogy based on constructivism. These include, "eliciting prior knowledge, creating cognitive dissonance, application of new knowledge with feedback and reflecting on learning" (p. 4). The first, eliciting prior knowledge, could include informal questioning, formal pre-tests and concept maps. Baviskar et al. (2008) remind teachers that the activity used to assess prior knowledge should "relate" to the new knowledge to be learnt.

The second feature of constructivist pedagogy is related to task selection. The tasks selected to facilitate new learning should be "problematic" for the student, create "cognitive dissonance" and require thought on the part of the learner (p. 4). Using concept mapping as an example, Baviskar et al. (2008) explain that students are asked to draw a concept map of their initial ideas about a topic. The student then develops the concept map by adding new ideas to their initial ideas. In doing so the student has to actively consider why they are making those links and to organise their thoughts. At the same time it allows the teacher to determine prior knowledge, find out how the student made the new links, and clarify misconceptions. Sewell (2002) agrees and emphasises that the learner has to be made aware of the difference between the prior knowledge and the new knowledge.

The third feature of constructivist learning is application of new knowledge with feedback. The suitable techniques for this aspect could include quizzes, group discussion, and presentations that allow students to compare their ideas with those of their peers (Baviskar et al., 2008). The final and fourth feature is reflection on learning. According to Windschitl (2002), once new learning has occurred and verified the "learner needs to be made aware of the learning that has taken place" (p. 4). Reflection can be in the form of informal time at the end of the lesson for students to think and write down what they have learnt. It could be in the form of a pair activity.

In New Zealand as part of the Learning in Science Project a constructivist pedagogical approach, an interactive framework was developed. This framework includes an initial focussing activity which leads into exploration and is followed by reflection (Biddulph & R. Osborne, 1984). A feature of this approach is that some students may want to explore a concept in detail and may develop deeper understanding while others may either explore an aspect of personal interest or develop a skill leading to different outcomes for different students.

3.2.5 Criticism of constructivism

Matthews (1994, 1995, 2002) has been a critic of the influence of constructivism on science education since the early 1990s and has provided an appraisal of constructivism and science education. He identified the following eight aspects and argued that part of the problem is the multiple ways in which constructivist writers and curriculum developers interchangeably apply the word "constructivism as a theory of learning, philosophy, education, cognition, personal knowledge, scientific knowledge, educational ethics, politics and world view" (Matthews, 2002, p. 124).

Matthews (2002) asserts that being constructivist in learning theory does not mean that one has to be a constructivist in all other aspects listed above. He accepts that constructivism has done a service to science and mathematics education by drawing teachers' attention to prior learning and by encouraging them to foster pupil engagement in lessons. Constructivism has also done a service to science by raising awareness of the "human dimension of science and its fallibility, its connection to culture and interests, the place of convention in science theory, the historicity of concepts and complex procedures of theory appraisal" (p. 124). He then points out that none of this is unique to constructivism.

3.2.6 Summary

Constructivism as a theory of learning became popular in the 1980s. The fundamental belief about learning in science, according to this theory, is that learning is an active process in which learners construct their own understanding based on their experiences. Potentially, by gaining an insight into this theory of learning the teacher can develop and use pedagogical approaches that help students to develop an understanding of science concepts; the nature of science and science investigation as required in *Science in the New Zealand Curriculum*.

A number of forms of constructivism relevant to science learning have emerged. Leading proponents of personal constructivism were Driver (1989) and R. Osborne and Wittrock (1985). Personal constructivism emphasises the prior understandings of individuals and the role of these understandings in constructing meaning in the context of sensory input.

Social constructivists believe that social setting has a major influence on what and how an individual learns. It is through reflection and having the views of others about their thinking that the learner makes meaning. Proponents of this theory include Solomon (1987) and Bell and Gilbert (1996). The implication is that the teacher is part of the social setting and has an input to the learner constructing meaning. Bell's (2005) contextual constructivism recognises the cultural as well as the social context.

In this thesis learning is viewed as both personally and socially constructed, and from this perspective the role of the teacher is highly significant. Pedagogy based on constructivism requires an interaction between teacher and learner that includes eliciting of prior knowledge, exploration and reflection.

3.3 Motivation to Learn

Schunk (1991) argued that motivation can influence "what, when, and how students learn" (p. 299) and Wellington (1998, 2005) drew attention to a lack of research in the affective domain of learning science investigation. Palmer (2005) posits that "If effort is required for learning then it follows that motivation is also required, because students will not make that effort unless they are motivated to do so" (p. 1855). Motivation is needed initially to get the students to engage in learning and it is needed throughout the knowledge construction process. Motivation is a much researched area in teaching and learning. A number of theories have been put forward to explain and help predict behaviour (McInerney & McInerney, 2002). Some relevant motivational theories have been reviewed here.

3.3.1 Relevant theories of motivation

Brophy (1987) posits that "motivation to learn is an enduring disposition to value learning as a worthwhile and satisfying activity, and thus to strive for knowledge and mastery in learning situations" (p. 200). It leads to task engagement with the goal to acquire knowledge or to master a skill. According to constructivist theory, learning is viewed as an active process that requires effort on the part of the learner (Driver, 1989). In Palmer's (2009) view, motivation is needed to initiate and maintain learning and is central to all action; he argues that motivation is an essential "pre-requisite and co-requisite" for learning (p. 147).

The role of motivation during learning to investigate is pivotal (Schunk, 1991). According to Meece (1991), students who are motivated to learn are likely to participate in activities that they think will help them to learn. They will engage in learning behaviours such as taking notes, reading the material over and over, be focused when instructions are given, make sure they understand and will ask for help when they do not. In contrast, students who are not motivated to learn have the opposite traits, and as a consequence their learning suffers.

Pintrich and Schunk (2002) emphasise “that motivation bears a reciprocal relation to learning and performance; and what students do and learn influences their motivation” (p. 6). When students achieve learning goals, goal attainment conveys to them that they possess the requisite capabilities for learning. These beliefs motivate them to set new, challenging goals. Students who are motivated to learn often find that once they are, they are intrinsically motivated to continue their learning (Meece, 1991). These are the students who are most likely to want to improve their performance and achieve.

In the 1960s reinforcement theory dominated the educational literature. This theory conceptualises motivation entirely in terms of observable behaviour. Reinforcement theory in the context of education would consider motivation not as a quality of a person but a set of behaviours and whether the individual was rewarded or punished. This theory is characterised in the educational setting as extrinsic motivation. Behaviour is reinforced through external positive reinforcement (reward) or negative reinforcement (punishment). According to Pintrich and Schunk (2002), behavioural theorists contend that explanations for motivation do not need to include thoughts and feelings and that people are motivated by environmental events.

From reinforcement theory arose the cognitive motivation theories. Cognitive theories emphasise learners’ thoughts, beliefs, and emotions. Proponents of these theories found reinforcement theory and the assumptions made about behaviour unsatisfactory and started to explore psychological variables that cannot be observed directly. Cognitive theories of learning suggest that the key to people’s motivation is the desire to solve problems, have insight, and gain understanding, particularly in ambiguous or problematic situations (McInerney & McInerney, 2002). An essential element in a cognitive perspective on motivation is the concept of intrinsic motivation (McInerney & McInerney, 2002). According to Ryan & Deci (2000):

> Intrinsic motivation.... refers to doing something because it is inherently interesting or enjoyable, and extrinsic motivation...refers to doing something because it has a separable outcome. (p. 55)

Intrinsic motivation generates “instinctive pleasure” when the learner succeeds in learning something new or completes a challenging task. Successful completion of the task leads to confidence and the learner is more likely to engage in learning activities in future. “Intrinsic motivation is characterised by enthusiastic task involvement, a want to experience novelty and adventure, striving for excellence, trying to understand something, wanting to improve and seeing a purpose in doing the task” (p.208). Deci, Koestner and Ryan (2002) further suggest that intrinsically motivated behaviours are undertaken out of interest. McInerney and McInerney (2002) highlight the nexus between intrinsic motivation and cognitive theories of learning as: “a facility for learning that sustains the desire to learn through the development of particular cognitive skills” (p. 208). In the context of learning to investigate, it can be argued that if the student has the choice of a question they are interested in investigating, it is more likely that they will engage in the process, they may make a real effort to find the answer to it, develop an understanding, and may even strive for excellence. In contrast, extrinsic motivation depends on external factors such as rewards, attention and praise. Deci et al. (2002) questioned its effectiveness in the long term.

Cognitive motivation theories include attribution and goal orientation theories. According to attribution theory, an explanation is given for certain behaviour. For example, a student gets a low mark in a test. They may attribute the low mark to the test having questions that were on material not taught by the teacher. Alternatively, a student may think the reason they performed poorly was due to their own lack of ability. In other words, attribution theory describes the processes of explaining events and the behavioural and emotional consequences of those explanations.

Weiner (1986) posits, a motivated high achiever will approach rather than avoid tasks related to succeeding because they believe success is due to high ability and effort and failure is caused by bad luck or a poor examination, i.e., not their fault. “Failure does not hurt their self-esteem and success builds pride and confidence” (p. 362). These people persist with the task rather than give up because they assume that failure was caused by lack of effort, something they can change. They select moderately difficult tasks because succeeding in these tells them how well they are doing. Difficult or easy tasks are not perceived as useful because they do not tell them how well they are doing. “They work with a lot of energy because they believe that success is determined by how hard they work” (p. 362). Unmotivated people, on the other hand, avoid success-related tasks as they doubt their own ability and assume success is related to factors beyond their control and, as a consequence, even when they do succeed they do not feel responsible for their success and success does not increase their pride. They give up because they attribute failure to lack of ability. They do not believe that success is related to effort, “they have little enthusiasm or drive to get started” (p. 362). Avoidance strategies used by these learners include procrastination, making excuses, avoiding challenging tasks, and not trying (Eccles & Wigfield, 2002). Weiner (1992) posits that how an individual interprets their achievement outcome is more important than either their motivational disposition or actual outcome and is an influential factor that determines their future quest for achievement. Weiner believes that ability, effort, task difficulty and luck are most important achievement attributions.

In their review of motivational beliefs, values, and goals, Eccles and Wigfield (2002) classified related theories of motivation into four major categories. These are:

> Theories focused on expectancies for success (self-efficacy theory and control theory); theories focused on task value (theories focused on intrinsic motivation, self determination, interest and goals); theories that integrate expectancies and values (attribution theory, the expectancy value model, and self-worth theory); theories integrating motivation and cognition (social cognitive theories of self regulation and motivation); and theories of motivation and volition. (p. 109)

Modern expectancy-value theory is based on an expectancy-value model which links achievement, performance, persistence, and choice directly to individuals’ expectancy related and task value beliefs (Wigfield & Eccles, 2000). In self-worth theory, Covington (1992, 1998) defines the motive for self-worth as the tendency to establish and maintain a positive self-image. Learners need to believe that they are academically competent in order to think they have self-worth as a person. In the school context, however, school evaluation, competition, and social comparison make it difficult for many learners to maintain the belief that they are competent academically. These learners develop strategies to avoid appearing to lack ability.

Goal theories link achievement goals and achievement behaviour. Goal theorists have used a number of terminologies to conceptualise goal orientation. Three goal orientations have been explained by motivational theorists (Covington, 1998): (1) learners with ego-involved goals want to out-perform others; (2) mastery oriented learners choose challenging tasks and focus on their own progress and are not concerned about how others perform; (3) learners with performance goals take on tasks that they know they can do. Their short-term goal is to complete the task. According to Covington (1998), performance goals can be further classified into performance-approach goals where engagement with task is for performance reasons. Contrary to this, learners with performance avoidance goals are disengaged so that they are not considered incompetent. Whatever their goal orientation, to achieve learners need to engage with the task, be willing, they need to get started, and to persist.

According to Corno (1992), motivation to learn requires volition to carry out the learning and volition has two elements, “the strength of will” needed to complete the task and the “diligence of pursuit” (p. 14). Corno and Kanfer (1993) argue that motivational processes only lead to the decision to act. Once the individual engages in action, volitional processes take over and determine whether or not the intention is fulfilled (Zimmerman, 1989). Volition is a broader concept than self-regulation because volition includes personality characteristics, aptitudes and other cognitive processes whereas most models of self-regulation focus more narrowly on self-monitoring and self-evaluation (Corno & Kanfer, 1993). Related to will and diligence is the student’s need to be in control of their learning.

Eccles and Wigfield (2002) posit that secondary school students need autonomy and self-control. If the school structures do not allow for this, it results in a mismatch between the students’ needs and whether they can be satisfied through opportunities and choices offered by the school. If this is not so, the students’ motivation to learn is affected (Eccles & Midgley, 1989; Meyer, McClure, Walkey, McKenzie & Weir, 2006; Wigfield & Eccles, 1992).

Pintrich and Schunk (1996) suggested interest as an effective motivator and, further, that interest is related to increased memory, greater comprehension, deeper cognitive engagement and thinking. According to Rennie et al. (2001), adolescents view science as a dull and boring subject which fails to motivate them. More recently, Palmer (2009) reported that many science students are lacking in motivation. As it has been argued that without motivation little learning occurs, it is essential for science education to deal with the issue of student motivation. Perhaps one way to address this in science and science investigation is through creating situational interest. Features that arouse situational interest include personal relevance, novelty, activity level, and comprehensibility (Alexander, Kulikowich & Jetton, 1994; Eccles & Wigfield, 2002; Schiefele, 1999).

Palmer (2009), in his study of situational interest during an inquiry science lesson, found that students identified learning as the most common reason for their interest in the investigation. He says that this is possibly because when “one learns something, one is learning something new” (p. 160). Palmer defines situational interest as “short term interest that is generated by aspects of specific situations”

(p. 148). Examples of such interest are experiments that have a 'wow' factor that can provide short-term interest for students who might not otherwise be interested. Other factors influencing interest are choice but he asserts it has to be "meaningful choice", and "cognitive engagement". In his study, Palmer created situational interest during a science investigation where students chose their own investigation and had ownership of the process they had come up with. The hands-on activity that the students engaged in involved them moving from their seats and working with others, thus having a social dimension to the learning activity. Additionally the tasks offered variety. There were, however, limitations in his research. The situated investigation that he did with the class was a change from the norm where the predominant method applied by the teacher was transmission of facts. He argues that the strongest reason for interest was perhaps the novel approach to learning for the students. Palmer believes situational interest is very powerful and overrides any other motivational orientation the students may have.

3.3.2 Assessment of motivation

According to Pintrich and Schunk (2002), when it comes to assessment, commonly employed indices of motivation are choice of task, effort, persistence, and achievement. While there is disagreement among the researchers about the nature of motivation and how motivational processes operate, there is some agreement that behavioural indicators can be used to determine the presence or absence of motivation. Brophy (1987) argues that despite the intuitive appeal, choice of task is not a useful index of motivation in schools because in many classrooms the students typically have few if any choices. Brophy adds that students who are motivated to learn are willing to put effort into learning. This learning could be of skills which require physical or cognitive effort. Effort, therefore, is an appropriate index. Those students who are motivated to learn could spend time on the task and will continue to do so even if they come up against obstacles.

There are three ways used to assess motivation – direct observations, ratings by others, and self-reports (Zusho & Pintrich, 2003). Direct observations would include looking for choice of task, effort expended, and persistence. However, one can only focus on overt actions and therefore these can be superficial and may not capture the essence of motivation. Direct observations also ignore the cognitive and affective processes underlying motivational behaviour.

Rating by others could include the parents or teachers giving a rating on a scale. This gives data that cannot be attained from direct observations. On the other hand, it involves the person providing the rating to remember what they have observed. As memory is selective and constructive, ratings may not be valid indicators but could be useful in conjunction with observations. Self-reports involve people's judgements and statements about themselves. Ways of self-reporting include questionnaires, interviews, stimulated recalls, and dialogues. In this research, a number of these methods have been used to assess student motivation to learn to investigate including observations, teacher interviews, student interviews, and questionnaires.

3.3.3 Motivation and approaches to learning

Motivational theorists (Entwistle, 2005; Entwistle & Ramsden, 1983) describe the relationship between student motivation to learn and their approach to learning. The learner can have a deep or surface approach to learning which is dependent upon what they want and how they want to learn, as well as the nature of assessment of this learning. Entwistle (2005) defines the features of deep and surface approaches to learning as follows:

> *Deep Approach*
>
> Intention to understand material for oneself
> Interacting vigorously and critically on content
> Relating ideas to previous knowledge/experience
> Using organizing principles to integrate ideas
> Relating evidence to conclusions
> Examining the logic of the argument
>
> *Surface Approach*
>
> Intension simply to reproduce content
> Accepting ideas and information passively
> Concentrating only on assessment requirements
> Not reflecting on purpose or strategies in learning
> Memorising facts and procedures routinely
> Failing to recognize guiding principles or patterns (p. 3)

A deep approach is linked to academic interest in the subject and with self-confidence, and a surface approach is linked to anxiety and fear of failure. Mastery goals have been found to be most beneficial and are related to deep learning as opposed to performance goals that lead to a surface learning approach (Palmer, 2005).

3.3.4 Motivational framework for the study

The selection of a framework for conceptualising motivation requires that elements of several theories of motivation should be considered. For this research, goal theory is one appropriate lens as the study investigates students' learning of investigation, focussing on assessment. Attribution theory would be useful to compare what in students' views are reasons for their success or otherwise when carrying out investigation. Expectancy and value theories may play a role in determining what leads to achievement, makes students persist and perform, and whether having choice influences students' motivation to learn investigation. In understanding whether students are willing to learn to investigate and what keeps them going may be found in volition theory. As is evident in recent research, situational interest may have a role to play.

3.4 Assessment

This section explores the literature in relation to assessment as a measure of learning and in particular learning science investigation. First, the multiple purposes of assessment are presented. Secondly, assessment of science investigation and its pros and cons are addressed. It is then argued that the internal investigation, as it currently takes place, does not fulfil the purpose it is designed for.

3.4.1 Multiple purposes of assessment in science

The following four purposes of assessment have been suggested in the literature:

1. ***Diagnostic assessment:***
   "Diagnostic assessment is used to identify students' prior knowledge and alternative conceptions, so that instruction can be planned to build on students' existing knowledge and to address students' alternative conceptions" (Hackling, 2005, p. 130). A key component in a constructivist approach to science teaching is to find out what the students' alternative conceptions, or preconceptions, are before planning the next learning steps (Birk & Kurtz, 1999; Driver, Guesne & Tiberghien, 1985; R. Osborne 1985). Diagnostic assessment is learner centred and a critical aspect of constructivist pedagogy.

2. ***Formative assessment:***
   Formative assessment is assessment *for* learning (Crooks, 2004). It is about making use of informal and sometimes formal ways to find out what is being learned. It is very powerful as it provides the learner with feedback on how learning can be enhanced. This kind of assessment is learner centred, and usually takes place during learning (Bell, 2005; Bell & Cowie, 1999, 2001a). Through formative assessment the teacher takes into account student thinking as part of the teaching process (Bell & Cowie, 2001b). Formative assessment is influenced by classroom factors including student-teacher relationships, the physical set-up of the classroom,

and learning opportunities provided by the teacher (Cowie, 2000). Crooks (2001) summarised the following five points from research. Formative assessment:

- Involves learning goals understood and shared by both teachers and students;
- Helps students to understand and recognise the desired standards;
- Involves students in self-assessment;
- Provides feedback which helps students to recognise next steps and how to take them;
- Builds confidence that students can improve their work. (p. 4)

The practice of formative assessment used in schools relevant to year 11 science investigation is not assessment of learning during learning, rather it is “a mock assessment known as 'the formative assessment', designed to give students practice at performing a whole investigation under test-like conditions” (Hume & Coll, 2009, p. 269). The students are provided feedback on how they could improve their performance in the summative assessment.

3. ***Summative assessment:***

   Summative assessment is assessment *of* learning (Crooks, 2004). This type of assessment is carried out to determine the effectiveness of teaching and learning. The purpose is to monitor educational progress or improvement. It usually comes at the end of the teaching and learning cycle and mostly provides a judgement about the learner either as a ranking within the group (normative), or as success against pre-set standards (standards based) (Bell, 2005). In Crooks’ (2004) view, although written feedback is not provided in this form of assessment (for example, in an external examination), it does influence future learning. Success in the examination communicates to the students (in the form of marks and grades) their areas of strength which in turn leads to choices made for future learning.

4. ***Assessment for evaluation:***

   Assessment for evaluation is about finding out the success or effectiveness of particular teaching and learning programmes. The results are used for policy purposes and to determine that the resources put into teaching and learning are being used effectively. It also includes national monitoring programmes, in other words it is about accountability (Crooks & Flockton, 1996; Hill, 1999). Scriven (2003) defines educational evaluation as the process of determining the merit, worth, or significance of things.

According to Biggs (2003), there are two ways of assessing. These are norm-referenced assessment and criterion-referenced assessment. In the former, the learner’s performance is compared with others in the group. In this type of assessment the learner's scores are often adjusted to ensure that the group's results fit the bell-shaped normal distribution curve with most falling in the middle and some at either end. It is a ranking system that uses marks, grades, or percentages. In the latter, criterion-referenced assessment, the learner is assessed against pre-set standards. The learning outcomes are defined and state what the learner has to do to achieve that standard. According to the assessment handbook (Ministry of Education, 1994d), "Standards-based assessment does not assume how many students are able to achieve the defined goals" (p. 9). Standards-based assessment (also known as criterion-referenced assessment) can be further classified into competency-based assessment where either the student is assessed as competent or not competent, or achievement-based assessment. In achievement-based assessment "a number of progressively more demanding descriptors are used to report students' achievement" (p. 9). The assessment handbook recommends that teachers share the grade criteria with the students to inform them of what will be assessed as well as helping them to set goals. In New Zealand both competency-based unit standards and achievement-based achievement standards are used to assess student performance in schools. The credits and grades generated from such assessments contribute towards the National Certificate of Educational Achievement.

3.4.2 The assessment debate in New Zealand

In the early 1990s there was a call for change in assessment policy in New Zealand. Willis (1993) argued that both normative and standards-based assessment had been designed on mathematical models to discriminate between individuals. Willis questioned the adequacy of context-free forms of assessment as "indicators of a range of learning outcomes and processes" (p. 246). Earlier, according to Willis, Blackmore (1988) had made a case for integration of learning and assessment so that feedback to students about their learning would be part of the "educative process" (p. 246). Bird and Willis (1992) suggested characteristics of this educative process which included: assessment of a range of processes and outcomes; a need to have a link between the curriculum and assessment through assessing content directly related to course-work; consideration of students' culture and prior experiences; diagnosis of students' learning needs; and a recommendation that students be involved in self-assessment. This was just the beginning of the assessment debate which was to follow when the Ministry of Education and New Zealand Qualifications Authority put forth the change in assessment policy and subsequently introduced the National Qualifications Framework and in particular a National Certificate of Educational Achievement. The debate included changes in the qualification framework for tertiary education and concerns about use of competency-based unit standards for assessment of academic subjects. The implications for senior secondary school assessment are relevant to this study and the debate on this is presented next.

Prior to the introduction of the National Certificate of Educational Achievement concern was raised about the new qualifications framework and the associated assessment process for secondary schooling. This provided a new approach; there was little international research and for such a substantial policy change it was not underpinned by empirical research (Elley, Hall & Marsh, 2004). The issues were raised and debated across New Zealand. Hall (1997) expressed pedagogical and educational concerns about unit standards and the fragmentation of course content for assessment. Later, Hall (2000, 2005) raised the issues of validity or "fitness for purpose", reliability with reference to "accuracy" and manageability of "practical aspects" associated with achievement standards. Hall (2000) put forth a course based system that integrated teachers' assessments with data from external examinations. Hall suggests:

> Such a system would represent a genuine blending of internal and external assessment: teachers would be used to monitor students' performance and to contribute valid and reliable information on students' achievement; the external examination would provide an independent assessment of students' work and act as a moderator of teachers' assessment. Together, the two would enhance both validity and reliability by building on each others' strengths. (p. 189)

Hall argued that the design of the National Certificate of Educational Achievement exposed the weaknesses of internal and external assessment because there was no blending of information from the two types of standards.

Issues of variability amongst students receiving scholarships were raised by Elley et al. (2004) as were the issues of moderation. Elley (2002) was critical of the level of difficulty of standards across different subjects both for achieving the standard as well as gaining an Excellence grade. Elley concluded that:

> It is not that standards-based assessment is bad in principle. It is just inappropriate in high stakes assessment where thousands of students are to be measured against a common, (vaguely expressed) standard. (p. 2)

More generally, Elley (2002) highlights other concerns that include: lack of clarity in the standards for teachers to assess their students; tasks set by teachers are not likely to be of a similar standard across schools; the cut-off points for grades are not based on "empirically-based" procedures; the Excellence grade in one subject is not equivalent to an Excellence grade in another; moderation procedures cannot ensure similar standards from school to school; students who fail may not be treated equally from school to school; only four levels of achievement may not be sufficient for tertiary institutions; and standards are less likely to be reliable compared with traditional examination marks. Elley sums up by saying that the visionaries of this assessment system would not have made the same choices had they studied the pitfalls before making such significant changes in assessment practice.

The National Certificate of Educational Achievement was implemented in successive years from 2002 to 2004. After the first results for level 3 and scholarship examinations led to public and media concerns about the variability in 2004 results, Elley et al. (2004) questioned the New Zealand Qualifications Authority's capacity to administer the National Certificate of Educational Achievement. They were critical of the Ministry of Education and New Zealand Qualifications Authority ignoring international research and not recognising the difficulties in implementing a "pure" form of standards-based assessment. These national assessment experts identified the problems that included variability, fragmentation of assessment, reporting of results (of only those standards that had an Achieved grade and not including the Not Achieved) and manageability of the assessment process, and made key recommendations to "rescue" the National Certificate of Educational Achievement.

In spite of the concerns raised in New Zealand, the New Zealand Qualifications Authority decided to proceed with their commitment to implement standards based assessment through assessment of student learning against a range of separate (non-integrated) achievement standards in each subject area. In relation to this study, in New Zealand achievement-based assessment is used to assess students' investigation in year 11 science.

3.4.3 Assessment of science investigation

In the past, in some countries, students' investigative abilities have been assessed by pen and paper examinations (Hofstein & Lunetta, 2004). Bryce and Robertson (1985) observed that although students spent considerable time in the laboratory, their knowledge of practical work, assessed in this way, was assessed out of context. Further to this, they argue that the hypotheses, questions, and laboratory skills students develop in investigative work are often neglected in pen and paper assessment. A number of researchers working in the United States, United Kingdom and Israel maintain that assessment should avoid the partitioning of curriculum and learning experiences, and teaching and assessment should become better integrated and holistic (Lunetta et al., 2007; Tamir, 1990, 2007; Van den Berg &

Guildings, 1992). Millar and Driver (1987) emphasise that the processes of science that are assessed should not be limited to those involved in a specific investigation.

According to Lunetta et al. (2007), there are too many goals set for laboratory learning which led to the disagreement in research and literature about assessment methods and what is a reliable and valid assessment of practical abilities. Firstly, the nature of skills to be assessed needs to be determined; secondly, a balance needs to be found between the assessment of prescriptive and investigative tasks; and thirdly, holistic and atomistic approaches in assessment should be balanced (Bennett & Kennedy, 2001; Lunetta et al., 2007). The following framework of Lunetta et al. (2007) for assessing practical investigative work identifies some of the same features as assessment of investigative work in New Zealand in year 11:

> **Performance** (conducting an investigation, manipulating materials and equipment making decisions about the investigative techniques, making organizing and recording observations).
>
> **Analysis and interpretation** (processing data, explaining relationships, developing findings, discussing the accuracy and limitations of data and procedures, and formulating new questions based on investigations conducted).
>
> **Planning and design** (articulating questions, predicting results, formulating hypotheses to be tested, and designing experimental procedure). (p. 415)

However, they suggest that students "should comment on application making predictions about new situations, formulating hypotheses on the basis of investigative skills and applying laboratory skills to a new experimental situation" (p. 416).

Four approaches to assessment of practical work have been put forward by Lunetta and co researchers (Hofstein & Lunetta, 2004; Lunetta, 1998; Lunetta et al., 2007):

1. Practical examinations
2. Laboratory reports
3. Portfolios
4. Continuous assessment or a combination of these.

According to Roberts and Gott (2006), in the United Kingdom, performance assessment of investigative skills is a component of the General Certificate of Secondary Education where 20% of the coursework is internally assessed for "investigative skills associated with scientific enquiry ... is often referred to as Sc 1" (p. 46). This assessment of performance has been criticised by Donnelly (2000), Gott and Duggan (2002), Roberts and Gott (2003) and others. The problem with assessment of performance is that it requires observation and the critics believe that it is not possible in large groups and often relies on written reports. Roberts and Gott

(2006) point out the limitations of laboratory reports which benefit the older students whereas inexperienced students are not able to communicate their observations in a written report successfully and therefore would be disadvantaged.

According to Lunetta et al. (2007), portfolios can help students to organise and make decisions about what they investigated and why they used a particular design. These include procedures they used, observations, findings, explanations, limitations in their findings, and new questions. The only aspect they do not demonstrate is the actual carrying out of investigation and the problem solving they may have had to do during the process. Problem solving is an important aspect of scientific investigation. Scientists may start with a plan, but upon experimentation they may abandon the original plan and follow a different line of thought and come up with a different method to solve the problem. This problem solving is an important part about learning to investigate and is a limitation of the portfolio approach of assessment. Lunetta et al. promote the notion of continuous assessment. Here the teacher would know what each student could or could not do in the normal course of learning to investigate. This is current practice in the form of formative assessment and has many benefits as the student continues to learn through teacher feedback. However, researchers found that in the United Kingdom teachers choose not to do this and instead do the assessment separately to the conventional laboratory activity. Lunetta et al. draw attention to anecdotal evidence that students do very little practical work beyond what is required for assessment.

Yung (2001), in his research in Hong Kong, found that the teachers did not believe that carrying out assessment in the class could improve their teaching and the students' learning. Alternative and multiple ways of in-class continuous assessment were researched by Hofstein et al. (2004) in Israel. These were inquiry-focused and criteria-based assessment where teachers observed students working in collaborative groups in the laboratory and marked "hot reports" (reports written by individual students while doing the investigation). Hofstein found this assessment of performance worked successfully but says that this process was resource intensive and there was a high commitment by both the state and the teachers involved in this project. Bennett and Kennedy's (2001) study of a combination of written and practical assessment was underpinned by their views that balance is required between prescriptive and investigative tasks and whether the assessment should be holistic or atomistic. Their research involved commitment to laboratory work by the state and teachers in Ireland. This large study of 700 students in 30 schools looked at the effectiveness of a new assessment model for practical work in physics and chemistry using a combination of written and practical assessment. Their findings were that this model provided a time efficient economical mode of assessment.

Tamir and Lunetta (1981) developed an instrument that had a comprehensive scheme for analysing laboratory investigation. They found that almost all investigations that were assessed were highly structured. They also found that:

> Seldom, if ever, are students asked to formulate a question to be investigated, formulate a hypothesis to be tested, predict experimental results, work according to their own design, formulate new questions based on their investigations, or apply an experimental technique acquired in the investigation just performed. (p. 771)

As there are parallels between the assessment processes for science investigation in the United Kingdom and New Zealand, a review of relevant literature was carried out and is presented here.

3.4.4 Assessment of Sc1 in England and Wales

The House of Commons, Science and Technology Committee (2002) in the United Kingdom reported that:

> The way in which coursework is assessed for GCSE science has little educational value and has turned practical work into a tedious and dull activity for both students and teachers. (p. 21)

In England and Wales the final year of compulsory school education ends with summative assessment for the General Certificate of Secondary Education. The examination consists of 75% of the final mark coming from written examination of knowledge and understanding in the science areas of physics, chemistry, and biology. Another 5% is allocated to questions related to the history of science. The rest (20%) is allocated to coursework which is internally assessed. Roberts and Gott suggest for Sc1:

> A typical coursework assessment is based on perhaps one to three complete investigations together with some shorter tasks. The pupils are required to write at length about the underlying theory and are given ‘rules’ as to what counts in terms of procedural understanding. (Roberts & Gott, 2006, p. 46)

Roberts and Gott (2006) warn that this may make the “assessment reliable but it does little for the validity, or for credibility amongst pupils and teachers” (p. 46), and the way this assessment takes place made practical work in science unattractive for students and teachers. This performance assessment has been criticised by Donnelly (2000), Duggan and Gott (2000, 2002), Roberts and Gott (2003, 2006), and Watson et al. (1999). The underlying issue for the criticism is that of validity and reliability.

According to Roberts and Gott (2003), the validity issue is that this is an assessment of performance that means the assessment needs observation which in their view is not possible with a large number of students being observed by one teacher. Roberts and Gott (2006) report that issues with reliability are due to the complexity of the task as a complete investigation can take 2 to 4 hours so not many of these can be carried out in a typical year of learning. To increase reliability a number of assessments would need to be carried out and an average taken. Gott and Duggan (2002) suggest that there are a number of factors that can affect students' performance that include content, context, how complex the procedure is, the number and types of variables, the skills of using the apparatus and, importantly, the openness of the task.

McNally's (2006) critique of Sc1 sums up the impact of assessment of practical investigation and the lost opportunity of learning to investigate in the United Kingdom:

> (Examined investigations)… were a false experience of science where pupils followed a procedure and wrote what the teacher said into their booklet to obtain a higher grade. The combined effect of triviality, being out-of-context, and emphasis on procedure seemed to negate the spirit of investigative work; it altered the whole character of the investigative experience to the extent that the investigation was not actually investigative in nature. (p. 426)

Roberts and Gott (2004a) note that:

> Sc1 has become routine, with a limited number of cases assessed. In some instances, Sc1 coursework has become so formulaic that performance is more akin to the recall of a complex protocol than the creative solution of a problem. (p.104)

So how could these issues be resolved?

Roberts and Gott (2004a) investigated alternative ways of assessing "practical work" in Sc1 and offer the usefulness and limitations of each. These are:

i) Observations and interviews: Performed by the teacher using detailed checklists, thus these could be valid assessments but not possible to do on a large scale, are time and resource intensive, and have reliability issues.

ii) Written reports: These could be an alternative to observations. The teacher would mark the written report presented by the student. Welford, Harlen, and Schofield (1985) reported that older students were able to write an accurate account of what they observed. Roberts and Gott (2004b) posit that context and subject matter that needs to be investigated, as well as procedural complexity, have such an effect that to reliably assess students' ability to investigate, one would need to do 8 to 10 assessments and take an average; this amount of assessment is impractical. To reduce the number of assessments from 10 to 2, Solano-Flores, Jovanovic, Shavelson and Bachman (1999) introduced the use of templates. These templates would be guides to the students, for example, if there were 10 spaces provided in the data gathering part of the template, it 'tells' the student that they need to have 10 trials. This was not successful as there was still too much variability to draw conclusions.

iii) Making the task routine: In this method of assessment tasks are developed that can be used as exemplars. This goes beyond the template model to more or less a seen examination. Students would be provided examples they could critique in the learning process and have access to these exemplars during assessment.

Following on from the ideas reported in Roberts and Gott (2004a) for assessing practical work, these researchers offered three alternatives for assessing "investigations" (Roberts & Gott, 2004b). One is using simulated investigation. Gott and Duggan (2003) had developed such a programme. The advantage was that several investigations could be done by the students making the results more reliable. However, Gott and Duggan found that because the students were not collecting real data they tended to gather a lot more than needed. Another option put forward by Roberts and Gott (2004a) was to assess parts of an investigation – a student may do several tasks that require planning an investigation or interpretation of graphs or processing of information or writing a report. Roberts and Gott (2004b) argue that this has several advantages such as reducing the complexity of the task, students do not have to keep too much information in their heads at a time, it reduces the possibility of routine recipe type investigation, and each task would be less time-consuming. As the third option Roberts and Gott developed a pen and paper assessment that they suggest could replace practical investigation. They report that this option was successful in their small research project but suggested that more research would be needed on a large scale for conclusive results.

The issue of assessment of the data gathering part (performance) of the investigation remains unresolved.

Cleaves and Toplis (2007) researched students' views of learning and assessment of science investigation and reported that students knew that their teachers trained them to do investigation. Students said that the teachers told them “this is what you have to do” (p. 92), “this is what you need to write” to get a good mark (p. 92). Additionally, students said they were taught to repeat data collection; they knew that they had to do this but did not understand why. Students also said they learnt to comment about anomalous results, but they considered it was good to have anomalous results because they could explain this to gain a better grade. Cleaves and Toplis report that students develop a view that investigation is a part of science that they have to learn to get marks, rather than a view that science is “predicated upon investigation” (p. 92).

At least in one school (out of nine) in Cleaves and Toplis’ (2007) study, students said they did “loads” of practical work. They frequently investigated, the teachers provided feedback, and then their best piece of work was selected for submission for assessment. Their teacher said that they followed the spirit of the curriculum with subject matter being taught through, and not separate from, investigation. Cleaves and Toplis also report that once the assessment of investigation was completed, no practical work was carried out in eight out of nine participating schools. Finally, Roberts (2009) found that if the purpose is to assess the problem solving aspect of investigating or the thinking behind the doing, then students need both the understanding of the concepts and the procedural knowledge in the context in which they are assessed.

To conclude, assessment of practical investigation is problematic as investigations are complex and involve not only theory and concepts but also procedural knowledge and are context specific. Internationally, there is agreement in science education literature that the components that make up an investigation are identifying a research question, focussing, planning, data gathering, processing, interpreting, and reporting. Of these, the data gathering is the problematic aspect when it comes to assessment. All other aspects can be assessed through written examination.

Alternative ways of assessing practical investigation include portfolios, reports, continuous assessment and assessment of parts of investigation. Each has its advantages and disadvantages. In the United Kingdom, assessment of science investigation is proposed through simulated tasks, parts of tasks and pen and paper tests.

3.4.5 Assessment validity and reliability

Internationally, teachers have asked for a reduction in assessment for summative purposes based on evidence that repeated external assessment had a detrimental effect on both teaching and the curriculum (Harlen, 2005). Assessment of science investigation in England and Wales in the 1990s, and in New Zealand more recently, resulted in a change in assessment policy at level 1. The guiding principles that underpin assessment are validity, reliability, and manageability (Hall, 2007).

Validity is an essential criterion for the worth of an assessment. "Validity refers to what is assessed and how well this corresponds with the behaviour of the construct that it is intended to assess" (Harlen, 2005, p. 246). Relevant to this research, Harlen describe two types of validity, construct and predictive. Construct validity is measured by aligning what knowledge and skills the task ought to measure to what it actually measures, whereas predictive validity is an indicator of the extent to which the results of an assessment can be used to predict future performance. Hall (2007) sees validity as "fitness for purpose" (p. 1). Hall puts forth the notion of three types of validity that include face validity, content validity, and consequential validity. He says that validity depends on a number of factors:

- the extent to which the purposes of an assessment are clearly described and the tasks used to judge students' progress and achievement seemingly relate to these purposes (called *face validity*)
- the extent to which the assessment framework for a course/module samples appropriately the content and learning outcomes (called *content validity*)
- the quality of the assessment tasks in terms of their relevance, diversity, construction and clarity (an aspect of *content validity*)
- the extent to which assessment criteria have been clearly communicated to students (an aspect of *content validity*)
- the extent to which assessment tasks do not have harmful side-effects, such as creating unnecessary stress in students or promoting surface learning instead of deep learning (called *consequential validity*)
- the extent to which the marking procedures and feedback processes help students improve their future performance (an aspect of *consequential validity*). (Hall, 2007, p. 5)

In Hall's view, validity issues can be addressed through pre-moderation by subject specialists. The difference between construct validity (Harlen) and content validity (Hall) is that construct validity is about the task used and whether it assesses what it is designed to assess. Whereas, content validity takes into account whether the task measures a wide range of knowledge and skills taught within the course rather than an aspect of the course. According to Roberts and Gott (2006), assessment validity in the case of a practical investigation is an assessment of performance either partly or in its entirety. The observation required for assessment of practical performance (p. 46) is not possible in mass education. Roberts and Gott maintain that “although assessment task reliability may increase by routinising tasks, its validity and credibility become questionable” (p. 46).

The reliability of an assessment is the “extent to which it can be said to be accurate and not influenced by the particular occasion or who does the marking or grading” (Harlen, 2005, p. 246). Hall (2007) supports this view by saying that “reliability refers to the extent to which the assessment provides an accurate measurement of each student’s performance“ (p. 6). According to Hall, reliability focuses on stability and dependability of the results. Hall posits that factors that can influence reliability include: defective assessment tasks that are unclear; assessment criteria that are poorly developed; inconsistencies in the judgements made by markers; and student factors such as stress, lack of practise, and poor health to name a few. In Hall’s view: “If students’ results can be replicated by giving them the same or similar test again a short time later, then the results of the two tests can be compared statistically to see how much they agree (“correlate”)” (p. 6).

Gott and Duggan (2002) analysed the reliability aspect of internal assessment of complete investigation and posit that performance of investigation is not assessed directly because it is time-consuming and resource intensive. The options available were: firstly, assessment of a written report which is limited by findings that older students could write better reports than younger ones, that some students could plan and carry out investigation, but could not write reports, while others could write a report based on “massaged data” (p. 188). Secondly, students’ performance can differ from one investigation to another depending on the content, context, and complexity of task, types of variables, and the openness of the task. In Gott and Duggan’s (2002) view, to get a reliable indication of a student’s ability to carry out investigation, students’ results for five to ten assessments would need to be averaged. Thirdly, a template approach could be used to tighten up the criteria but this did not have a significant effect on the reliability of the carrying out aspect of the investigation.

Manageability deals with practical considerations including affordability, access to resources, time, and workload for teachers. In Hall’s (2007) view, standards-based assessment is problematic due to teacher and student time required in dealing with management issues that in turn affect validity and reliability.

There is no denying that assessment has an important place in teaching and learning in school science. What is debatable is teaching *for* assessment and teaching *to* assessment as Cleaves and Toplis' (2007) research suggests.

3.5 Summary and Research Problem

This chapter presented a literature review of science investigation which is the phenomenon of interest in this research. The literature review highlighted the paucity of empirical research in this field in year 11 science in New Zealand and identified the need for this research. The many international studies have provided guidance through the ways they have used research for the learning of science investigation in their countries.

School science investigation is understood as an activity requiring identification of a question, using both conceptual and procedural knowledge in planning and carrying out the investigation, gathering, processing, and interpreting data and drawing conclusions based on evidence. Ideally, the process is iterative and the student has some choice in what they want to investigate. Such investigation would potentially lead to deeper learning for understanding.

Learning to investigate is viewed from a social constructivist perspective. Constructivist pedagogies include eliciting prior knowledge, creating cognitive dissonance, application of the new knowledge with feedback and reflecting on learning. In a constructivist approach to learning the teacher's role is to create learning opportunities, listen, introduce ideas and support and guide the learner and encourage reflection. In this view of learning it is acknowledged that students learn not only through interaction with the teacher but also with each other.

The constructivist approach to assessment involves diagnostic assessment to determine what the student already knows, determining students' strengths and weaknesses and identifying gaps in their learning or alternative conceptions they may have. The information is applied to inform planning and help students to make links between their prior knowledge and new knowledge. Ongoing formative assessment is promoted to enhance learning as it occurs. Providing feedback to the student is an essential element of formative assessment. Summative assessment is used to evaluate the effectiveness of teaching and learning.

As motivation is an essential pre-requisite for learning, goal theory of motivation is considered a useful lens for the purpose of determining what motivates students to want to learn to investigate and what leads to success. This theory is closely related to deep and surface approaches to learning.

In New Zealand, the science curriculum promotes open-ended science investigation, but the assessment regime in year 11 requires investigation with “direction” and a more limited understanding of investigation. The research problem is the teachers’ response to this contradictory situation, including their understanding of science investigation and the teaching practice they undertake, and how student learning and motivation to learn are related to this teaching context.

The next chapter presents the rationale and justification for the design of this study and the methodology followed. Figure 3.2 represents the aspects that will be explored in this thesis to understand the connectedness between learning, motivation to learn and internal assessment of science investigation in year 11.

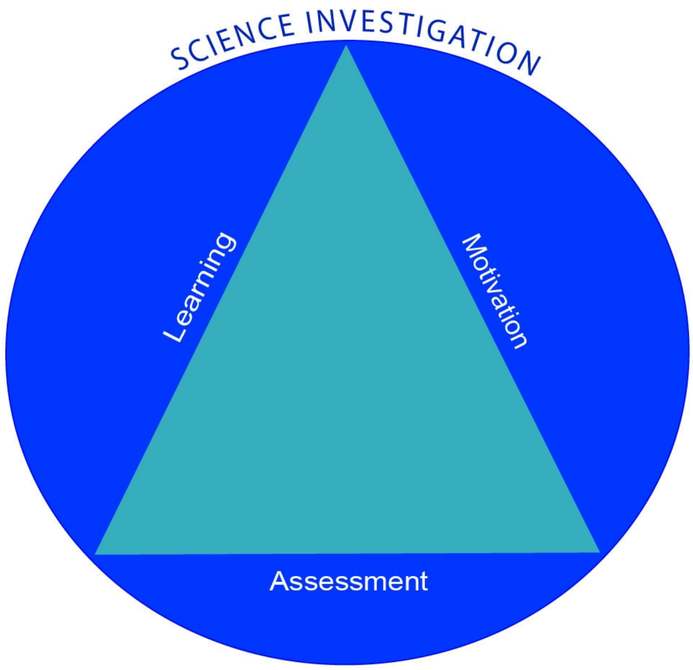

Figure 3.2: Learning motivation and internal assessment of science investigation

CHAPTER FOUR
Methodology

This chapter discusses the research design and process. The research design is the framework that guides a research project. The nature of the research questions guided the research design. Denzin and Lincoln (2005) suggest that the research design depends on the selection of a paradigm, how the empirical materials interact with the research paradigm, the object being studied, the strategies being used and the methods to be used to collect and analyse the empirical data.

The research questions are presented, and then qualitative research is defined and compared with quantitative research, followed by comparison of the roles of researchers who choose either qualitative or quantitative design. Reasons for choosing qualitative research are described. Within qualitative research, the methodological options available are discussed. A case study is defined with justification as to why a case study design was appropriate to answer the research questions.

A description of the study structure including methods of data collection is given. Participant selection, instrument construction, and the administration of data gathering tools are set out for each aspect of the study. An overall summary is provided.

4.1 Research Questions

There were four research questions that the study sought to answer. These were:

1 How do year 11 science teachers understand “science investigation”?

2 How do year 11 science teachers practise science investigation?

3 What types of science investigation are carried out in year 11 science?

4 How does the type of science investigation taught relate to student learning and motivation to learn?

4.2 Research Approach

Scott and Usher (1999) argue that conducting educational research and applying it to educational practice can get in the way of philosophical issues that should have a central place in educational research. They emphasise that educational research must be underpinned by sound philosophical understandings.

Qualitative research is interpretive, has a naturalistic orientation and allows the use of multiple methods (Denzin & Lincoln, 1994, 2005). Qualitative research seeks to understand situations in their unique contexts and through the interactions that take place in that setting (Merriam, 1998). The purpose is to communicate to those interested the understandings the researcher has developed through being part of the social setting, observing the participants, and recording the everyday life of the participants as it unfolds before them (Merriam, 1998; Patton, 1990). The researcher is responsible for being in the field for extended periods of time, being fully immersed in the field and collecting, analysing, and interpreting the data. It is their task to communicate what emerges from data analysis which is inductive, building from particular to general (Creswell, 2009). There are three possible reasons for selecting a qualitative approach: the researcher's world view, the nature of the research questions, and practical reasons of choice of particular methods of data collection. Qualitative methodology is appropriate, for example when the research involves the investigation of a new process, implementations of a policy, or development of a programme where the impact of a change on the participants is researched (Mertens, 2005; Patton, 2002).

Qualitative researchers are interested in understanding the meanings people have constructed and how they make sense of their world. The researcher has the opportunity to be in the social setting where the action is taking place and may become part of the scene (Creswell, 2009; Merriam, 1998) or be a distant outsider present in the participant's world. As the researcher gains the trust of the participants, they become willing to share their experiences and meanings that would normally not be shared with outsiders. The researcher has the opportunity to listen, ask, understand the way the participants see their world, and the activities they participate in (Guba & Lincoln, 1981). The role of qualitative researchers is defined by Guba and Lincoln as:

> Qualitative evaluators do not measure. Rather, they do what anthropologists, social scientists, connoisseurs, critics, oral historians, novelists and poets throughout the years have done. They emphasize, describe, judge, compare, portray evoke images, and create, for the listener, the sense of having been there. (p. 149)

Qualitative researchers use data gathering methods like semi-structured interviews and observations. They build toward theory to guide the investigation from observations and intuitive understandings they have gained in the field (Merriam, 1998). Qualitative data gathering is a "messy and unpredictable" process and the researcher has to be prepared to manage complex situations, unpredictable behaviours, and at times deal with a "lack of personal control" (Blaikie, 2000, p. 234).

Conversely, quantitative research is conducted by researchers who tend to assume that features of human environments have an objective reality. They believe that these features exist independently of those who have created them or are observing them. These researchers have a positivist epistemology and they assume an objective social reality (Gall, Gall & Borg, 2005). They believe that the world can be studied by traditional scientific means. Quantitative research typically involves testing theories deductively, controlling variables, and being able to generalise statistically and replicate the findings. Quantitative research can be experimental, and involve treatment or intervention, survey of large samples (whole populations can be involved). Quantitative data gathering methods include structured observational approaches, pre-set interviews (respondents answer structured questions), standardised tests, attitude inventories, and questionnaires (Bryman, 2001; Creswell, 2009).

Qualitative researchers do use data gathering methods applied by quantitative researchers, for example, surveys, but may include open-ended questions to determine reasons for the answers offered by respondents. This allows them to make better sense of participant responses.

Patton (2002) is in favour of using both qualitative and quantitative data gathering methods within qualitative research because they can provide breadth, depth, and numerical data that can give a more complete picture of the phenomena under study. This view is in agreement with Blaikie (2000), Bryman (2001), and Merriam (1998) who posit that using a combination of both types of methods for data collection can give the fullest picture of the nature of educational phenomena as qualitative researchers may also use numerical data (as frequencies and percentages) to summarise aspects of non-numerical data.

Qualitative methodology was selected for this research because the intention was to understand the phenomenon of science investigation. Qualitative research was also appropriate because learning was viewed from a constructivist perspective. To understand how the participants learnt science investigation, making links between existing ideas and new learning, it was optimum to be in the setting for extended periods of time, observing, talking, and seeking explanation. Qualitative research was appropriate because the intention was to understand both the implementation of *Science in the New Zealand Curriculum* (Ministry of Education, 1993a) in relation to science investigation and the change in assessment policy for internal assessment of science investigation. Most importantly, the open-ended research questions required qualitative research. The questions demanded understanding and therefore rich data from a range of sources.

To understand the data collected from multiple sources interpretation is required. Interpretation is integral to qualitative research. According to Stake (1995), interpretation has two meanings: first, the researcher explains why something is taking place, and the second is about what the experience holds for those who are being studied. Geertz (1983) drew attention to three central elements of interpretation. First is “thick description” which means paying attention to details, meticulous recording, careful analysis, considered interpretation, and accurate reporting. It means recording the actors’ circumstances, their intentions, and anything else that may shed light on the situation. The second is experiential understanding which requires being in the site observing and in a small way experiencing what the participants are undergoing, always with the awareness that the researcher is unlikely to have the same experiences as the actor participants due to their different situations, roles, or the power relationships. The third is multiple realities, the ability to view and interpret the data from several perspectives. Scott and Usher (1999) suggest that everyday experiences are the subject matter and the researcher makes sense of the world, not through pre-determined categories but through the frames and prior understandings of the participants.

4.2.1 Case study research

Qualitative research may be undertaken by various research methods and approaches including ethnography, phenomenology, grounded theory, case study, and action research (Merriam, 1998; Patton, 1990). Yin (1994) describes “a case study as an empirical inquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident” (p. 13). Merriam (1998) defines a case study as an “intensive, holistic description and analysis of a single instance, phenomenon, or social unit” (p. 27). She explains that case study is appropriate for studying educational practice with the intention to improve practice. Stake (1995) posits that case study research focuses on a “bounded” system and could be the study of a single person, event or system or can be the study of several individual cases studied either concurrently or over time.

A case study provides a number of options. Stake (2005) suggests that according to purposes for studying cases there are three types of case studies – “Intrinsic case study where a researcher wants to better understand a particular case, Instrumental case studies that provide insights into an issue or refine a theoretical explanation and Collective case studies that involve extensive study of several instrumental cases” (p. 378).

According to Cohen, Manion and Morrison (2001), case studies have strengths, they communicate to the readers in simple everyday language and are easily understood, they capture the unique elements which are often lost in large-scale studies and can be carried out by a single researcher. Cohen et al. argue that case studies can allow establishment of cause and effect and their strength is in the recognition of the power of the context, they allow the researcher to observe "effect" in the real context. Cohen et al. highlight that case studies have weaknesses too. Results cannot be generalised in the same way as large-scale studies allow, except when other researchers can see their application in similar situations. "They are not easily open to cross-checking; hence they may be selective, biased, personal and subjective. They are prone to observer bias, despite attempts made to address reflexivity" (p. 184).

Stake (1995) and Merriam (1998) describe a case as a "bounded system". A case has functioning parts – like all systems they have boundaries within which they operate.

As this research aimed to explore a phenomenon, school science investigation, in its real life context, an intrinsic case study was selected as the most appropriate qualitative approach to use.

4.3 The Research Design

The research design provides the framework that guides how the research is to proceed. In the following section the design of the case study of the phenomenon of science investigation in year 11 in New Zealand is presented.

The case of science investigation in year 11

In this research, the case was the "bounded system" of school science investigation in year 11 in New Zealand. The functioning parts of the system were the requirement for learning, teaching and assessment set down in legislation, their interpretation by teachers, and the classroom processes teachers put in place and the learning that ensued.

The research case of science investigation was designed to study the case from multiple perspectives including the curriculum documents, the perspectives of year 11 science teachers, the science department in a selected secondary school, and the science teacher and students of a selected year 11 science class in that school.

In studying the phenomenon of science investigation the approach taken was to have a deep understanding of the legislated requirements for the teaching and assessment of science investigation; therefore the first step was to analyse the *New Zealand Curriculum Framework* (Ministry of Education, 1993b) and *Science in the New Zealand Curriculum* (Ministry of Education, 1993a) as well as achievement standard AS1.1. These were presented in Chapter two.

To answer the first two research questions – How do year 11 science teachers understand science investigation? and How do year 11 science teachers practise science investigation? – it was considered useful to have a broad and detailed overview of a large group of teachers' understanding and practice of science investigation. This was addressed by conducting a regional science teacher survey through a questionnaire involving all year 11 science teachers in the greater Wellington region. The survey allowed an understanding of the views of year 11 science teachers to be gained more generally. The data from a large number of teachers in a diverse range of schools could be collected either through interviews or a questionnaire. A questionnaire was considered to be a time efficient mode for gathering this information rather than interviewing a small group of teachers.

Bryman (2001) and Merriam (1998) argue that a case study is usually conducted to gain an in-depth understanding of the case on site where the case is unfolding. Although the initial large teacher survey was likely to provide teachers' perceptions in some detail, to understand the intricacies of what was taking place in the school and more importantly in the classroom further exploration was needed. With this in view, a nested case study was designed and conducted in one state coeducational school. Within this case study, all teachers of year 11 science were interviewed. Adopting this stance provided a more comprehensive understanding of the case than could have been possible by collecting data from one source. School structures, profile of science within the school, and the resources available to enable an investigative approach were explored through analysing school documentation and consultation with key persons responsible for science teaching within the study school. As with the regional survey, these interviews assisted with answering the first two research questions and were useful in eliciting teachers' perceptions in relation to the third and fourth research questions: What types of science investigations are carried out in year 11 science and teachers' views of how the type of assessment relates to student learning and motivation to learn.

Although interviews provide more depth and the opportunity to clarify teachers' "meanings" through probing, their limitation is that the information provided is still what the teachers "say they do" rather than what they "do". To peel away the next layer and experience what "does" take place in the classroom where the teaching and learning happens, an in-depth case study of science investigation within one class in the case study school was considered an informative option. Stake (2005) regards "different ways of seeing as new ways of knowing" (p. 378) which underpins this decision. Although aware of Geertz's (1983) view that researchers' experiences are not the same as those of the participants, being in the class where the action was and experiencing in a small way what the participants experience in their learning of science investigation allowed an observer's view in making sense of the phenomenon of interest. This led to the decision to conduct a case study of a single class in the study school.

The key participants in the case study class were the teacher and the students. This case study of one class in depth over an extended period of the school academic year added a different and rich perspective to the case study of science investigation. This class case study was designed to provide the teachers' and students' perspectives about the teaching, learning and motivation to learn science investigation. It also allowed the researcher first-hand experience to answer the third research question, what types of science investigations are carried out in year 11?

Although through working with the students, observing student engagement, and having some understanding of students' interests, teachers can say what they think motivates the students to learn but it is only the students who can say what motivates them. The study of one class provided the information needed to answer the fourth research question, how does the type of science investigation relate to students' learning and motivation to learn?

Being a participant observer in the study class added another dimension in constructing personal understanding of the phenomenon. It allowed for the researcher's view of the teaching, learning and assessment taking place to develop and gave the researcher the opportunity to ask questions and interpret what the participants were experiencing and communicating. In Cohen et al.'s (2001) view, because the observations are carried out over an extended period of time, the researcher develops relationships with the participants that allow construction of shared meanings. The advantage is the opportunity to clarify interpretations on an ongoing basis.

A combination of archival records, questionnaires, interviews, and observations was needed to obtain rich data from the various sources that would allow a holistic interpretation of the phenomenon of interest and cross-validation of findings (Patton, 1990).

The overall structure of the case study of science investigation in year 11 science is presented in Table 4.1 and illustrated in Figure 4.1.

Table 4.1: Data collection sources and instruments used

Levels	Sources	Data collection methods
National	Curriculum documents	Document analysis
Regional	Survey: Wellington region year 11 science teachers	Questionnaire
School	School case study: Science department documentation Archival records Year 11 science teachers	Document analysis, analysis of records, teacher interviews
Class	Class case study: Year 11 study class teacher and students	Observations, teacher interviews, teacher reflections, student questionnaires, focus group, and informal discussion

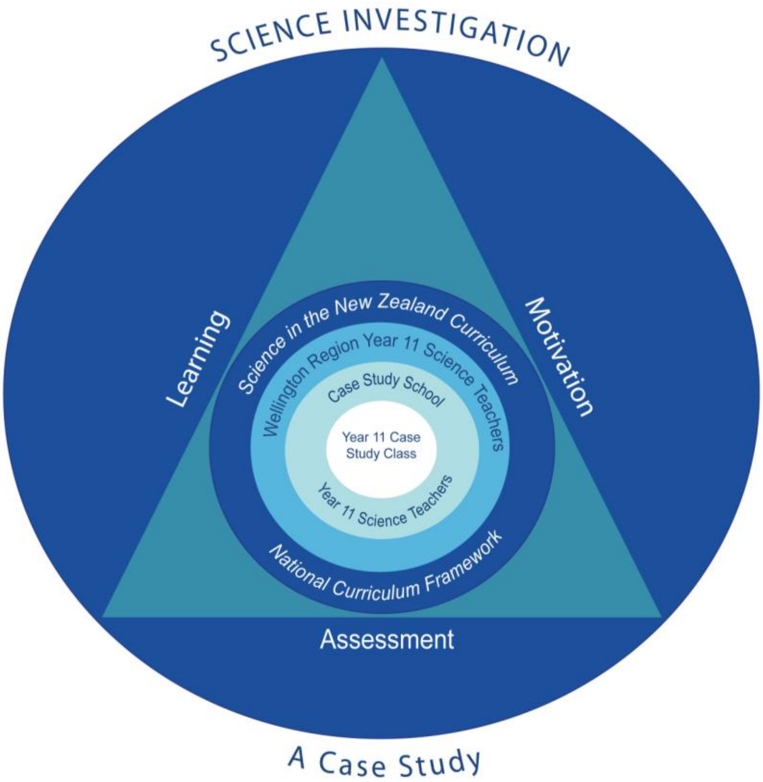

Figure 4.1: The case study of science investigation in year 11 science

Although the results of a case study cannot be statistically generalised, theoretical generalisation is possible through the process of "logical inference" (Scott & Usher, 1999, p. 87). The present study would be useful to many state secondary, coeducational schools within New Zealand. Further, the survey of a large number of year 11 science teachers allowed cross-checking of the observations from the study class and application to the wider teaching community. The following section presents the information gathering process applied in this research.

4.4 Regional Science Teacher Survey

While a national survey could have represented the views of the population of year 11 science teachers in New Zealand, as resources of time and funding were limited it was decided to select all the year 11 science teachers from one region in New Zealand that was accessible to the researcher, namely greater Wellington. The greater Wellington region is a large region with 52 secondary schools of various types. The 165 year 11 science teachers in these schools at the time of the study in 2006 comprised the population of year 11 science teachers in the region, and was the sample selected for the study.

Year 11 science teachers were surveyed through a postal questionnaire to gain an insight into their understanding of "science investigation" and how they teach their students to investigate and, additionally, to find out how they assessed investigation and whether the introduction of internal assessment influenced practice. Their views about the role of investigation and practical activities in their students' motivation to learn were also sought. A postal survey was the most appropriate method to gather data as the teachers could complete it in their own time.

The sample obtained were all the teachers teaching a year 11 science class in the greater Wellington region in the year of the survey who returned a completed questionnaire. The results of the regional science teacher survey are presented in Chapter five.

4.4.1 Questionnaires

Questionnaires can be designed to collect vast quantities of data from a variety of respondents, they are usually inexpensive to administer, can be easily and quickly analysed, may protect the anonymity of the respondent, are a reliable data gathering tool, and allow the researcher to maintain control and ability to direct how the topic is approached (Birmingham & Wilkinson, 2003; Blaxter, Hughes & Tight, 2006;

Denscombe, 2003). Possible disadvantages of using questionnaires include low response rate, and respondents providing superficial data or indifference, due to overuse of surveys in the community (Birmingham & Wilkinson, 2003; Denscombe, 2003).

The language, length, and structure needed to be considered to minimise “respondent fatigue” and reduce the likelihood of return of incomplete questionnaires (Bryman, 2001, p. 129). Pilot testing was carried out to gauge appropriateness and to refine all questionnaires.

Questionnaire construction

This was a researcher constructed questionnaire (Appendix 2). A combination of open-ended, closed and checklist questions was used. The questionnaire addressed the main concerns of the research, teaching, assessment and learning of science investigation, student motivation to learn, and gathered demographic data. It had four parts as follows:

Part A: Teaching science investigation

This section was intended to find out how teachers understood and practised science investigation. The construction of Part A was developed in relation to the literature about understandings and practice of science investigation, the curriculum statement and document analysis. The assessment questions with respect to change in practice were related to the introduction of the National Certificate of Educational Achievement.

Part B: Assessment of science investigation as required by AS1.1

Questions in this section were used to elicit information about how the teachers prepared their students for AS1.1 for the National Certificate of Educational Achievement level 1, as well as to gain an insight into the investigation they used for formative and summative assessment. These questions related to classroom preparation for science investigation assessment. The approach to formative assessment here is not assessment of learning during learning (Cowie, 2000), rather formative assessment as a mock examination that appears to be a common practice prior to formal assessment (Hume & Coll, 2009). The questions were designed to determine the reasoning behind teachers’ choices for this internal assessment and to find out their views about the advantages and disadvantages of formative assessment as a trial run of science investigation.

Part C: Science investigation, learning, and motivation

Questions in this section explored teacher perceptions about what motivated the students to learn in investigating for AS1.1 and their views on the motivational value of doing other practical activities in their science classes. Questions were informed by the literature on practical work in science as well as literature on motivation to learn, assessment of motivation and motivation and learning.

Part D: Demographic data

This section gathered demographic information to describe characteristics of the sample obtained, including teacher experience, type of school, the socio-economic decile rating of the school, and school size.

Part E: Other comments

Participants were invited to add any other comments relevant to the study in this section.

Pilot testing

The questionnaire was pilot tested and two changes were made for clarity of the intended purpose of the questions. One change was to an open-ended question asking the teachers to identify the types of investigation they did with their year 11 science class in physics, chemistry, biology, geology, and astronomy and to give one example. This required teachers to identify types of investigation they did with their classes. In the pilot survey, teachers ticked the example provided and very few gave any other types of investigation. Therefore, a list of the types of science investigation (Watson et al., 1999) was added and teachers were asked to indicate which of these they did with their students. The other change was to allow for more space for the first open-ended question as suggested by the teachers who did the pilot questionnaire.

4.4.2 Administration

A courtesy letter, along with an information sheet about the overall purpose of the study, was sent to principals of all 52 secondary schools in the greater Wellington region to seek permission to approach the heads of science departments (HoDs) regarding participation in the study. Since all principals agreed to participation, this was followed up by a letter to the HoDs of the same schools explaining the purpose of the proposed research with a request to communicate the information to teachers in their departments and asking the teachers if they would participate in the study. It was made clear that the survey was anonymous and that teachers and schools would not be identified. Most HoDs responded and agreed to participate in the study; however, HoDs from five schools did not respond. No school declined the invitation to participate, and two schools pointed out that they did not have any students taking year 11 science in that year. The HoDs from the five schools that did not respond initially were contacted by telephone. Three HoDs said they did not receive the initial letter and were willing to participate in the study. Two had received the letter but had not responded as they had been busy. Thus all 50 schools with students taking year 11 science agreed to participate.

Subsequent to the initial contact, all HoDs were contacted by email to find out the numbers of teachers in their department who were teaching a year 11 science class in that year. The total number of teachers in the sample of schools responding was 165 and 11 of these teachers taught more than one year 11 science class.

Parcels including the information sheet for science teachers, a copy of the questionnaire, an unmarked, self-addressed and postage paid envelope (a packet) for each science teacher were posted to HoDs of participating schools. Two extra packets were included to be used as replacements if the first ones were misplaced by teachers. These parcels were sent out on 6 October 2006 by mail. A repeat mailing was made three weeks later and a follow-up email was sent in November asking HoDs to encourage teachers to complete the questionnaires. The completed questionnaires were coded as they were received. Codes 001 to 101 Regional Science Teachers (RTS) were used. Independent check of codes allocated to open ended questions was carried out by my supervisor.

4.5 The School Case Study

This nested case study of the organisation of science investigation in a secondary school involved archival data analysis, including analysis of the school strategic plan, Education Review Office audit reports, science department management plan, and school results. The HoDs and all teachers teaching a year 11 science class in 2006 were interviewed.

Nationally, there is a variety of secondary schools in New Zealand that include urban and rural schools, coeducational and single sex schools, large and small schools, and schools with socio-economic decile ratings between 1 and 10. According to the Ministry of Education (2008), a school's decile rating indicates the extent to which the school draws its students from low socio-economic communities. Decile 1 schools are the 10% of schools with the highest proportion of students from low socio-economic communities, whereas decile 10 schools are the 10% of schools with the lowest proportion of these students. A school's decile rating does not indicate the overall socio-economic mix of the school.

Purposive sampling was used in the selection of the case study school as this approach is useful in situations where the researcher has some knowledge of the participants and selects specific participants because they are most likely to produce the most appropriate data (Denscombe, 2003). A purposive selection was made to identify a secondary school that was typical of secondary schools that many New Zealand students attend. The criteria used to identify such a school were that the school was a coeducational state school of medium size located in an urban area with a decile rating of 5-7. A further consideration in choosing the school was the researcher's access to the school on a weekly basis. The researcher had good relations with the school and visited the school as a visiting lecturer to observe student teachers during teaching practicum. As a teacher educator the researcher had taught several teachers now teaching in the science department.

Case study results may not be used to generalise to a wider population but there are many schools of this description in New Zealand and therefore the results will be of special relevance to them.

4.5.1 Access to study school

After receiving ethics approval to proceed with the study, the formal process of obtaining access to the school and consent of students and their parents, the teacher of the study class, and the other teachers started in December 2005. An initial meeting was held with the principal of the school to explain the purpose of the research and ask for permission to carry out research in the school. The principal gave written consent for access to the school and approaching the teachers in the science department. Consent was also sought for access to the school database for students' results to find out the ethnic composition of the school, and the number of students that would be involved. A meeting with the teachers in the science department followed in January 2006, when the purpose and background of this research were explained. The researcher invited all science teachers who would be teaching a year 11 science class in 2006 to participate in the research. All 11 agreed to participate.

4.5.2 Science head of department interview

Unstructured interviews are conducted with respondents who have considerable experience and knowledge of the subject. Anderson (1996) calls such interviews "elite" interviews. An unstructured elite interview was held with the HoD in the study school on 16 January 2006. The interview was focussed on the organisation of the science department and sought the department's management documents, teaching schemes, and HoD's report to the School Board of Trustees. The HoD provided access to these documents and information regarding science technician support, textbooks, and workbooks used for year 11 science. They also took the researcher to see the recently upgraded laboratories and the science resource room and talked about the department's policy about homework and student behaviour management.

4.5.3 Archival data analysis

Archival records were used to gather information that could not be collected through the use of questionnaires, interviews, and observations. Archival records analysed included the study school strategic plan, Education Review Office reports 2002 and 2005, science department management document, teaching schemes, and the HoD's report to the school board of trustees.

4.5.4 Study school year 11 science teachers' interviews

It was decided that semi-structured interviews would be appropriate for school science teacher interviews. In semi-structured interviews, a list of questions is prepared and questions do not need to be asked sequentially. The questions allow for explanations by the respondent and probes for elaboration, clarification, and evidence can be used to elicit more meaningful information if the responses are vague and unclear. These can potentially create a vast amount of data but are valuable because, unlike questionnaires, they provide face-to-face interaction and an opportunity to probe and ask for clarification adding authenticity to the participant's view and reducing the need for interpretation (Birmingham & Wilkinson, 2003; Bryman, 2001; Stake, 1995).

All year 11 science teachers in the case study school in 2006 were invited to an individual interview that would last for about an hour and were given time to consider participation. They were told that every effort would be made to ensure anonymity, so pseudonyms would be used. Permission was sought to audio-tape the interview and teachers were told that they would have the opportunity to review and amend the transcript. There was no pressure for them to agree; however, all teachers of year 11 science agreed. In 2006, when the data were collected, 11 teachers taught year 11 science in the study school. One of these teachers was the study class teacher who was separately interviewed three times during the year. As the questions for the first interview for the study class teacher were similar to the study school teacher interview questions, the study class teacher was not asked to participate in this interview.

Interview schedule construction

An interview schedule was prepared and pilot tested for a semi-structured interview. Questions were divided into four sections with background information on philosophy of science teaching, teaching and learning, assessment, and motivation (Appendix 3). The first set of questions was to encourage teachers to share background information and then to talk about their philosophy of science teaching. The questions about teaching and learning investigation were underpinned by the substantial international literature. Assessment questions that referred to both formative and summative assessment of AS1.1 were informed by the literature as well as the National Certificate of Educational Achievement information. Teachers were also asked their views about students' motivation to learn investigation and doing other practical work, which was based on relevant literature on student motivation to learn investigation (Roberts & Gott, 2006), and underpinned by theories of motivation. The schedule was semi-structured and allowed for prompts as required.

Pilot testing

The interview questions were pilot tested with an experienced science teacher from another school of similar size and demographics as well as two teacher educators. Changes were made to the questions so they were more focused; for example instead of asking, "In your view, do the students enjoy investigating"? The question was changed to, "Thinking about your year 11 science class, in your opinion, have the students enjoyed investigating?" This question was more useful to focus the teachers to think about their year 11 class making the data relevant to the study rather than getting information about whether year 9 students enjoyed investigating. Secondly, questions were linked to other aspects of the research, for instance teachers were asked about their goals for student learning through investigating which could be cross-referenced to study class students' goals for science investigation. Thirdly, a philosophy question was included as during the first pilot testing at the start of the interview the teacher talked in some detail about their beliefs about science teaching citing episodes from their personal experience. Such a question would be a comfortable way to lead into the interview. The third pilot with a teacher educator was carried out to confirm that no further changes were required.

Administration

Interviews took place over a period of two weeks, between 6 and 17 November 2006. An interview timetable was prepared depending on teacher availability. Only two teachers were interviewed on any one day, allowing time to listen to the recorded tapes, think about the contents, and process the information. Interviews took place either in the science laboratory preparation room or school interview rooms that were booked beforehand to avoid disruptions. The tapes were transcribed and checked, and transcripts were given to the teachers to check for accuracy. One teacher took the transcript to read but did not make any changes. Others did not want to check the transcripts.

4.6 The Class Case Study

The study class was chosen by the selection of the study class teacher. The criteria for selection for the study class teacher were:

1. Teaching a year 11 class in 2006.
2. Teaching year 11 science before and after the introduction of the National Certificate of Educational Achievement.
3. Not taught by the researcher during teacher education.

Of those who offered to participate in this in-depth phase, only one teacher met all the above criteria. After a meeting on 20 January 2006 the teacher selected was invited to participate and discuss in detail the requirements of the study – time was allowed for them to consider participation in the research. The teacher gave consent and helped with setting up the classroom-based research. The study class was a mixed ability mainstream science class taught by the study class teacher.

On 8 February 2006, information about the study was shared with the students of the study class and they were invited to participate in this research. Of a class of 31 students, 26 gave written consent to participate and two students did not want to participate in focus group interviews. As some students were under the age of 16 years, information sheets and consent forms were sent to all homes to gain parental consent and avoid potential embarrassment by identifying these students. They were reminded twice (by the teacher) to bring back the forms. This was followed by the school mailing another copy of the information sheets and consent forms along with self-addressed envelopes to their homes. Twenty-six parents gave consent to participate and two declined. The two parents who did not want their children to participate were the parents of those students who themselves did not want to be in the focus group but were willing to participate. These two students later informed the researcher that they did not want to participate. The remaining three did not return the forms. Two other students declined to participate in all aspects of the study. Overall, 24 students participated in the research as both their parents and the students themselves consented to participation. Consent was given to observe the students in the science class, to consider the student participation in focus group interviews, to ask the student questions in class, to audio-tape the student during any special moments of learning, to access their exercise and workbooks, and to access their results for both internal and external assessment. To avoid potential embarrassment to non-participants, effort was made not to treat them in any way that would identify them, for example student workbooks were collected by the teacher and only participants' workbooks were passed on to the researcher.

The study class was researched in depth for a year. Several tools were used to gather information. The following describes the data collection instruments used. Each instrument, its development and administration, is presented.

4.6.1 Classroom observations

Observations are useful for closing the gap between what is said and what exists. It may not be that the respondents do not want to communicate the information; rather they may think that it is improper or insensitive to say something during an interview or they may consider some things insignificant or irrelevant (Birmingham & Wilkinson, 2003; Mertens, 1998). According to Hopkins (2002) and Stake (1995), the researcher has multiple tasks – looking, listening, participating, sharing, negotiating, knowing when to stand back, refraining, recording, and describing. The researcher gains the participants' viewpoint or the emic perspective through observations and conversations with the participants and at the same time maintains the viewpoint of an outsider, which is the etic perspective (Birmingham & Wilkinson, 2003; Gall et al., 2005).

The researcher's decision to be a participant observer was related to her having a different ethnicity and being a lot older than most of the students; these factors made it highly unlikely that she would be "a fly on the wall" and not disturb the situation. While participant observers do not usually have the same experience as the participants, they do have "direct experience of the activities under investigation" (Scott & Usher, 1999, p. 100).

There are a number of options about what to observe and how to record observations. These include: one, using an open observation where the observer records most observations on blank paper; two, to do focused observations where what to observe would be decided beforehand, for example questioning or giving instructions; and the third, structured observation where all key aspects are built into an observation schedule that is filled out during observation. There are a number of variations of the third (Hopkins, 2002). It was decided to use a structured observation schedule that included all aspects of the study and to keep a running record with details to use for cross-checking.

To get as holistic a picture as possible, lesson observations were made one day each week throughout the academic year. One of the class's four science lessons was observed each week. Thursday, lesson four, was selected because the teacher identified this lesson as when they were most likely to do practical (including investigative) work with the class. Initially, observing one class for half a year was considered, which would have reduced the data collected but would not have explored the expected change in teaching investigation following AS1.1. Also there were many disruptions to the life of the school which would mean that a significant number of lessons could not be observed within a half-year period; this would make it less likely for robust conclusions to be drawn from the observations.

The observation schedule (Appendix 4) was a modified version of one developed by Averill and Clark (2006) for mathematical learning. This observation tool was informed by sample schedules developed by Good and Brophy (2003) and was designed to be used in a multi-cultural classroom to observe teacher caring about students' mathematical learning. Its development was underpinned by McCombs and Whisler's (1997) strategies for increasing student motivation and achievement. The decision about what to include in the modified observation schedule was based on aspects that were relevant to this research. These aspects included teaching and learning, class set-up, motivation, science investigation, and assessment.

Teaching and learning aspects included teacher presentation of the lesson, learning intentions, choice of tasks, instructions, organisation of materials, start of the lesson, transition between activities, questioning, checking for understanding, and finally on the ending of the lesson. The physical environment was also recorded. Pintrich and Schunk's (2002) list of indicators of motivation was consulted to determine which of these could be observed by an observer sitting at the back of a classroom. Engagement, enthusiasm, perseverance, attention, and on-task behaviour were included. As the main interest of the research was science investigation, types of investigation and whether investigation skills were taught, practised, or applied were noted on the schedule. Information recorded about assessment included whether diagnostic, formative, or summative assessment took place and whether feedback was given to the students.

In addition to completion of the observation schedule, a running record was also kept to ensure that the desired depth of data was obtained. As a teacher educator the researcher was a skilled writer of running records. The observation schedule was refined after pilot testing it with four teachers in the study school, including the study class teacher.

4.6.2 Case study class teacher semi-structured interviews

The study class teacher was interviewed three times during the course of the year. The first interview, at the start of the year, explored the teacher's background, philosophical beliefs, and views about teaching and learning of science. The second interview, comprising questions related to student progress and assessment, took place after the internal assessment of science investigation (AS1.1). The final interview was a reflective session about the teaching, learning, assessment and student motivation to learn that took place throughout the year, and to allow for clarification of events. A copy of the questions used as a prompt for these interviews is in Appendix 5.

4.6.3 Teacher reflection on observed lessons

The study class teacher was asked to record their reflection on each observed lesson. This was possible as each lesson was followed by a lunch break; the reflection involved only five minutes of the teacher's time. A tape recorder and tapes were made available to the teacher. This unstructured reflection served as a teacher account of the lesson.

4.6.4 Focus group interviews

Focus group interviews provide informal discussion where one person's ideas bounce off another's, creating a chain reaction of information dialogue. They allow the discussion of a specific topic in depth in a comfortable environment and are useful for answering the how and why questions (Anderson, 1996; Yin, 1994). Focus groups encourage the researcher interacting with the participants and participants interacting with each other that might be inappropriate in other situations. They are time efficient ways of data collection (Birmingham & Wilkinson, 2003; Morgan, 1998). Focus groups and participant observations have an overlapping interest in group interaction and Morgan (1998) notes that either can be used and the trade-off is between the natural setting and being in the field for long periods of time versus being in an unnatural setting and concentrated interaction over a short period of time. It was decided that to explore the students' perceptions of what was observed one focus group would be established to meet at key points in the year.

In determining the size of the focus group there are no hard or fast rules. Group sizes of 6-12, 6-10, and 5-10 have been respectively suggested by Krueger (1998), Merton, Fiske and Kendall (1990) and Morgan (1998). It is suggested that the number of participants should depend on the objectives of the research and if the participants have a lot of information to share then a size of 4-6 is preferable (Krueger, 1998; Stewart & Shamdasani, 1990).

To select participants for the focus group, students from whom consent to participate had been received were asked to write what they thought science was and the reasons that students should learn science. This information was used in consultation with the study class teacher to select six students with a range of views for the focus group. The teacher agreed that this focus group, which included four boys and two girls, was diverse and representative in terms of student ability. Having six students also had the advantage of having at least a minimum of four if one or two students were absent. As twenty-four students were being observed, a group of six comprising a quarter of the students was deemed appropriate.

The limitations of focus groups include possible domination by one member or participants not saying anything, or saying something to please the researcher. This was addressed through communicating to the students that the researcher was interested in the response of all members of the focus group and that they needed to allow time for each one to have their say. A researcher's interest can be a weakness as the researcher creates and interacts with the group (Morgan, 1998). The researcher was aware of this and only refocused the group if the discussion was off track.

Three focus group interviews took place during the year. All students had spent four hours each week in the science class and had lengthy experiences of the topic. In order to reduce disruption to learning, interviews were conducted at lunch time and allowed a maximum of 50 minutes each. Some participants travelled to school by bus or had sporting commitments so after-school interviews were not an option. Food was provided prior to the interview. Interviews followed an observed lesson, providing an opportunity to ask for clarification about something that had happened in the preceding lesson which added a reflective dimension to the interview.

The questions focused closely on the purpose of the interview, for example, the interview after the internal assessment focused on student experience of undergoing this assessment and the teacher feedback on their performance (Appendix 6). These interviews allowed the participants to engage naturally in conversations. All participants were given equal access to the discussion without any restrictions.

4.6.5 Student questionnaires

Both researcher designed and standardised instruments were used.

Researcher constructed questionnaires

Two researcher constructed questionnaires were used. The first (Appendix 7), administered in term 2, was to gather information about learning to investigate and assessment of science investigation. The questions were informed by learning of science investigation literature (Millar, 2004), for example, question 7 was designed to find out if students could make links between investigation and science ideas. Questions related to formative assessment were to determine students' perceptions about the learning opportunities provided by the teacher in the form of "formative assessment" (Cowie, 2000) rather than a formative "mock examination".

The second questionnaire (Appendix 8) focused on motivation and learning and was administered in school term 4, just before the external examination. This brief questionnaire was a self report on motivation and learning (Zusho & Pintrich, 2003). The questions focused on enjoyment as an indicator of motivation. This questionnaire explored learning for understanding science ideas and how students access help when they do not understand any aspect of their science learning.

Both questionnaires were pilot tested and minor changes were made to the format. Students responded anonymously.

Science Laboratory Environment Inventory (SLEI)

A standardised instrument, Science Laboratory Environment Inventory (SLEI) (Fraser, McRobbie & Giddings, 1993) was selected for use. Fraser, McRobbie and Giddings (1995) developed and validated this instrument which is specially suited to assessing the environment of science classes because of the importance of laboratory settings in science education. The inventory comprises 35 items, each of which is judged on a scale of 1 to 5. This SLEI has an actual and a preferred version of the learning environment. In the actual version the students respond to the questions by selecting options that indicate how things happen in their laboratory class. In the preferred version they choose responses that indicate what they would like the classroom environment to be. Both versions (Appendices 9 and 10) were administered in the study class in lesson 9 on 25 May 2006. The SLEI was field tested and validated with 5447 students from 269 classes in seven countries including Australia. Fraser et al. used individual students as a unit of analysis and reported the internal consistency (alpha reliability) and discriminant validity (mean correlation of a scale with the other four scales). The statistics are reported in table 4.2.

Table 4.2: Internal consistency (Cronbach Alpha Reliability) and Discriminant Validity (mean correlation with other scales) for actual and preferred versions for a cross-validation sample for class mean as a unit of analysis

Scale	Alpha Reliability		Mean correlation with other scales	
	Actual	**Preferred**	**Actual**	**Preferred**
Student Cohesiveness	0.80	0.82	0.31	0.31
Open-endedness	0.80	0.70	0.25	0.15
Integration	0.91	0.92	0.44	0.36
Rule clarity	0.76	0.80	0.43	0.35
Material Environment	0.74	0.85	0.34	0.40

Note: Table from Fraser et al. (1995, p.15).

The alpha reliability data show how the numbers in the left hand columns are all relatively high, they show how the items in each set are internally correlated (e.g. all those items that measure actual student cohesiveness are quite highly (0.80) interrelated). The numbers in the right hand columns are all relatively low, they show that the sets themselves are not highly correlated, for example, actual student cohesiveness has a low average correlation (0.31) with all the other scales.

Although this instrument was not tested in New Zealand, it was considered appropriate because the instrument was using items that were relevant to this research. This inventory has five scales – the description of each scale and an illustrative sample item are presented in Table 4.3 which is from Hofstein (2004, p. 355).

Table 4.3: Descriptive information and sample items for each scale of SLEI

Scale name	Description	Sample item
Student Cohesiveness	Extent to which students know, help and are supportive of one another	Members of this laboratory class help one another
Open-endedness	Extent to which the laboratory activities emphasise an open-ended, divergent approach to experimentation	In our laboratory sessions, different students do different experiments
Integration	Extent to which the laboratory activities are integrated with non-laboratory and theory classes	We use the theory from our regular class sessions during laboratory activities
Rule clarity	Extent to which behaviour in the laboratory is guided by formal rules	There is a recognised way of doing things safely in this laboratory
Material Environment	Extent to which the laboratory equipment and materials are adequate	The laboratory has enough room for individual or group work

4.6.6 Archival data analysis

Student workbooks and exercise books, and results for both the internal and external National Certificate of Educational Achievement were analysed. Minutes of the moderation meeting for AS1.1 were also used to understand the moderation process followed by the school.

Students in this class used workbooks which set out tasks similar to worksheets and templates for practical work including investigations. Each student also had a notebook in which they copied notes from the board or did tasks set from textbooks. Both notebooks and workbooks were relevant to science investigation and were collected and analysed to get a feel for the written work students were doing in class in relation to the practical work. Workbooks were accessed through the teacher in May and October 2006. Students' National Certificate of Educational Achievement marks for internal and external assessments were analysed in August 2006 and February 2007 respectively.

Additionally, it was school practice for students to set goals for their learning for the year. Students in the study class set goals about the National Certificate of Educational Achievement grade they were aiming for in internal and external achievement standards. With students' consent, the researcher was given access to these goals written on named pieces of paper.

4.7 Data Analysis: Processes used to ensure trustworthiness

This section presents the data analysis process and how the issues of validity and reliability were addressed in the research design.

In qualitative research, data analysis starts from the first piece of information gathered to the end of the research and involves pulling apart the observations made in the field and making sense, identifying connections, and working out how one part relates to another. Qualitative research is a product of interpretation because data are not out there waiting to be discovered. According to Merriam (1998), "data collection and analysis is a *simultaneous* activity in qualitative research" (p. 152, emphasis is original). The researcher accumulates pieces of information or uses individual pieces of information to make sense (Denscombe, 2003; Merriam, 1998; Stake, 1995). In the present research, the interest was in both participants' views in general as well as individually about the phenomenon and how individuals handled it. In qualitative classroom observations the instances are pulled apart and put together to try to make sense, while analysis and synthesis take place in direct interpretation (Stake, 1995). An example of direct interpretation from the classroom observations was when a student was asked to plan an investigation to determine whether a plastic, polystyrene, or metal cup was the best insulator. The student drew three cups and drew a line in the middle and declared he had finished. One could interpret this in several ways: can they actually do the task? (Experience would say that they could.) Were they being lazy? Did they need some help? When asked if they had written the plan, they pointed to a drawing. When probed through questioning step by step they were able to communicate the entire plan and the method to follow. Why then did they choose not to write it down? The answer was "This is dumb, we did it for National Certificate of Educational Achievement assessment last year" and "I already know what will happen" (Student Ed, 18 May 2006). As a non-participating observer, one would not have been able to glean this information to interpret the observation.

Validity or *fitness for purpose* is a vital consideration in qualitative research design. As Hall (2007) explains, validity is about ensuring that the research answers the questions that it sets out to investigate. In qualitative research trustworthiness is a comparable idea to validity. Research is considered trustworthy if the design is coherent, research methods and strategies used for data gathering are appropriate, data analysis is sound and interpretations are evidence based, and the reporting is clear. The researcher needs to demonstrate that based on the evidence, they have taken into account the multiple perspectives shown in the data. It is important that the reader can see alternative interpretations in the findings. Initially, Guba and Lincoln (1981) suggested four elements to trustworthiness that included credibility, fittingness, auditability, and confirmability. These were later refined by Lincoln and Guba (1985) to credibility, dependability, transferability, and confirmability. Credibility is concerned with the confidence in how well data and processes of analysis address the intended focus. For instance, in this research the credibility of the analysis of teacher interview data was increased through ongoing code checking throughout the long period of data collection, frequent debriefing with supervisors and the background experience in level 6 science teacher practice that the researcher brought to the study. According to Patton (1992), credibility in the findings can be increased by choosing participants with various experiences as it allows understanding of the research questions from multiple perspectives. In this research, participants included students, classroom teachers and teachers in management in a selected school, and teachers from a wide range of schools in a large region of the country.

Dependability is primarily about the detail and accuracy in reporting of the research. As with credibility, dependability can be increased by keeping a diary and referring back to it to check for accuracy. According to Shenton (2004), “Lincoln and Guba stress the close ties between credibility and dependability, arguing that, in practice, a demonstration of the former goes some distance in ensuring the latter [63. This may be achieved through the use of “overlapping methods”, such as the focus group and individual interview”. Triangulation can be used to strengthen a study by combining methods (Patton, 2002). Denzin (1978) identified four types of triangulation including: data triangulation; investigator triangulation; methodological triangulation; and theory triangulation. In this research, data triangulation was used by having multiple sources of data (students, teachers, curriculum materials, and school documentation). Method triangulation was applied through using multiple instruments, including questionnaires, interviews, observations and content analysis as was theory triangulation, for example, multiple theories of motivation were used which included goal and attribution theories.

Transferability of findings from a case study is limited to similar settings. The findings of the present study may be found useful by other state secondary schools. According to Geertz (1983) the researcher can provide “thick description” through detailed description of the methods followed, the process of selecting the participants and the provision of as much information as possible about data collection and analysis. By providing appropriate quotations, it is possible for the reader to see where the findings may be transferred to similar contexts.

Confirmability is about an ‘audit trail’. It is demonstrated in this research through careful and detailed descriptions of the reasons for selecting various methods and how each data source was applied to represent the participants’ views and to reduce researcher bias. To this end, maintaining a diary and referring back to it frequently and having regular meetings with the supervisors was useful.

The quantitative data were aggregated through the use of the Statistical Package for Social Sciences (SPSS, 2001). This allowed for the responses to be coded and aggregated providing frequencies and percentage. According to Bryman (2001), percentage distributions and the number of participants who have used this particular category are easy to interpret. The results in this study have been reported both as frequencies and percentages for the reader to make judgment about the conclusions reached.

All data reported are anonymous. Participants providing quantitative data were given code numbers and participants providing qualitative data were given pseudonyms. These are provided in Appendix 11.

Every effort was made to allow the phenomenon to be seen through the perspective of the teachers and students who provided the data. Their voices have been reported along with the researcher’s reflexive interpretation. On the matter of reliability, unlike quantitative research, qualitative research cannot usually be replicated because of a range of possible contextual differences from one study to the next. However, Denscombe (2003) suggests that reliability issues can be dealt with by providing an explicit account of the aim of the research, how it was carried out, and the context, explaining the reasons behind the choices made in sampling, data collection, and interpretation.

In qualitative data analysis it is imperative that the researcher reads the field notes and transcripts over and over in order to attempt to identify patterns, similarities, and differences (Denscombe, 2003; Mertens, 2005). The process of data analysis started from the design and pilot testing of the first questionnaire and the first classroom observation. Analysis started with the regional science teacher survey and its open-ended questions. All responses to all questions were read before generating the list of categories for each question. Both positive and negative responses were marked out as potential quotes to include as the respondent's voice increasing the credibility of the process. A similar process was followed for the analysis of all open-ended questions in all other questionnaires used in the study.

Interviews were audio-taped and transcribed as soon as possible after the collection of data. This was done to reduce the effect of inconsistency in researcher's decisions during the analysis process, thereby increasing the dependability (Guba & Lincoln, 1981). The transcripts were read several times for making notes and identifying the range of perspectives. If there was a point of interest in the study class teacher interview or student focus group interviews that needed further exploration, it was noted and added to the list of questions for the following interview. In each case, the transcripts were colour coded to classify the responses into areas of interest (investigation, learning, motivation, assessment).

In analysis of the data from focus group interviews, individual responses were not used as units because the focus group was the unit. As noted by Denscombe (2003), attention was paid to what the participants said about learning, investigation, practical activities, assessment, and indicators of motivation that included interest, participation, effort, and persistence as a useful means of cross-checking the observational data.

Classroom observation schedules completed for all 21 observed lessons were integrated with the running record and analysed through creating a table. Each lesson was given a column. Each category of information was given a row that was sub-divided into a row for each piece of information in that category. For example, assessment had three sub-categories as diagnostic, formative, and summative. Each column was summarised. Next, the running record was used to add or clarify the summary, for example, if the class was recorded as being off task in the first quarter of the lesson, the running record provided the details about the classroom activity at that point. All entries were cross-checked with the running record for each lesson.

The 12 study class teacher reflections were integrated with the teachers' interviews and the relevant classroom observations (the teacher was only able to provide audio-taped reflections for 12 lessons due to other commitments). Teacher reflections for the lessons explained the 'event' through the teacher's lens (e.g., why was the class not on task?). Additionally, being able to talk with the students about a point of interest or get to know why they were shifted to sit next to the researcher provided insight and understanding of events. A sample of teacher reflection and analysis is provided (see Appendix 12). The following section deals with ethical issues involved in qualitative research and how they have been addressed in this research.

4.8 Ethical Issues

This research was carried out within the guidelines and procedures outlined by the Massey University Human Ethics Committee (see approval Appendix 13).

Merriam (1998) draws attention to ethical dilemmas that are likely to arise in the collection of data and dissemination of information as well as the researcher-participant relationship. Stake (1995) explains that when observing, qualitative researchers are guests in the private spaces of participants and notes that "their manners should be good, and their code of ethics strict" (p. 244). Merriam (1998) draws attention to the consideration of the questions asked in interviews as they may cause embarrassment to the participant and their privacy may be invaded. Participants may say things they did not mean to reveal. In these situations the participants should have the right to ask for this information not to be included. These issues were taken into account when designing the observation schedule and interview questions.

In this study, potential harm was avoided by choosing to study aspects that would not expose the participants to physical harm, harm to self-esteem, or to cause stress. For example, one of the participants in the focus group was concerned that if they were critical of their teacher then the teacher would find out that they had made the statements. They were put at ease by letting them know that they would not be identified and no-one would know that they had made the statements. Further to this, they could choose not to share anything that may cause them stress. Effort was made to preserve the anonymity of the school, though in a small country like New Zealand this cannot be absolutely ensured. The school has not been named and some characteristics that would identify the school have not been reported.

The participants have the right to know the details about the research, and for the research to be empowering the purposes and aims of the research should be communicated to the participants (Bryman, 2001; Merriam, 1998). For this research, information sheets were prepared for the participants as well as the parents and caregivers when the students' age was less than 16 years. An information sheet was prepared for all participants and a sample is given in Appendix 14. The participants were encouraged to ask further questions and were provided with contact information for the researcher and the research supervisors. Informed consent was gained from the principal of the study school, the teachers interviewed in the study school, the teacher of the study class, and students in the study class. The students and parents were able to give consent for participation in the study and/or participation in the focus group interviews. Altogether 24 students participated in the study though some parents or students declined consent to participate. A sample consent form is given in Appendix 15.

Research ethics is about the nature of the agreement between the researcher and the participants and maintaining anonymity or confidentiality is paramount (Blaxter et al., 2006). The anonymity of the study school, science teachers in the school and the teacher of the study class was protected through the use of pseudonyms. In the Wellington regional science investigation teacher survey the teachers were anonymous and the demographic data were collected in such groups that their schools could not be identified.

During the surveys of year 11 students, the students were informed that they could choose to return a blank questionnaire if they did not wish to participate and they could choose not to answer any question that they did not want to. Teachers who participated in the interviews were given a copy of the transcript to check for accuracy. All audio tapes and transcripts were kept in locked cupboards and access to these was limited to the researcher and the research supervisors.

Lastly, but importantly, advice from Scott and Usher (1999) that "ethics and epistemology cannot be conveniently separated" indicates that the rights and responsibilities of the participants need to be considered along with the knowledge created by the research (p. 134). The decisions made by the researcher in the field affect the participants.

4.9 Limitations arising from the study design and its implementations

To investigate the phenomenon of interest, a case study research was designed to allow for the analysis of relevant national curriculum and assessment requirements. The research included a regional survey of teacher perceptions of school science investigation. Additionally, nested case studies of the school organisation and classroom practice of science investigation using diverse data gathering methods was expected to provide an insight into the phenomenon.

The response rate for the Wellington regional science teachers' survey was 60%; a limitation of the study was that it did not represent the views of the 40% who did not respond to the survey. Deeper insights may have been possible if a national teacher survey was carried out; perhaps focus group interviews of regional teachers would have enriched the data collected through questionnaires.

The setting where the action was taking place covered a quarter of all the lessons for students involved. This provided the researcher with a small window into the everyday experiences and learning that took place. Observations of all lessons in which science investigations were carried out and of the following lesson where some of these investigations were discussed may have provided further useful information. Although the researcher was able to observe all lessons in which investigations took place, sometimes the lessons did not have a final reflection and the researcher did not see if or how the investigation was concluded. Although student engagement in science investigation appeared to be low in the study class, a slightly greater number of students in this class gained an Achieved grade for AS1.1 compared to other classes in the study school, and fewer achieved Merit or Excellence. Engagement in other classes in the school and how it may have influenced student results is not known.

Further, this study did not include the learning of science investigation experienced by other classes in the school or in other schools. Given that no two schools are identical and learning experiences differ from class to class, multiple case studies would have been useful.

Dissemination and repetition were predominant teaching strategies in the study class. Although the study provided an in-depth view of one classroom, the limitation of the study is that the results and practices observed cannot be representative of all 11 classes in the school or year 11 science classes generally.

Teachers' philosophical beliefs about teaching and learning in science were explored in teacher interviews. A limitation of the design was that the relationship between teachers' philosophical beliefs and how these influenced their teaching and student learning were not explored.

CHAPTER FIVE

Results of the Regional Science Teacher Survey

A survey was conducted to investigate regional science teachers' views about teaching and assessment of science investigation in year 11 classes. The purpose was to gain an understanding of what science teachers thought a science investigation was, how they taught it, and how they internally assessed it as required by the National Certificate of Educational Achievement AS1.1 for science. Additionally, the intention was to gain an insight into teachers' perceptions about the change in assessment policy and how it may have influenced their teaching, student learning, and student motivation to learn to investigate. The survey was conducted through a questionnaire sent to all secondary school science teachers in the Wellington region who were teaching year 11 sciences in 2006. The survey contributed towards answering all research questions from the participating teachers' perspective. For details see Chapter four and the questionnaire (Appendix 2). The questionnaire had four parts.

Part A: Teaching Science Investigation (Questions 1 to 3)

Part B: Assessment of Science Investigation as required by AS1.1 (Questions 4-6)

Part C: Science Investigation, Learning, and Motivation (Questions 7-11)

Part D: Demographic Data (Question 12-17)

Results are presented starting with Part D (demographic information) followed by Parts A, B, and C because participants' demographics provide important information for setting the scene. Part E provided very few responses and therefore has not been reported. The national data for school type, school size, and school decile, have been accessed from the Ministry of Education database.

5.1 Science Teacher Characteristics

This section reports Part D, questions 12-17. In all, 165 year 11 science teachers in the greater Wellington region were invited to participate. Of these, 101 (61%) responded to the postal questionnaire. To maintain anonymity, teachers did not identify their schools but they did identify the types of schools. Of the 101 respondents, 65 were located in coeducational schools (64%), 17 in boys' schools (17%), and 19 in girls' schools (19%). Proportionally fewer teachers participated from coeducational schools than from single sex schools (Table 5.1).

Table 5.1: Type of secondary schools of participating teachers

School types	Participating teachers (n=101)	
	no.	**%**
Coeducational	65	64
Boys	17	17
Girls	19	19

The teaching experience of participants ranged from under five years to over 16 years (Table 5.2).

Table 5.2: Number of years of teaching experience of participating teachers

Teaching experience	Teacher numbers (n=101)	
	no.	**%**
Less than five years	40	40
6 to 10 years	14	14
11 to 15 years	17	17
More than 16 years	29	29
Missing response	1	1

Sixty-one teachers were female and 40 male. Sixty-six of the 101 respondents had taught year 11 science before the introduction of the National Certificate of Educational Achievement in 2002. The survey was conducted in 2006.

Considering the socio-economic decile rating, proportionally more teacher responses came from high decile schools and fewer from medium decile schools (Table 5.3).

Table 5.3: Decile rating of secondary schools of participating teachers

Socio-economic decile rating	Participating teachers (n =101)	
	no.	**%**
Low (1-3)	21	21
Medium (4-7)	33	33
High (8-10)	47	46

The proportion of responses was higher from large schools than from smaller and medium size schools. It is significant that the region includes the second largest city in the country and the Correspondence School and is likely to show this distortion. Nevertheless, almost one-fifth of teachers in the sample came from small schools. The size of secondary schools from which the participating teachers were drawn is presented in Table 5.4.

Table 5.4: Size of secondary schools of participating teachers

School size	Participating teachers (n=101)	
	no.	**%**
Under 500	19	19
500- 799	32	32
800 +	50	50

5.2 Teaching Science Investigation

This section relates to Part A of the questionnaire and had three questions relating to teaching of science investigation both currently and before the introduction of National Certificate of Educational Achievement.

5.2.1 Features of science investigation perceived to best support learning (Question 1)

This was an open-ended question for which up to three comments were coded for each respondent. Results are shown in Table 5.5. Features of investigation identified most often (39% of responses) related to the nature of investigation. These responses related to four different ways of supporting the learning of investigation and four correspondingly different ways of understanding 'investigation'.

Table 5.5: Features of science investigation supporting student learning identified by teachers (101 teachers responded)

Features best supporting learning	**Teacher responses (n=209)**	
	no.	%
Investigation related	**82**	**39**
Experiment	35	17
Scientific Method	24	11
Fair testing	17	8
Topic-based Investigation	6	3
Teacher and teaching related	**45**	**22**
Management, administration	23	11
Teaching and learning	22	11
Student related	**44**	**21**
Student interest	25	12
Student skills	18	9
Student futures	1	1
Assessment related	24	12
Curriculum related	8	4
Other	6	3

The most sophisticated responses, which were also the most fully articulated, supported learning that began with consideration of a topic or phenomenon, followed by identification of a question or hypothesis and the development and carrying out of an investigative process to respond to the question. One example described:

> Observing phenomena and asking questions about them; Developing predictions (hypotheses) from observations; Identifying key variables and controlling relevant factors to validly establish a fair test; Carrying out a plan developed by investigator; Collecting raw data by measurement and observation; Processing of data – ranking, means, graphs – to identify trends or patterns; Relating observed patterns to the initial hypothesis and explaining it in terms of scientific ideas/principles; Critiquing and constructively analysing own experimental practices. (RST 060)

Just six of the 82 investigation related responses (7%) gave this ‘topic-based’ understanding of investigation.

The other three response categories may be seen to provide parts of this topic-based understanding. Almost 30% of investigation-related responses described learning of investigation as best supported through ‘the scientific method’ which was described as a process starting with a given aim, purpose, hypothesis or prediction and proceeding through planning, data collection, analysis, and interpretation, to a conclusion. Responses that explicitly identified scientific method or included description of most of these stages, for example “(a)n investigation that allows the student to demonstrate knowledge of scientific method … (and) work confidently and independently using skills of planning, carrying out, recording, processing, analysing etc.” (RST 033), were identified in this category.

Twenty percent of investigation-related responses identified fair testing as the best way to support investigation. These responses explicitly named fair testing or identified, manipulation or control of variables or a concern with validity and reliability, for example “fair test … valid, reliable” (RST 071). An immediate focus on data collection, or hands-on or practical activities as the best way to support learning of investigation occurred in 18% of the investigation related responses. These responses were categorised as ‘experiment’, for example “measure/collect data” (RST 042) and “experiments to help grasp concepts” (RST 048). Most investigation-related responses were coded in one category, though occasionally two were coded, for example scientific method and fair testing.

Teaching-related and student-related features were respectively identified in 22% and 21% of all responses. Student-related responses included supporting learning through responding to student interest, for example "it helps because students are really interested and love doing things" (RST 036). A smaller number of teachers said that "doing hands-on practicals" (RST 075) facilitated the development of student skills such as lighting a Bunsen burner or using a measuring cylinder. Teacher related responses described the management of materials, setting up investigation, and issues of time and resources. A smaller percentage (12%) of responses related to assessment and curriculum. They included teaching science investigation because they are assessed for National Certificate of Educational Achievement: "students will be doing AS1.1 so they need to learn to get at least Achieved and I try to prepare them. My class are not very able" (RST 082).

5.2.2 Types of investigation carried out in year 11 science (Question 2)

Question 2 asked the teachers about the types of investigation they did with their year 11 science class. This closed question provided Yes, No, and not applicable options for the types of investigations in each year 11 science subject. A not applicable response was not selected by any respondent. The curriculum uses the terminology Making Sense of the Living World, Material World and so on (section 2.2). In this question subject related terminology has been used as the achievement standards use, for example, biology instead of the Making Sense of the Living World. As well as this, the curriculum strands Planet Earth and Beyond includes both astronomy and geology which have separate achievement standards. The number of responses in each case represents the number of teachers that selected that type of investigation. The results are presented in Table 5.6 and Figure 5.1.

Table 5.6: Number of each type of investigation carried out in each subject in year 11 science (101 teachers responded)

Types of science investigations	All subjects	Chemistry	Physics	Biology	Geology	Astronomy
Fair testing	228	80	78	63	5	2
Pattern seeking	224	75	62	37	31	19
Classifying & identifying	195	57	21	58	57	22
Exploring	169	37	40	43	26	23
Investigating models	165	47	39	26	17	36
Making things	139	36	33	35	22	13
Developing systems	59	16	19	10	7	7
Other types	6	1	2	3	0	0
All types	1185	349	294	275	165	122

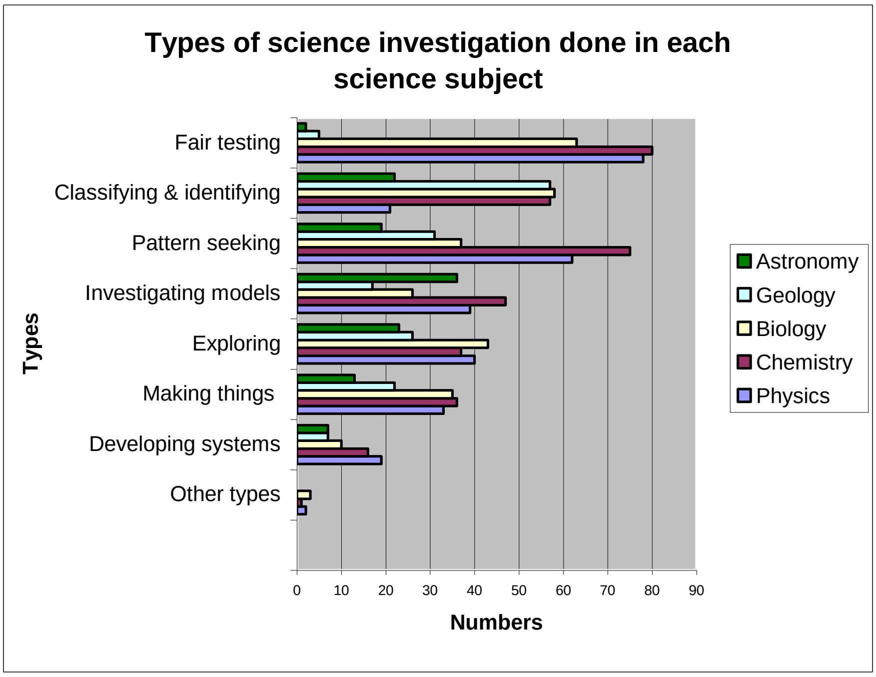

Figure 5.1: Types of investigation in year 11 science

More investigations were taught in chemistry (349) and physics (294) than in any other science subject. Fair testing was the most common choice and was utilised most frequently by teachers in chemistry, physics, and biology and not often in geology and astronomy.

Pattern seeking was a more common investigation in chemistry, physics, and biology than in geology or astronomy. Classifying and identifying was selected nearly equally by teachers in biology, chemistry, and geology topics. Models were explored in chemistry, physics, and astronomy. Exploration was done in biology, physics, and chemistry and to a lesser extent in geology and astronomy. Overall, the data showed that teachers carried out slightly more fair testing type of investigation which was followed by pattern seeking.

5.2.3 Science investigation and the introduction of the National Certificate of Educational Achievement (Question 3-3d)

Teachers were asked to indicate if they had taught science before the introduction of the National Certificate of Educational Achievement. The second part of the question asked whether their practice of teaching science investigation had changed due to the introduction of the National Certificate of Educational Achievement and, if so, to explain in what way their practice had changed.

Teaching before the introduction of the National Certificate of Educational Achievement (Question 3)

Sixty-six respondents (65%) had taught year 11 science before the introduction of the National Certificate of Educational Achievement.

Change in practice since the introduction of the National Certificate of Educational Achievement (Question 3a)

Fifty-five (83%) of the teachers who had taught before the introduction of the National Certificate of Educational Achievement reported a change in their practice of teaching science investigation after the introduction of the National Certificate of Educational Achievement.

In what way had teachers' practice changed after the introduction of the National Certificate of Educational Achievement? (Question 3b)

For this open-ended question, teachers who had noted a change in practice were asked to indicate how their practice of teaching science investigation had changed. Three responses were coded for this question. The data show that most teachers gave reasons that had to do with the investigation and assessment (see Table 5.7). Investigation related changes made up 66% of the responses. These included teachers saying that they did more complete investigation (31% of responses), and that the investigation had become compartmentalised (13% of responses). A further 11% of responses recorded that teachers did more holistic investigation. A small number expressed concern that teachers were doing fewer student initiated investigations. Although this was a very small percentage (6%), it is important as open-ended investigation is student initiated and usually based on something that the student wants to find out.

Table 5.7: Change in practice of teaching science investigation since the introduction of the National Certificate of Educational Achievement (55 teachers responded)

Change in teaching	Teacher responses (n)	Percentage (%)
Investigation related	**96**	**66**
Complete investigation	45	31
Compartmentalised	19	13
More holistic	16	11
Fewer student initiated practicals	9	6
More methodical and rigorous	7	5
Assessment related	**29**	**20**
Constrained by assessment	24	16
More time on assessment	5	3
Other	**20**	**14**
Less time for short practical activities	9	6
Change in content	7	5
Less time	4	4
All changes	145	100

Teachers described complete and holistic investigations as:

> Complete investigations are done in year 9 and 10 which include the whole process rather than the parts e.g., fair testing, planning, gathering information reporting etc. …linking of results to draw conclusions, evaluation of results and the method. (RST 054)
>
> The process of doing a complete investigation can take up to three lessons. Kids do the planning task in one lesson and then wait to do the investigation (gather data) in the next lesson and then I either get them to write the report for home work or it has to be done in the next lesson. Sometimes they forget what they had done the last time. To me this complete investigation feels like more compartmentalised than complete. (RST 073)

Twenty percent of the responses were assessment related. A typical response was:

> Investigations become an exercise in fulfilling criteria for credits. (RST 036)

Some teachers indicated that their practice included teaching the students the language required to get a particular grade:

> Emphasis on small things, in other words do these things and you will get an A, M or E. (RST 069)
>
> (Note: A means Achieved, M Merit, and E Excellence grades for the National Certificate of Educational Achievement).

Concern was expressed that there was less time available to do other practical activities.

Change in the number of investigations in year 11 science (Question 3c)

This part of the question asked teachers if there was a change in the number of investigations they did with their year 11 class. Of the 55 teachers who had said that there had been a change in their practice, eight said they were doing more investigations, 22 reported doing the same number of investigations, and 25 said they did fewer.

Reasons for doing more, the same or fewer investigations (Question 3d)

The reasons for change in practice were coded under the five categories of learning, assessment, less time, student motivation, and future use. Reasons coded as learning included responses such as "students need to learn to investigate in science because it is a practical subject" (RST 016). Assessment reasons offered included, "they need it because it will be assessed" (RST 023) or "for achieving in AS1.1" (RST 032 & RST 079). Teachers who said there was less time to do investigation gave reasons such as "each investigation takes several lessons to complete so there is less time for investigations" (RST 082). Some teachers said they did investigation as "students like doing them", "enjoy them" or they are "more motivated when doing investigations" (RST 093). A few teachers reported reasons such as "students need to know how to investigate for science in senior school" (RST 056). One teacher did not respond to this question (Table 5.8).

The data show that those teachers who had taught more investigations since the introduction of the National Certificate of Educational Achievement were concerned with assessment and student learning, but also had less time than before. Those teachers who were doing the same amount of investigation as they did before the National Certificate of Educational Achievement had similar concerns about time; however, they stated doing science investigation had motivational benefits (although these teachers did the same number of investigations they said how they taught investigation had changed). The teachers who were doing less science investigations were concerned about assessment and the lack of time but offered motivational reasons for not doing it.

Table 5.8: Numbers of investigations done in year 11 and reasons for change in practice. (55 teachers responded)

Change in number of investigations		Teacher responses (n)	Responses (%)
More	**Reason**	**19**	**100**
	Learning	7	37
	Assessment	8	42
	Less time	4	21
	Student motivation	0	0
	Future use	0	0
Same	**Reason**	**39**	**100**
	Learning	8	21
	Assessment	16	41
	Less time	7	18
	Student motivation	6	15
	Future use	2	5
Fewer	**Reason**	**48**	**100**
	Learning	2	4
	Assessment	24	50
	Less time	19	40
	Student motivation	3	6
	Future use	0	0

Note: Eight teachers reported doing more investigations, 22 the same, and 25 fewer.

Meeting assessment requirements was the most frequent reason given for change in the number of science investigations whether the teachers were doing more, the same, or fewer than they had before the introduction of the National Certificate of Educational Achievement. The next factor was having less time. It is noteworthy that those doing more investigations considered enhancing student learning as the second most important reason. The data show that learning becomes less important for those doing the same amount of investigation but becomes still less when teachers choose to do fewer investigations. Some typical teacher responses were:

> I do less practicals in class as less time is available. Once main AS1.1 is done for the year students will not do anymore fair testing investigations willingly as they have already achieved the credits. (RST 029)
>
> The timeframe still allows for the same number of investigations but two of them are formal i.e., Eligible for AS credits. (RST 091)
>
> Do lots more now. The kids love doing stuff and I believe it is the best way to learn science. Preparation for NCEA (Bonus!). (RST 101)

5.3 Assessment of Science Investigation Undertaken for NCEA AS1.1

This section relates to Part B of the questionnaire and explored the preparation teachers made for assessment of student science investigation through AS1.1 including formative assessments and the formal assessment they undertook. They were asked how they prepared the students, if they did formative assessment, and what they thought were the advantages and disadvantages of formative assessment.

5.3.1 Teachers' preparation of students for AS1.1 assessment (Question 4-4a)

All participating teachers were doing AS1.1 with their science class. This was an open-ended question and the first two responses were coded. More than a quarter of the responses (28%) indicated that teachers prepared their students for AS1.1 by doing tasks similar to those used for assessment and using the template from the Ministry of Education website, Te Kete Ipurangi (TKI).[1] Another quarter of the responses indicated that teachers used fair testing type tasks. Only 16% of responses recorded that teachers used formative assessment and gave student feedback as to how the students could improve. Other responses indicated that they prepared their students by teaching them the skills of planning, interpreting and processing information, and reporting. Some indicated that the teachers started preparing students from year 9 and familiarising them with the terminology used for AS1.1 (Table 5.9).

Table 5.9: Teachers' reported student preparation for AS1.1 (97 teachers responded)

Student preparation	Teacher responses (n=189)	
	no.	%
Doing tasks similar to those assessed	53	28
Practise fair testing	47	25
Formative assessment and giving feedback	30	16
By teaching skills needed for investigation	22	11
Start preparing students from year 9	18	10
Teach the science concepts	17	9
Do lots of practical work	2	1

[1] Te Kete Ipurangi (2005). *Watch that car go*. Retrieved 8 March, 2010 from http://www.tki.org.nz/e/search/results.php?1%3Aelem=DC.Subject.Classification&1%3Aval=NCEA%3BNCEA%20Science&1%3Avalop=AND&1%3Asearchtype=term&2%3Aelem=TKI.Level&2%3Aval=NCEA+Level+1&2%3Avalop=AND&2%3Asearchtype=term&xsl_lang=en&xsl_path=/search/results_e.php

A response illustrating the process followed by a teacher to prepare their student for AS1.1 said:

> Start at year 9, introducing fair test, develop through year 10 until full practice at end of year 10. Format of level 1 introduced end of late year 10. Revising start of year 11. (RST 011)

5.3.2 Science investigation task used to assess students for AS1.1 (Question 5-5a)

This open-ended question required the participants to identify the task they used for the last internal assessment of investigation conducted. More than half the 96 teachers said they used a chemistry investigation for assessing AS1.1, acid and metal reaction (Bubble trouble) as the most common investigation used (29%). Although it was an open-ended question, it asked for 'the investigation' they did last time; therefore there was only one response per respondent. A variety of tasks related to rates of chemical reaction such as effect of acid concentration, surface area, or temperature were reported. A physics investigation was used by 38% with a speed/acceleration investigation (Watch that car go!) used by 20%. Biology or geology investigations were used by only a few (Table 5.10).

Table 5.10: Teachers' reported science investigations used for assessment of AS1.1

Investigations used for assessment		Teachers (n=96)	
		no.	**%**
Chemistry			
	Acid metal reaction (Bubble trouble)	28	29
	Rates of chemical reactions	18	19
	Acid carbonate reaction	2	2
	Acid/base reaction	3	3
	Other	2	2
	Total for chemistry	53	55
Physics			
	Speed and acceleration (Watch that car go!)	19	20
	Simple pendulum	8	8
	Hooke's law	6	6
	Other	3	3
	Total for physics	36	38
Biology			
	Disinfectants	3	3
	Other	2	2
	Total for biology	5	5
Geology		2	2

Teachers' reasons for choosing the assessment task (Question 5a)

Teachers were asked to respond to a checklist of reasons with the option of checking as many responses as applicable and to note "others" if required. The data show that teachers considered the expense of using a particular task and chose inexpensive tasks (15% of responses). Their students' understanding of the science concepts was a consideration in 13% of responses followed by the availability of equipment (12% of responses). The accessibility of a task or a moderated task on TKI was also a consideration. Student interest in the task was a reason offered by some teachers. The data show a prevalence of management related reasons in teachers choosing the assessment task for AS1.1 (Table 5.11).

A typical response from a low decile school was:

> We have little technician support, not enough funding for resources and photocopying and the students cannot afford to pay for workbooks. We have to give our students the best deal under such conditions. (RST 025)

Table 5.11: Teachers' reported reasons for choosing the assessment task for investigation (101 teachers responded)

Reasons	**Teacher responses (n=390)**	
	no.	**(%)**
Inexpensive	59	15
Helps student understanding of concepts	53	13
Requires little equipment	45	12
Students find it easy	43	11
Exemplar on TKI	40	10
Moderated exemplar on TKI	23	6
Students find it engaging	36	9
Easy to differentiate	36	9
Others		
Manageable	24	6
Convenient	14	4
Others decides	14	4
Other	3	1

5.3.3 Formative assessment (Question 6-6b)

The questions about formative assessment were framed around the common school practice of conducting a "trial run" or "mock exam" before the assessment of AS1.1, and teachers providing students feedback for this formative assessment. This is not the understanding of formative assessment as described in literature which is assessment of learning while learning is taking place and used in schools to enhance learning. Formative assessment was conducted by 78% of respondents (Q6). Although 78% of the responses indicated that teachers did a mock examination or trial run in this question, in question 4a (section 5.3.1) only 16% had said they did formative assessment and provided feedback. This appears to be related to some teacher understanding of formative assessment as assessment of learning during learning and others considering formative assessment as a trial run before summative assessment.

Science investigation used for formative assessment (Question 6a)

In response to this open-ended question teachers identified the task they used for formative assessment. These results are the self-selected sub-sample of those responding yes to question 6. Tasks used for formative assessment (see Table 5.12) were similar to the ones used for AS1.1 (see Table 5.10). There were few differences, for example, the percentage of responses using “Bubble trouble” for assessment of AS1.1 was 29% and those selecting it for formative assessment were 16%. However, rates of chemical reaction was selected by 19% for assessment but by a larger 24% for formative assessment. Similarly, “Watch that car go” was selected by 20% for AS1.1 but used by 9% for formative assessment. The pattern indicates that tasks available as exemplars that are not used for AS1.1 were used for formative assessment.

Table 5.12: Teachers’ reported science investigations used for formative assessment

Investigations used for assessment		**Teachers (n=79)**	
		no.	**%**
Chemistry			
	Acid metal reaction (Bubble trouble)	13	16
	Rates of chemical reactions	19	24
	Acid carbonate reaction	7	9
	Dissolving rate of disprin	3	4
	Rusting	2	3
	Total for chemistry	44	56
Physics			
	Speed and acceleration (Watch that car go!)	7	9
	Simple pendulum	6	8
	Hooke’s law	8	10
	Ohm’s law	2	9
	Resistance	2	9
	Other	3	4
	Total for physics	28	36
Biology			
	Disinfectants	3	4
	Muscle strength	1	1
	Total for biology	4	5
Geology		3	4

Advantages and disadvantages of doing formative assessment (Question 6b)

This was another open-ended question and provided the opportunity to identify both advantages and disadvantages of the particular type of formative assessment as guided by the question (using terminology, trial run, mock examination, practice examination). Two responses were coded for each respondent for both advantages and disadvantages. More responses identified advantages of formative assessment (see Table 5.13) including, preparing students for assessment, familiarising them with the format, for teaching of skills and to increase familiarity with the context than disadvantages (see Table 5.14). Some responses on advantages (26) pointed out that students' alternative conceptions could be identified that would inform their practice.

Table 5.13: Advantages of formative assessment, trial or mock examination (101 teachers responded)

Advantages of formative assessment	**Teacher responses (n=153)**	
	no.	**%**
Student preparation for assessment, practice	75	51
Student learning skills needed to investigate	28	18
Teaching, identifying alternative conceptions and gaps	26	16
Student motivation, and gain confidence	20	13
Management of assessment, grades can be used for real assessment	4	3

The main disadvantages of formative assessment (38% responses) included added workload in terms of marking, preparation, organisation, management, and financial cost of doing a formative assessment in large schools. Some responses (19%) highlighted teacher concern about their own practice when doing formative assessment and that they may be giving too much help to the students, pre-teaching to the assessment and that the final tasks were sometimes very similar to the formative assessment. A few teachers reported that they felt this was unethical but had the dilemma that not providing help could disadvantage their students. Some examples of their comments were:

> We may give them too much heads up. (RST 015)
>
> It is very similar to the one used to assess. Not sure how valid it is to do that. (RST 088)
>
> You can teach them to do the test and all pass, is this ethical? (RST 091)

Other disadvantages cited were students becoming demotivated if the task was too hard, or becoming confused if the formative task was similar to the final assessment task.

Table 5.14: Disadvantages of formative assessment, trial or mock examination (80 teachers responded)

Disadvantages of formative assessment	Teacher responses (n=105)	
	no.	**%**
Teacher workload and cost	40	38
Ethical issues, may give too much help, pre-teaching	20	19
Demotivates students/too hard to understand	16	15
Causes confusion if task too similar to real one	12	11
Results may not reflect student ability	10	10
Other	7	7

Generally, teachers saw more advantages of formative assessment for the students than disadvantages. As one teacher puts it:

> It is the only feedback they really take notice of and learn from so that they can improve their grade in summative. Moving from Achieved to Merit to Excellence. (RST 021)

However, their responses indicate more disadvantages for the teachers in terms of organisation, preparation, administration, and management of formative assessment. Some concern was noted about ethical issues in the way formative assessment was used.

5.4 Relationship Between Science Investigation, Learning, and Motivation

The questions in this section relate to Part C of the questionnaire and sought information on teachers' views of science investigation and its relationship with motivation to learn. Question 7 queried teachers about the motivational aspect of science investigation; question 8 about motivational aspects of assessment; question 9 related to motivational aspects of practical activities not just investigation. Question 10 asked the teachers if they used a textbook and/or a workbook and to identify the names of these.

5.4.1 Teachers' views about the relationship between learning and motivation in the context of teaching science investigation (Question 7)

Two responses to this open-ended question were coded for each respondent for both motivating and demotivating characteristics of science investigation. There were 180 responses from 101 teachers. Responses (39%) show that the practical aspect of investigating (doing) and engaging in interesting and fun activities that had a 'wow' factor was motivational. Understanding how to carry out an investigation and knowing what is expected and achievable were also reported to be motivational (19%). Some responses (18%) show that teachers believe aspects of assessment – achieving credits and knowing how to improve their grade – to be motivational. Relevance of task to real life contexts was also reported as motivational. Results are presented in Table 5.15.

Table 5.15: Teachers' views about motivating characteristics of science investigation (94 teachers responded)

Motivating characteristics	Teacher responses (n=180)	
	no.	%
Doing, hands-on fun investigation with 'wow' factor	70	39
Understanding, knowing what is expected, achievable	35	19
Achieving credits, success, improved grade	33	18
Task in context, relevant	22	12
Working in groups and with friends	12	7
Teacher enthusiasm an element of competition	6	3
Other	2	2

Teachers also identified aspects of science investigation that demotivated students, for example task difficulty and lack of teacher support. Inflexibility of assessment criteria such as not getting credits or getting a lower than expected grade, student perception of the task being irrelevant to their everyday life, lack of investigational skills for the less able students, and lack of challenge for the more able were also considered to be demotivating factors (Table 5.16).

Table 5.16: Teachers' views about demotivating characteristics of science investigation (84 teachers responded)

Demotivating characteristics	Teacher responses (n=149)	
	no.	%
Task difficulty	31	21
Lack of teacher support	28	19
Rigid assessment criteria, not getting credits	23	16
Task perceived as irrelevant and not related to life	22	15
Lack of investigational skills	15	10
Lack of challenge for more able students	14	9
Takes too much time out of the school day	8	5
Other	8	5

Overall, teachers identified more motivating than demotivating characteristics of science investigation.

5.4.2 Effect of assessment for AS1.1 on student motivation and learning (Question 8)

As with the previous open-ended question, for this open-ended question two responses were coded for each respondent for both motivational and demotivational aspects. In all, for motivating characteristics, 159 responses were provided by 101 teachers. The most common responses were related to achievement (41%) and included achieving credits, getting an Achieved, Merit, or Excellence grade, and knowing the criteria for each of these grades. They said that students were motivated when they achieved, or believed they could achieve. For example, one teacher said:

> Assessment needs to be easy to understand with clear guidelines as to what gets an "Achieved", Merit or "Excellence". (RST 084)

This was closely followed by having done formative assessment and receiving feedback from the teacher (33%) so that students could improve their grade. Task familiarity, preparation, and learning were considered motivational. Some teachers believed that students enjoyed the hands-on aspect, particularly having all the equipment to be able to do the practical themselves (Table 5.17).

Table 5.17: Teachers' views about motivating characteristics of AS1.1 assessment for students (86 teachers responded)

Motivating characteristics of AS1.1	Teacher responses (n=159)	
	no.	%
Achieving, achievable task, appropriate level	65	41
Formative assessment and feedback	52	33
Familiar context, theory practical link	14	9
Learning to prepare for assessment	12	8
'Hands-on', doing fun activity	11	7
Other	5	3

In response to the second part of the question regarding demotivational aspects of assessment, teachers reported nearly as many reasons for assessment being demotivating as motivating. The most common response (37%) related to the National Certificate of Educational Achievement grades, number of credits, and differentiation between Not Achieved, Achieved, Merit, and Excellence grades as demotivating aspects of assessment of AS1.1 for those students who either did not achieve or did not get the grade they expected. This was followed by too much assessment (18%). Some thought that the language used for assessment makes tasks inaccessible for some students to achieve and not achieving is demotivating. The assessment for AS1.1 takes several hours which some teachers view as demotivating for students (Table 5.18).

Table 5.18: Teachers' views about demotivating characteristics of AS1.1 assessment (79 teachers responded)

Demotivating characteristics of AS1.1	Teacher responses (n=177)	
	no.	**%**
National Certificate of Educational Achievement exam issues, credits, grades	66	37
Too much assessment/ too much formative assessment	32	18
Unclear task format, task language	23	13
Not achieving	21	12
Lack of skill about doing exams	18	10
Assessment that takes several hours to do	13	7
Other	4	2

Teacher responses indicate that in their view assessment can be both motivational and demotivational. Adequate preparation including formative assessment helps the students to succeed and getting the credits motivates them. On the other hand, if there is too much assessment, then those students, who find it difficult to achieve or find the tasks too hard, give up.

5.4.3 Other practical science related activities undertaken with year 11 science (Question 9a)

This question explored practical related activities other than investigation that teachers did with their year 11 science class. Ninety-two teachers responded and gave a long list of practical activities they did with their year 11 classes. Their first three responses were coded and were grouped into subjects or general practical skills as shown in Table 5.19.

Table 5.19: Teachers' reported science related practical activities carried out in year 11 science (92 teachers responded)

Practical related activities	Teacher responses (n=257)	
	no.	**%**
General practical skills	90	35
Chemistry related practical activities	49	19
Biology related practical activities	48	19
Physics related practical activities	31	12
Geology and astronomy related practical activities	25	10
Other	14	5

Practical skills included being able to light a Bunsen burner, measuring liquids, and separation techniques including filtering and evaporating. Chemistry practical activities included preparation and testing of common gases and physical and chemical properties of metals and their compounds. Physics practical activities included energy transfer and transformation, making electrical circuits, and measuring current, voltage, and resistance. Geology activities identified were investigating rocks and classifying them, and making models to demonstrate folding and faulting of the Earth's crust. Astronomy practical activities included exploring models to understand an eclipse, the rotation of Earth, and the relative size of various planets.

5.4.4 Teachers' views about motivating and demotivating aspects of practical activities (Question 9b)

Ninety-five teachers responded to this open-ended question for which two responses were coded for each respondent (173 responses). Doing a practical activity (hands-on) was reported as motivational in 35% of responses. Interesting and fun activities motivated students according to 18% of the responses. If the students were interested, they worked with their friends or the task had an element of competition, it was considered motivational (17%). Learning new skills and students not seeing the task as 'work' or requiring thinking was also said to be motivating (Table 5.20).

Table 5.20: Teachers' views of motivational aspects of practical activities other than investigation (95 teachers responded)

Aspects that motivate	Teacher responses (n=173)	
	no.	**%**
'Hands on', doing	60	35
Fun, pop and wow activities	31	18
Student interest/competition/working with others	29	17
Learning new skills and content	18	10
Not perceived as work/learning/needing thinking	16	9
Credits	10	6
Not assessed	7	4
Other	2	1

More teachers viewed practical activities as motivational and only 20 responses indicated that practical activities were demotivational.

5.4.5 Use of a textbook and or workbook for year 11 science (Question 10a)

The final questions in this section asked teachers whether they used textbooks and/or workbook, and if so what were these (there are no prescribed text or revision books for science in New Zealand schools for year 11 science). All teachers said they used textbooks or workbooks. Analysis of the following question where teachers named the textbooks and workbooks showed that some of the textbooks identified were revision books. A list of all the text books, revision books and workbooks is provided in Appendix 16. Forty-five percent of the textbooks identified were actually revision books. Textbooks set out all topics and focus on learning tasks whereas revision books focus on aspects of the course that would be assessed. The most frequently identified textbook was *New directions in science* (Wignall & Wales, 2003), the most frequently identified workbook (60%) was NCEA level 1 workbooks (Abbott, Cooper & Hume, 2005). These workbooks had five booklets, one for each achievement standard for AS1.1 and the questions are set out allowing space for writing. The tasks include the fair testing type of investigation in the context of physics, chemistry, biology, geology, and astronomy.

5.5 Summary

The results of the regional science teachers' survey are indicative of teachers' understandings of science investigation. Teachers described science investigation as 'experiments', 'scientific method' and 'fair testing'. Few responses demonstrated a contemporary 'topic-based' understanding of science investigation. Other responses to the provision of learning support included aspects such as student interest, teaching student skills, learning, management, administration, as well as assessment as features best supporting learning through investigation.

Overall, teachers reported carrying out a range of investigations in all topics. Fair testing was the most common type of investigation followed by pattern seeking, and classifying. More investigations were taught in chemistry, physics, and biology than in geology and astronomy.

More than half of the participants had taught year 11 science before and after the introduction of the National Certificate of Educational Achievement. Of these, 83% reported a change in their practice of teaching science investigation to fulfil the assessment requirement. Now they carried out 'complete' and 'holistic' investigation that included following the process from planning to reporting. Some mentioned compartmentalised investigation because the entire process, although 'complete', took two to three days.

Whether teachers were doing more, the same, or fewer investigations, the most common reason for the change in practice was attributed to the pressure of assessment. However, for those teachers who started doing more investigations, student learning was an important factor but student motivation was not. For those doing the same number of investigations learning was offered as a less important reason but student motivation was important. Teachers doing fewer investigations said that they did so because of insufficient time. For this latter group, learning and student motivation to learn were not as important as assessment.

Teachers prepared students for internal assessment through AS1.1 by doing tasks similar to those that were assessed and these were a fair testing type of investigation. Assessment of science investigation was undertaken mostly in a chemistry or physics context where ‘Bubble trouble’ and ‘Watch that car go’ were commonly used tasks, both accessible as exemplars from TKI. Expense of materials required for assessment, students’ understanding of concepts, and manageability of the assessment process were the most common reasons for task selection for assessment.

Teachers (78%) carried out formative assessment in the form of a ‘mock examination’ or ‘trial run’. Their reasons for doing formative assessment were to prepare students and familiarise them with the assessment context, enhance investigative skills, and provide feedback to improve their performance. Some teachers indicated that through formative assessment they could identify and address students’ alternative conceptions. In their view, formative assessments increased student motivation and confidence.

Teachers saw disadvantages of formative assessments for themselves in terms of workload issues of preparation and marking (38% of responses). Some teachers (19% of responses) were concerned about the ethical issues in giving students too much help through formative assessment. Some saw assessment as demotivational if the task was too difficult.

Teachers said that they believed ‘doing’ interesting, real science, having fun, and the investigation having a ‘wow’ factor were the most motivating aspects of investigation. Students gaining an understanding, knowing what is expected, and that it was achievable were also believed to be motivational. Teachers identified getting credits and improved grades as motivating factors. In their view, if the investigation was too difficult, it was demotivating for the students.

When considering the influence of AS1.1 on student motivation and learning teachers reported that achieving, knowing the assessment criteria, what to do to get an Achieved, Merit, or Excellence grade was motivational. Formative assessment and getting feedback were identified as motivating characteristics of AS1.1. Specific issues of the National Certificate of Educational Achievement examination, too much assessment, number of credits, and differentiation between the grades were considered demotivational.

In addition to investigation, teachers said they carried out many hands-on practical activities in year 11 science. Teachers reported that these activities were carried out in multiple contexts in all subject areas and their reason for doing so was to teach students practical laboratory skills, skills of measurement, and how to safely use equipment. Few reported practical activities to be demotivating.

Text books and workbooks are used in schools for year 11 science. Sixty-two responses reported workbooks; of these, 60% used National Certificate of Educational Achievement workbooks that set out tasks providing templates similar to those used for assessment of science investigation through AS1.1.

This chapter presented the results of a large survey of science teachers in the Wellington region. Chapter six presents the case study of science investigation in one secondary school. The data from the school, the department and the science teachers are integrated and presented while Chapter seven deals with the results of the case study of one class.

CHAPTER SIX
School Case Study

This chapter presents the study of the organisation of science investigation at year 11 in the study school. It includes observations, document analysis and the results of the data collected from science teachers in the study school through semi-structured hour-long interviews. The case study locates the teachers within the school and the science department. The school science curriculum, departmental policies, and guidelines are examined focussing on science investigation. Science teachers' understanding and approach to teaching and learning of science investigation in year 11 science classes are explored. Teachers' views about assessment, formative assessment, and how teachers prepare their students for internal assessment through AS1.1 are reported along with the process of AS1.1 assessment. Teachers' views about student motivation to learn are presented next. This case study was carried out in 2006. Care was taken not to include details that would identify the school.

6.1 The Study School

The study school was selected from the secondary schools in Wellington region by a purposive process. The study school was a medium size coeducational urban school situated in a community that had several science-related organisations and businesses. This meant that students came from homes where some parents worked in science related employment. Like many New Zealand state schools, the school competes to attract students with other secondary schools in the area (evident in advertising and through observation). The school has a tradition of academic and sporting excellence (Vision statement). The school's strategic plan shows that the school values the teaching of science and in recent times has invested funds raised from international students' programmes to upgrade the science laboratories. The school received positive evaluations from the Education Review Office in several areas of teaching and learning including science.

It was observed that teaching staff were valued and were provided professional development opportunities. School documentation showed that teachers were given options regarding the focus for professional development. The Board report for 2005 indicated that of the areas of professional development suggested by the management, more teachers wanted professional development to enhance critical thinking in their teaching; the second favoured option chosen was further development of questioning skills. Conversations with several staff suggested a positive response from staff to the school's professional development programme. Teaching critical thinking skills and questioning were the professional development foci for the school in the year of this data collection.

6.2 The Science Department

An "elite" interview with the HoD was held on 16 January 2006. At the end of the interview, the HoD took the researcher to meet the staff, including the science technician, and gave her a tour of the laboratories and the science department workroom. According to the HoD, science has a high profile within the school and, the science department endeavours to have high achievement in external national examinations. The department has a culture of student participation in science related extracurricular activities such as science fairs, science badge programmes, and science competitions (for example, the Australian Science Competition, Chemistry Quiz, and titration competition organised by Victoria University of Wellington (VUW). The HoD reports to the school Board of Trustees (2005 and 2006) noted that each year between four and eight senior science students attended the Auckland Genesis Science School, Seimen's Science holiday programme at VUW and Otago University's Hands-on Science Summer School.

According to the HoD, the science department was well resourced with a full-time science technician and 10 science laboratories. Beginning teachers did all their teaching in one laboratory and experienced teachers shared as there were not enough laboratories for all teachers. The department had a workroom with enough computers for all science staff. Departmental management documents and electronic resources and student records were kept on a common drive. The room also had a large table to sit around. Books, reference materials, and specific resources for each level from year 9 to 11 science and senior biology, physics, and chemistry were stored in an organised manner. There were tea making facilities and the physical environment was both attractive and comfortable. It appeared to be a well-organised department and collegiality amongst the teachers was evident – they were supportive of each other in terms of sharing resources and helping each other with writing and moderation of tests (observation, 16 January 2006).

Compulsory science in years 9 and 10 was offered through 13 and 12 classes, respectively, in the year of the study (2006). One science course was compulsory for all year 11 students. Students could choose from science, human biology, or alternative science. There were 11 year 11 science classes, two human biology classes and one alternative science class. Year 11 science was a general science course for the National Certificate of Educational Achievement. Human biology was taken by students who had a particular interest in biology and who did not wish to carry on with physics and chemistry. The alternative science course had a practical focus. Biology, chemistry, and physics were offered in years 12 and 13. There were two classes each of biology, chemistry, and physics in year 12, and there were two biology, one physics and chemistry class each in year 13.

The science department management document showed that at least one year 11 science class was taught by each full-time teacher in the department. The year 11 science course was organised to deliver *Science in the New Zealand Curriculum* and covered the contextual strands Making Sense of the Living World (biology), Making Sense of the Material World (chemistry), Making Sense of the Physical World (physics), and Making Sense of Planet Earth and Beyond (geology and astronomy). Geology was not taught beyond year 10 and students were not offered the associated achievement standard in year 11. The school science scheme set out the learning objectives for all contextual strands and indicated that Developing Scientific Skills and Attitudes and Nature of Science and its Relationship to Technology should be integrated in the planning of the taught curriculum. The Nature of Science and its Relationship to Technology integrating strand was not identified in the unit plans for each topic although Developing Scientific Skills and Attitudes was. The teaching scheme for years 10 and 11 showed overlap in much of the content to be taught. For example, the genetics topic taught in year 10 covered all the content required in year 11 and the only difference between year 10 and year 11 electricity topic was that Ohm's law was covered in year 11 and not in year 10 (see Appendix 17). When this was raised in the interview with the HoD, the reason offered was that it reduces the time needed in year 11 to cover the course and requirement for assessment. Having covered these topics in some detail in year 10 meant they only needed to be revised in year 11 (HoD interview January 2006).

Assessment in year 11 science was through internal and external assessment; this included the internally administered standard AS1.1 (investigation) and external science achievement standards for physics, chemistry, biology, and astronomy. Additionally, the school offered an external achievement standard (organic chemistry) from the chemistry level 1 standards. This in the HoD's view was useful for those who choose to take year 12 chemistry. An extra standard had implications for the rest of the course as time was needed to teach organic chemistry. The school National Certificate of Educational Achievement results showed that only

10% achieved this standard and in the following year this chemistry standard was no longer offered (school records in 2007). Human biology was assessed through a combination of externally assessed level 1 biology achievement standards and internally assessed unit standards that had a human biology component. Alternative science was internally assessed offering some unit standards.

Teachers carried out at least one formative assessment or “trial run” of science investigation with their classes just before the formal assessment of science investigation AS1.1. The formative assessment was organised by the teachers themselves in their own laboratories. As the school had a large number of classes (11), for consistency formal assessment for AS1.1 was set up in the school hall during the ‘mock examination’ week and all classes were timetabled to do the data gathering part of the assessment there. Students were offered one opportunity to resit AS1.1.

The department used two textbooks for the year 11 science course (Wignall & Wales, 2003; Hook, 2001) and issued a revision book to all year 11 students for the year (Hannay, Howison & Sayes, 1995). Students were expected to purchase a set of workbooks (Abbott et al., 2005), one for each achievement standard offered. The workbooks had practical activities and investigations were set out as templates that teachers used to teach students to investigate. According to the HoD, teachers were expected to do most tasks set out in the workbooks, and science teachers interviewed indicated that they did use most of them (November 2006). Students purchased these workbooks which reduced the costs of photocopying for the department.

The department had regular meetings and the minutes of the meetings indicated teachers had an input in the decision making processes within the department. The agendas and minutes of the meetings were analysed for two meetings in terms 1, 2 and 3 and one meeting in term 4. The meeting documents included items relevant to teaching and learning, report writing, sharing and purchasing of resources, responsibility for writing end of topic tests, marking and moderation, upcoming events such as science competition and organisation of these events. In some meetings staff suggested the purchase of new resources or books they had seen. Sometimes new activities such as making hot air balloons from plastic bags and practical activities were tried out. There was time allocation for sharing information about professional development activities individual staff had attended and feedback from conferences. Teachers were encouraged to volunteer their services for an "open-evening" for prospective students to promote school science, organising science fair entries, fieldtrips and technology challenge. To support the local intermediate school and promote science, weekly science extension classes were held for one class to come to the college each week. Teachers also organised revision lessons during lunch times for year 11 science and years 12 and 13 physics, chemistry and biology. In a school with several classes at each level, these revision lessons were open to the students from all classes. The minutes provided an insight into the collaborative approach to the running of the department where responsibilities were shared and colleagues supported (meeting minutes, 14 March, 28 March, 9 April, 23 April, 25 July, 8 August, 17 October 2006).

To have consistency in marking, all assessments involving multiple markers were moderated using unmarked "guinea pig" papers, a process followed for AS1.1 (minutes of moderation meeting 13 June 2006). Setting and marking of homework was a school-wide practice. A timetable displayed in the science workroom showed that the HoD organised a lunch time detention for students who were persistently not doing homework and teachers used this support when their own strategies for managing homework did not work. The structure of the science department and responsibilities of staff are presented in Table 6.1

Table 6.1: Departmental structure and responsibilities of staff in the science department

Departmental Structure and Responsibilities	
Responsibility of HoD	
Functioning of the department. Department Management Documentation: includes departmental goals; yearly report to the Board of Trustee (including departmental activities in the previous year; departmental achievements, analysis of results), Goals for next year.	
Areas of responsibility delegated to:	
Teacher in-charge:	
Junior science:	Teaching schemes, Unit plans, Topic tests, End of year examination for juniors
Year 11 Science:	Teaching schemes, Unit plans, Topic tests, Mock examination, Organisation of AS1.1
HoD Physics:	Teaching schemes, Unit plans, Mock examination, Organisation of year 12 &13 internal assessment
HoD Chemistry:	Teaching schemes, Unit plans, Mock examination, Organisation of year 12 &13 internal assessment
HoD Biology:	Teaching schemes, Unit plans, Mock examination, Organisation of year 12 &13 internal assessment

Table 6.2 Science department teaching schemes, unit plans and lesson plans

Teaching schemes for each area, for example, year 11 Science • List of all the topics to be taught and achievement standards offered by the school • Allocation of laboratories • Safety procedures • Availability of technician support • Shared responsibility for writing topic tests and mock exams.
Unit plan for each topic • Indicates achievement objectives from contextual and integrating strand • Timeframe for each topic • Suggests content to be covered in each lesson • Sets out learning outcomes to be met in each lesson • Suggested learning activities • Lists resources available within the school (Texts, videos/CD/DVD) • Assessment required for each topic
Lesson plans Teachers write their own lesson plans based on the school unit plans

6.3 Year 11 Science Teacher Interviews

All ten teachers of year 11 science, other than the study class teacher, were interviewed individually between 6 and 17 November 2006. The interviews took place in either the preparation room or the school meeting room to avoid disruptions and took between an hour and one hour 10 minutes. Each interview was audio-taped and transcribed. Only two interviews were held on any one day, allowing for time to listen to the tapes and transcription.

The interviews were semi-structured and the questions were used as prompts and guides to keep the conversation focused. The interview schedule had four parts, namely, teacher background, teacher perspectives on teaching and learning, assessment, and motivation (Appendix 3).

To protect privacy and provide anonymity, pseudonyms have been used (see Appendix 11). Two teachers chose their own pseudonyms and the others were given pseudonyms by the researcher. Teachers were given the transcripts to read and check for accuracy. One teacher took the transcript but did not make any changes. Others declined the opportunity to read the transcript. For reliability in coding the interview transcripts five transcripts were coded by the researcher and a knowledgeable teacher from another region. The codes were compared for accuracy. All coded transcripts were further checked by the same teacher and two discrepancies that occurred were corrected.

6.3.1 Teacher background

Other than the study class teacher, of the 10 teachers interviewed nine were New Zealand trained and one, although trained overseas, had completed a refresher course in New Zealand. Six were females and four males. Among them, the minimum teaching experience was two years and the maximum 32 years. They were of mixed ethnicities but predominantly European New Zealanders. All had taught their specialist science subjects in the past except for one who was a trained chemistry and biology teacher but taught physics and was confident about the content knowledge. Half of these teachers had taught before the introduction of the National Certificate of Educational Achievement. The school was therefore reflective of the sample of Wellington regional science teachers surveyed.

In reporting the data, the actual number of participants responding is indicated. Where there was only one respondent of a particular theme it has been written as "one of the participants". Data analysis was done thematically by reading the transcripts and colour coding and pulling together similar responses (a sample of analysis is included in Appendix 18). Integration of data from the interviews is in Appendix 19.

Teachers' philosophies of teaching science

Teachers were asked about their philosophy of science teaching and learning. Teachers said that it was important to follow the national curriculum (n=9), encourage students to ask questions (n=7), and challenge students to think critically (n=7).

An example of a teacher's comment was:

> You know kids need to be able to critically look at the information they are given and critically assess things….they need to be able to ask questions. How does this (science) fit into my life? How does it fit into the world? How does it relate to religion? Is science a religion? (Lillian, 6 November 2006)

This teacher was applying the school's professional development focus on teaching critical thinking skills to her classroom practice. She said that encouraging students to ask questions was important. If her students were critical about the science they were exposed to, then it was likely that they would be asking questions that could lead to their wanting to do science investigation to answer some of their own questions. Another teacher, Keith, said that he wanted the students to "broaden their horizons" and to never take things at "face value". Science, he said, had real life application and he wanted his students to draw this conclusion and see the application of science in everyday life.

Engaging children in the science lesson and in science generally and making learning fun were paramount for half (n=5) of the participants:

> I don't have the choice in it, it is compulsory so my philosophy is to make it fun and as engaging and as relevant to their everyday life as possible. (Beth, 17 November 2006)

Teachers (n=8) considered it important that students should be curious and want to find out about their world and how it works. If the students are not curious about the science curriculum, they have to teach them to be curious. At least one teacher considered it the teacher's responsibility to present the lesson in such a way that it raised curiosity. Another teacher believed that the students should be able to apply their science learning and if they can do this they have learnt something about science. When asked if students were able to apply what they had learnt, the teacher looked despondent and added, "Reality is, few get to this point" then added, "but some do" (Beth).

Half the teachers (n=5) said that it was important for students to "do" practical work. Here is how Tanya puts it:

> I don't believe taking lots of notes is a good way to learn science. I did not learn through note taking and I try to do lots of practical work, investigations with my students. I think when students get to do lots they are motivated to do the harder stuff. (Tanya, 17 November 2006)

The teacher used practical work and investigation as meaning the same thing. Lillian saw value in teaching the history of science, and learning about the nature of science, and said she often challenged her students to think about how historical and political events have led to scientific discoveries. An aspect common to all respondents was that they were passionate about their beliefs about teaching, and their comments about their practice of teaching science reflected their philosophy.

Highlights of teaching during the year

Teachers were asked what they thought were the highlights of their teaching for that year. Teaching the accelerated learning class was the highlight for two teachers but the reasons were quite different for each. One said because it allowed her to "go a bit wider, take the children on fieldtrips because they were nice" (Stella). The other more experienced teacher said that "being a very able class, the students challenged him to question his own thinking" (Mike, 10 November 2006).

Beth said the highlight of the year was to turn a very difficult year 9 class around and have them participating and working for her when other teachers were struggling with this class. Tony was having a difficult year and said that he had spent most of his energy in just trying to balance all that he had to do within the allocated time. He said he could not think of anything that he would consider as a highlight. Len was feeling comfortable with what he had taught in his year 12 physics class and said "seeing them enjoy their learning" was the highlight for him. Mandy was excited about her year 11 class enjoying their learning, asking questions and others keen to answer them which she said was the highlight for her. The highlight for Keith and Tanya had been their electronics classes for quite different reasons. For Keith:

> Seeing the students making electronic devices and the excitement and pleasure that they get from applying all that they have learnt into something that works, for example, the last unit standard that they did was to build a stereo amplifier and the eyes were lighting up when the music was coming out and they knew that they had done it. (Keith, 6 November 2006)

Tanya said that she had worked hard with her "low ability" class that had literacy and numeracy issues but she felt she had been able to get the students to enjoy their science learning. Sandra who started at this school at the start of the year, said the highlight was that the students had settled down and she was able to manage them and the teaching.

6.3.2 Teachers' views about teaching and learning of science investigation

Teachers were asked their views about student progress in science, their teaching and student learning of science investigation as well as their goals for learning from this.

Student progress in learning science during the year

Teachers (n=7) talked about progress in science learning in their classes either in terms of assessment or students engaging in the learning. Two teachers said that being able to manage difficult classes so that they could learn was an indicator of progress. Teachers (n=5) talked about students being able to answer questions at the Achieved level and improving and writing at Merit and Excellence levels demonstrated their progress. For example:

> Their questions became less at the Achieved level. They were more thinking and explaining why things had happened for the units that we did at the beginning, because you had a lot more time to go over them. Because you did the exams in the beginning of October and we had a lot of revision time, you could see that they were starting to answer Merit and Excellence (level answers). (Stella, 9 November 2006)

Beth said she managed to convince all her students that they could get an Achieved grade and taught those who wanted to do better how to write Merit and Excellence level answers. Her concern was that they were not emphasising how to get a Merit or Excellence grade to their students in year 10.

> I think with year 10, and I need to be a bit more careful, we don't stress the importance of the differences between discuss and explain and such like, whereas at year 11 we start stressing it an awful lot. So, I think I would be really hammering that into the kids this year. (Beth, 17 November 2006)

Mike and Tony attributed the slower progress of their students (end of topic common test results compared to other classes) to either the students being less capable or not taking an interest in what was happening in class (Mike said his class was a low ability class. The classes are not streamed and the school already has an 'alternative science class' for those who are unable to manage a full year 11 science course). Tony's class was a mixed ability class like all other year 11 classes. Mandy thought her classes had gained knowledge and had enjoyed the new learning. Tanya also said that she had turned around a class that she had taken over from another teacher. In her view, students were now motivated and learning. Tony was disappointed and felt that his students did not want to learn and just wanted to know the 'right' answer. Len said that the test results showed that his classes had made some progress but he was not satisfied with it. He attributed less than optimum progress to having to cover a lot of material over a short period of time.

Keith thought that those who wanted to learn were progressing. However, he had a theory for the lack of progress of a large number of his students.

> It's an attitude thing that has appeared, particularly in the last ten years. I have noticed it coming into teaching, in students who are of lower socio-economic backgrounds. Often those also who have been raised in very religious backgrounds or sort of environment, where it either happens or it doesn't. (Keith, 6 November 2006)

Keith was the only teacher who linked the unsatisfactory progress of his class to his students' background.

It can be said that most teachers interviewed saw progress in terms of improved National Certificate of Educational Achievement grades. Six teachers thought their students had made progress and four thought it had been less than what they would have liked. For a few teachers, being able to manage difficult students and get them focused on learning meant that the class had improved.

The role of science investigation in science learning and teaching

Science investigation was seen by most teachers as children 'doing' science to find out, see theory proven "so they can believe it", learning skills and applying them in new contexts, and in students' everyday lives (n=9). More specifically, Beth thought it was a logical process that could be applied beyond the science classroom. She also said she made sure that students thought about the reliability of their results.

Lillian said that there was a place for science investigation, and that investigation should be done as a way of testing the theory learnt. She emphasised the need to teach students to investigate, she modelled the process in her teaching and then extended their investigation by getting them to apply what they had learnt.

> We did magnesium and acid, magnesium and water, magnesium and oxygen. It took two periods. And they looked at all of those and by the end of two periods they could tell me all of the information for anything. They could tell me what they were going to make (the product of the reaction). And then I said well okay if magnesium does this, what do you think copper will do? And then I said here you've got four metals. You go and decide which one is the most reactive, which one is the next and so on. And that was their brief – go and sort them out, I'll be helping you do it. So I'd given them some information, I'd said okay go and work it out. And I think that's how investigations have to be used rather than, finding things in the dark. (Lillian, 6 November 2006)

Students start from knowing the process as it has been modelled for them, and then they find out. Lilian saw this modelling as crucial to teaching students to investigate. In Mike's opinion, investigation is what science is all about. Tony said he would like to do more investigations but found it a real challenge to get his students to take anything seriously. Tanya, Mandy, and Sandra believed that learning to do science was really important and was the way all science should be taught.

Science teachers' goals for student learning through science investigation

When talking about the goals for student learning through investigation, all teachers (n=10) focused on the fair testing type of investigation that is assessed in AS1.1. Although most talked about the importance of learning skills, four saw teaching students the vocabulary for them to do well in the internal assessment as a key goal. Two teachers believed that this should be done before year 11. Stella said:

> Start the children off in year 9. Teach them the vocabulary used as far back as that. Knowing that they need to back up their results with evidence and then discuss them. (Stella, 9 November 2006)

Beth said she was concerned about the fair testing type of investigation she was teaching and was dissatisfied with doing investigation that did not lead to new learning. She did more investigation in chemistry than other content areas, but said she was not sure what students learnt from it. Her explanation was that she was getting the students to do investigations that had such obvious answers that she could not expect students to want to do them. She talked about "Excellence kids" getting involved in them. When probed about this statement she explained that for those students they could see beyond the obvious results and could think about the energy changes involved in a car rolling down a ramp, and demonstrate the conceptual understanding beyond the fact that as you increase the slope of the ramp the car will travel further:

> I don't feel I do a very good job with investigations at year 11….Chemistry we do a lot of investigations, like the antacid investigation, acids and bases and all that kind of stuff. What do they learn from it? …A lot of the stuff I think they already know so I'm not too sure that they're actually learning anything. Like our AS1.1 this year was raising the height of the ramp and I mean they knew what was going to happen anyway. And further… It is only the Excellence kids who delve into it. (Beth, 17 November 2006)

Some teachers (n=4) talked about how learning the scientific method, learning how to carry out a fair test type of investigation, students could see theory being applied. Len's response covered aspects of investigation:

> Science is fun and by doing they learn about gathering data. They can have fun, carry out the investigation, collect data and be able to talk about it, about what they have gathered. And from that use the principles of science to help explain a little bit clearer. (Len, 10 November 2006)

Overall, the goal was to teach a 'fair testing type of investigation' and learning skills, and there was a concern that students were doing investigation for which they already knew the answer.

Teachers' views about students learning through doing science investigation

Teachers (n=10) said that students learn the process skills of planning, gathering information, processing and interpreting information, and reporting it, which are those identified in the assessment guide for AS1.1. They said that students need to learn these skills and also know what they will need to do for assessment. Teachers (n=6) said they teach students the vocabulary they need to use for the assessed investigation. Four teachers mentioned teaching what students need to write to get an Achieved, Merit, or Excellence grade. Two teachers said they wanted the students to know that science is real and that we investigate all the time. Lillian thought that her students were learning to go 'through the hoops' and were 'being trained' to do this kind of investigation:

> Mostly you can train anybody to do it. It's orders. It's a training exercise. This is what you need. Write this, write this, write that. There's your Excellence. It's kids jumping through hoops, and okay it gets them five credits or four credits. Lovely, they pass everyone. That's great, but I'm not entirely sure that you've taught them a lot of anything. (Lillian, 6 November 2006)

None of the teachers were satisfied with the process followed for the assessment of AS1.1 (following the requirement of fair testing, controlling variables and following steps to get to an answer already known). Their reasons were different but each expressed a genuine concern for their students and that was obvious during the interview. They were despondent, upset, not impressed, uneasy, questioned the fairness, and pragmatic saying “this assessment had to be done” (Mandy, 14 November 2006).

6.3.3 Teachers’ views about assessment

In this section results of questions on teachers’ views about assessment in general, formative assessment, and science investigation for AS1.1 were explored.

Teachers’ approach to assessment

Teachers (n=10) said that “formal” assessment should come after learning. Teachers (n=8) gave examples of ways in which they used classroom informal assessment to support learning. Mike talked about casual assessment:

> There is casual assessment, you’ve got formal assessment. Formal assessment I think has a place but it should not be the end focus. And I think for the NCEA, I have an idea that in the minds of a number of staff both in science and in other areas the assessment is the end goal. (Mike, 10 November 2006).

Mike said his views about assessment were different to those of the other teachers. His response showed that by ‘casual assessment’ he meant informal formative assessment but in his view his colleagues both in science and in other subjects were focussing on summative assessment. At the time of the interview he was dealing with all teachers in the school with all issues related to the National Certificate of Educational Achievement. However, other teachers’ responses showed that they also did formative assessment which is often a formal assessment as a trial run or mock examination. Mandy talked about giving feedback to students and going over the test with her class so that her students knew how to improve their performance, for example from Achieved to a Merit or better. And Keith saw assessment as:

> [being] for a number of reasons, one is to help the students, so that they go away and learn something and can recall it and reuse it. For me it is to determine how much they do know and what they need to be taught to satisfy the requirements of the course structure and NCEA. (Keith, 6 November 2006)

His response indicated that he was talking about both diagnostic assessment to find out what his students knew to inform his planning and teaching, as well as fulfilling the requirements of the National Certificate of Educational Achievement and preparing his students for summative assessment (AS1.1).

Although the teachers wanted to use assessment to improve learning, it seemed in most cases it was to improve their students’ achievement grade. Keith was the only teacher in the study who mentioned diagnostic assessment.

Assessment of AS1.1 in 2006 including formative assessment

All teachers taught students to investigate following the requirements for AS1.1. All teachers gave students the opportunity to do at least one formative assessment (trial run), which was the department's policy and was very similar to the task students were going to be assessed on. They also provided feedback to the students. Len said he got his students to roll a marble down a slope onto various surfaces. This was very similar to the task "Watch that car go" used for AS1.1. He explained in detail, first teaching them why things would roll downwards, energy changes that take place in the process, how the texture of the surface affects the distance the marble would travel, and the effect of changing the slope on how far the marble would travel. In spite of this, he felt he had to give his students a lot of help when they did planning for AS1.1.

During the interview, teachers (n=7) said they felt uneasy about the task for formative assessment being very similar to the actual assessment. The following quote exemplifies this:

> We usually do something that reasonably parallels, especially at year 11, what we would be using in the summative. A number of the students that we have, have a great deal of difficulty translating material from one area to another unless they are very, very close. There is always the potential of looking at it and maybe making the comment are you doing essentially a repeat of what you've done before? And at year 11 with what we are doing at year 9 and 10 hopefully we can move away from that in the future, but currently that's where we tend to sit. (Mike, 10 November 2006)

Mike explained that if the task for formative assessment was to investigate how far a marble would travel on various surfaces (wooden floor, carpet, grass etc.) and then for AS1.1 students had to investigate the effect of altering the height of the ramp on the distance travelled by a toy car, in his experience, most students in his class could not do this without a lot of help from the teacher. According to him, the current situation was that he was giving the students "too much help" for AS1.1. However, his view was that now as they are using the format required for AS1.1 in years 9 and 10 (a simplified AS1.1 template), it would change the practice of having to teach to the AS1.1 assessment.

Change in practice of teaching science investigation since the introduction of the National Certificate of Educational Achievement

Only half of the teachers interviewed had taught before the introduction of the National Certificate of Educational Achievement and so only those teachers could comment on this aspect, and all five said that their practice had changed. For one of them, it had become a matter of teaching students to use the 'template' for the assessment of AS1.1. Mandy prepared students to write their answers in the right place in the template. Mike taught it so that the learning tasks were almost identical to the assessed task. This approach is beyond providing feedback during formative assessment. Len had only taught for one year before the introduction of the National Certificate of Educational Achievement. It was his first year in teaching and he could only remember that his HoD was very well organised and gave him support. Keith said that in the past he taught students to investigate in different ways, to explore, make observations only, and write up the investigation. At the time of the interview he followed the procedure required for assessment. He was also concerned that with large classes and the assessment taking place in one go he was not able to assess individual skills. Other than the AS1.1 grades, he was not sure that he could tell which students knew what skills. This he said he could do before the National Certificate of Educational Achievement.

Stella reported that she now emphasises the structure and how to write up investigation. She also said “I guess where we used to probably rush through a few practicals; personally I’ve tried to put it in the National Certificate of Educational Achievement style so they’d have a lot more practice on it”. She did fewer practicals before the National Certificate of Educational Achievement and at the time of the interview did the types that were assessed. Lillian said that “maybe the way I view investigation and the way NZQA view the investigation don’t necessarily align”. When asked to explain what she meant, Lillian said that she would like to do open-ended investigation because that would challenge the students to think and added that “the requirement to do and write in a particular way is leading to the template approach in writing up the investigation”.

Issues in assessing, implementing, and administering AS1.1

All teachers responded to this question. Assessment of AS1.1 was carried out over three days. The task used was “Watch that car go” (TKI, 2005, Appendix 20). The assessment aspect was covered by the teachers in different parts of the interview. Most teachers saw the administration part as easy to set up in the hall. As the task did not involve consumable items, once the stations were set up, the gear only required tidying up after each class. The process was quick and efficient. However, teachers (n=7) were concerned about issues of reliability as the students who were gathering the data for AS1.1 were doing so in full view of another class doing a ‘mock’ external examination. The mock examination was a one-hour examination that assessed the external achievement standards in practice for the formal assessment at the end of the year. Unlike AS1.1, which contributed to their final result, the grades of this mock examination did not contribute to their final results for the year:

> Yeah it was hard to treat it as a form of assessment because the kids can easily see what the others …they picked that up from others …and you can tell in the papers. They wrote down what they think they will be doing and after seeing others crossed out what they planned and changed the plan and did the investigations differently. (Len, 10 November 2006)

Another concern was that of the subject context in which the assessment was carried out. The teachers had taught students how to investigate when they were teaching in the same subject as the one they would be assessed in, in this case physics. But when it came to assessment, more than half the teachers (n=7) were teaching either a chemistry or biology topic. They said that their students were disadvantaged because the assessment was out of context. Three of these teachers said that they decided to go back and revisit the 'physics assessment task' in the week prior to AS1.1:

> I was teaching chemistry at this point but this college runs AS1.1 in the exam week, so I was teaching chemistry and somebody else is teaching physics and somebody else is teaching biology and the context of the assessment is a physics one. We are assessing out of context. It is not fair to my students. (Keith, 6 November 2006)

There were also supervision issues related to being in a very large space with more than one class. Beth felt uncomfortable about supervision. She said she saw a student talking with another during the exam. However, the student said he was just borrowing a ruler.

The assessment for AS1.1 took place in three chunks as three tasks. These were planning, data gathering and processing, interpreting and writing the report. The planning task was carried out in the class. For this, some teachers (n=7) gave students one hour and a few two hours (n=2). Two had equipment available in the class so the students could try out what they would like to investigate. Other teachers did not give this opportunity to their students but had carried out a formative assessment very similar to the assessed one with their classes. The second task was carried out in the hall. For most classes this was more than three days after they had done the planning and in a week where they were doing other mock examinations. The third and final task took place in their science class in the week following the mock examinations:

> (It is) Not always possible to gather data that I can put my hand on my heart and say is collected in a valid way. That said, we are really assessing them on their …ability to make sense of the data. At least that is how I sort out the "Achieved", Merit and Excellence students. (Mike, 10 November 2006)

Sandra, Stella, Tony, and Mandy had similar issues about the reliability and AS1.1 not being assessed as one assessment but in three tasks. They did not have any suggestions as to how the situation could be improved. Tony found that students did not have the same concerns as he did. He said that his students were only interested in credits and would have done the task if it meant credits.

Commenting on the task selected for assessment, Lillian considered the task manageable with large groups of students and several classes to be assessed. She also said that in addition to the assessment for year 11 during the examination week, the technician had to prepare resources for the assessment of investigation for years 12 and 13 physics, chemistry, and biology. Using “Watch that car go” did not require support from the technician once it had been set up in the hall.

All teachers said they were comfortable with the processes in place for marking and moderation of the assessed task. Len said it was very useful to get another teacher to check the grade “especially if it was a border line grade between Not Achieved and Achieved and Merit or Excellence”.

Change in the practice of doing science investigation after AS1.1

All teachers said that once the assessment was over they did not give the investigation the same amount of time (investigation as required for AS1.1 took three lessons to complete). Teachers (n=8) said they got students to investigate and just write the plan and results. Others (n=2) said that they still insisted on fair testing and looking at the reliability of the data. Two teachers said that once the assessment was done, students were just not interested in doing practical work so they put the time into preparing for the examination:

> To be perfectly honest we lead up a lot to that and then after that I’m still very insistent on reliability and fair testing, but things kind of start to flag a bit after that. (Beth, 17 November 2006)

All teachers still did investigations but were not so particular about the follow-up writing. Some were also continuing to do investigation where they may ask the students to do the planning of an investigation or, as Sandra said, do a POE (Predict, Observe, and Explain) type of investigation using models and doing demonstrations. As is reported in the following chapter, the study class teacher continued to do investigation after AS1.1. It was clear that teachers conducted limited forms of investigation after the formal assessment was carried out.

Relationship between student learning and assessment of science investigation for AS1.1

Teachers were asked how they thought science assessment through AS1.1 related to students' learning of science investigation. Teachers (n=9) had concerns about the reliability of the assessment. They were concerned that students could see the task being performed by the other class. Stella's concern was that students could see what others were doing and some made changes to their 'plan'. There was also concern that in preparing for assessment they were teaching to the examination (AS1.1 assessment). Beth felt very uncomfortable in doing so:

> I don't know if it's the same for all teachers for NCEA level 1 – teaching to the exam – that's basically all we have time for. I know we're not supposed to do that, but with the amount of time we've got I feel like I am teaching to the exam. (Beth, 17 November 2006)

Len's concern was that the way the National Certificate of Educational Achievement assessment was set up there were few opportunities for students to achieve an Excellence grade. This was because only a few questions allowed for a Merit or Excellence level answer and if the students did not get that right, all they could get was an Achieved grade. He thought that was not fair and was demotivating. Tanya was critical of the entire process of teaching and assessing science investigation as required by the National Certificate of Educational Achievement:

> I think the current focus of assessments on investigations is pedantic and I don't think it assesses understanding….I have seen it put many kids off science because it just takes all the fun out of science. You know those worksheets you have got to fill out, "how did you measure this" I measured the length with a ruler in millimetres ... My outcome from an investigation like that would be to have a good graph of results and if I have got length in millimetres in the graph, I'm not going to care if the kids write it down in the right box on the right page. (Tanya, 17 November 2006)

Lillian was concerned about the process and what the students had to learn to be assessed. However, she had a pragmatic approach to it all. She believed that in her school, given the number of classes, the process was the best way forward.

> The only way one can ensure that students do not look at each other and change their mind about how they will collect the data is to put them one at a time in a separate room. We both know that is not possible. So we do the best we can under the circumstances. (Lillian, 6 November 2006)

The teachers' responses indicated that some were not thinking about students learning to investigate and as far as the relationship between learning and assessment of investigation went they felt they had to teach the students the investigation that would be assessed. They said they did not like the focus of their own teaching and student learning of investigation being on assessment rather than on learning. Teachers questioned the amount of help they were giving to the students and were also concerned about the reliability of the results.

6.3.4 Teachers' views about learning science investigation and student motivation

Questions in this section were to elicit teachers' views about the link between students' motivation to learn and their learning to investigate.

Students' experiences of science investigation and their motivation to learn

Teachers were asked about the effect of internal assessment of science investigation on students' motivation to learn science.

Teachers identified two main aspects that motivated students to do science investigation: one that it was worth National Certificate of Educational Achievement credits and grades; and the other that 'doing' practical work was motivational. According to teachers (n=8), the National Certificate of Educational Achievement credits and grades seemed the main reason that motivated most students to investigate:

> In some small way the kids value the learning because it matters in terms of tangible credits. (Mike, 10 November 2006)

Teachers (n=8) talked about practical work being motivational. Stella commented that she did not see that she was motivating students but this does not mean that practical work was not motivational. In her opinion, children who came from homes that had a background in science were motivated. She also noted that in the accelerated learning class students were engaged and motivated because of high expectations from home. Beth was not sure that investigating motivated the students. They may participate, be interested in it at the time, but not be motivated to learn from the experience:

> I don't think it has any impact. I don't think it increases their motivation. They like doing practical stuff, they like hands-on stuff, so for example when I did the formative all their things were outside (equipment needed was set out for the students), they liked that. But I don't know if that motivated them. (Beth, 17 November 2006)

According to Lillian, four aspects of an investigation could be motivational. These were "credits", "being in control of the investigation", "knowing what they are being asked to do", and "encouragement and praise". She also added that AS1.1 did not give them control and said that an element of competition helped:

> I say to my class it doesn't matter how good you write something, I will find a hole in it. So before you bring it to me, find the hole. And they will do that. It then becomes a bit of a competition for them. (Lillian, 6 November 2006)

There were other aspects of investigation that according to some teachers were motivational. Tony and Len found that teaching in a context that appealed to the boys – toy cars – was useful. However, Tony was despondent about his class and said that for the "good students their motivation is still there because they enjoy the hands-on stuff and learn from it but I don't want to be negative but most are not motivated in my class."

Keith commented that year 12 and 13 investigation motivated students. (Investigations in year 12 and particularly in year 13 are more open-ended. Students have some choice about what they want to investigate.) Sandra noted that her students were more engaged in the task when doing an investigation. The teachers talked about the motivational aspects in relation to AS1.1 and, although not asked, most talked about their own ability to motivate students with varying degrees of success.

Effect of completion of AS1.1 on students' motivation to learn

Two teachers talked about the effect of having either Achieved the credits or Not Achieved on students' motivation after AS1.1. Len said there were some students who could not be bothered but most were motivated to do practical work:

> I think the majority of the class, I think about 80% of the class is still into it, and there are some, ones who say oh I've got the credits why bother. (Len, 10 November 2006)

Keith commented on the effect of not achieving in AS1.1. He was the only teacher who commented about those who did not achieve the standard:

> If they succeeded in it, it was quite a boost to them. They felt good and they strived and maybe it was not as bad as they thought. If they didn't achieve it, it had a negative effect on them in my opinion and for a few people it could totally undo them. (Keith, 6 November 2006)

Not answering the question about the effect that the completion of internal assessment had on student motivation, Mandy said that her students were highly motivated when they receive feedback on their formative internal assessment task. They paid attention and worked on what they had to do to change it into a Merit or Excellence grade. Keith was not sure if the internal assessment had any impact on students' motivation to learn:

> I am not really sure actually, I'm not sure if all the kids would particularly do science so that they could do the investigation. (Keith, 6 November 2006)

A few felt uncomfortable in saying that they actually did not have a lot of time to do investigation after the assessment. Four teachers linked student motivation to learn after AS1.1 to a change in their own teaching approach. One said that after AS1.1 was over she emphasised the learning and preparation for the external assessment (Sandra, 9 November 2006). Another said that she continued to do some practical work as the topic required it and she knew that "…it motivates the students and gives them a break from the written work" (Beth). Mike said that there was so much of the course still left to cover after AS1.1 that it was difficult to keep doing AS1.1 types of investigation but he too said that he gave the students some time to do practical work and made sure that "they were thinking about the theory it relates to". When probed further, he said that he had recently asked his students to test various types of rocks to see if they had limestone. He said "they need to remember that fizzing happens because it is an acid and carbonate reaction". He added that the students "enjoyed the practical after learning a whole lot about rocks". Stella said she used it as a "carrot" to get them to do other work. Lillian allowed students to try out investigations. She said they liked to choose what they wanted to find out and within reason she allowed this to happen.

Student enjoyment of investigation

In response to this question teachers (n=7) talked about not just the internally assessed investigation but practical work in general and said that their students enjoyed investigating. Mike was unsure if the students enjoyed doing investigation or just playing:

> There are those that enjoy doing the practical and enjoy getting a positive outcome. There are those that simply enjoy playing. So whether it is heightened after doing a formalised assessment like 1.1 I'd be guessing. (Mike, 10 November 2006)

Tony believed that students may be motivated to investigate so that they did not have to do written work. Len was disappointed that his students only worked to achieve the credits. Mandy's students were keen to do practical work and although she found it annoying that they were always asking about it she believed they learnt science through doing it.

Students' achievement goals for AS1.1

Teachers (n=8) said that in all classes there were students who just wanted to gain Achieved but there were also students in each class that wanted to get a Merit or Excellence grade. The less able or average student just wanted the credits but there were more able students in most classes who worked hard to get a Merit or Excellence:

> There's definitely both. I've got some kids here, I've got a kid who came for a tutorial yesterday, she gets Merits easily but she's still coming to tutorials because she wants Excellence, and she's not a minority. (Beth, 17 November 2006)

Teachers were supportive of students who wanted to get a Merit or Excellence grade.

Changes to teaching of science investigation in the future

Teachers were asked what change they might make to their teaching of science investigation in the future. Even though this was the last question and at the end of nearly an hour-long interview, most teachers took time to think before responding. Some of the ideas were getting students to investigate using the AS1.1 template from year 9. Stella thought this would enable students to 'breeze' through in year 11. Beth wanted to get her students to work on their graphing skills. She was not sure what the school's policy was regarding formative assessment and how much help teachers should give their students:

> I think the formative assessment I did was too close to the actual assessment but I know some other teachers were doing other ones which were even closer, and to me I don't know, it's a hard call because you want your kids to succeed. But I think that formative assessments should be quite a different thing. You don't want to be discussing the same concepts necessarily and such like. So that bugs me and I would like to change that, whether I will or not depends because I think that probably needs to be a school policy actually as to how close …because I know some were having apparently particular ramps made with rulers and they were actually moving the marble from here. To me that was way too similar. But yeah, I don't know. It bugs me. (Beth, 17 November 2006)

For Lillian it was an issue of time. She thought that there was too much content in year 11. When asked if the National Certificate of Educational Achievement allowed the flexibility to reduce the number of standards that they assessed in year 11, her response was:

> If we drop a standard are we doing our kids an injustice by teaching them less? And given that they're still going to be assessed by the same bit of paper. Okay we've got that side of the coin, we've got the other side of the coin, can we create some time while we get kids to do more work in their home time? (Lillian, 6 November 2006)

Setting more homework would be a possible way of managing the content and getting some more time to do investigation. However, Lillian thought this required a change in policy at school level and she could not see that happening in the near future. Mike said he was always looking at how other people in the department managed and did things and that he was always willing to take on board what was working for others. Although Tony had found it a difficult year, he was still thinking of things he would like to improve:

> I know I should do more practice ones and that is something I will try in future. I even think getting them used to it in junior science will also help. (Tony, 14 November 2006)

For Sandra, Tanya, and Len, putting more effort into teaching the 'terminology used for assessment' was a priority. They also thought they would continue to emphasise what the students were expected to write for a Merit or Excellence answer.

6.3.5 Summary of science teacher interviews

Teachers' philosophical beliefs included the importance of following the curriculum, encouraging the students to ask questions and challenging them to think critically. They believed that making learning of science fun was important. Most considered it important that children should be curious and want to find out about their world and how it worked. Half the teachers considered that it was important for students to do practical work.

Half of the participants considered student progress in relation to assessment and progressing from Achieved to Merit grades. Most teachers considered the role of science investigation as doing science to see theory proven and applying skills to new context in everyday life. Teachers' goals for student learning through investigation were focused on the fair testing type of investigation as assessed by AS1.1 and they all said that students needed to learn the skills of planning, gathering information, processing and interpreting information, and reporting. Additionally, students needed to know the vocabulary and the process of assessment.

All teachers provided opportunities for the students to learn to investigate and do formative assessment, and provided feedback to the students. They taught what an Achieved, Merit, and Excellence answer should look like. Although they did not like doing so, they were teaching to the assessment and sometimes the formative task used was identical to the summative. Although uncomfortable with this practice, they justified it by saying they also did not want their own students to be disadvantaged.

Half the teachers had taught before the National Certificate of Educational Achievement was introduced and reported that their practice of teaching science investigation had changed. This change included use of a template, use of a learning task that was identical to the assessment task, and using the process followed for AS1.1.

Assessment of AS1.1 was carried out over three days with the data collection phase done in the school hall. This process was quick and efficient but teachers were concerned about its reliability as the students gathering data were doing so in full view of other classes not involved in data collection. For half of the classes, assessment was done out of the normal learning context as they were then involved in topics other than that of the assessment task. The organisation of AS1.1 had to consider the resources required, the large number of classes and technician time needed. All teachers were satisfied with the marking and moderation processes followed. Once AS1.1 was over, most teachers did not give the same amount of time to investigation and when they did, they did not require students to write up a full investigation.

Most teachers considered practical work to be motivational. However, most teachers thought the National Certificate of Educational Achievement credits and grades were the prime motivational factor for students to investigate. Teachers said that they did not do as much practical work (activities or investigation) after AS1.1. According to the teachers in all classes, there were students who just wanted to achieve but also students who wanted to get a Merit or Excellence grade. Teachers suggested ways in which they would change their practice in the future. This would include using the template for AS1.1 from year 9, practising processing skills, setting homework to allow more time to do investigation in class, and teaching the terminology needed for assessment.

It can be said that in the perception of the teachers interviewed, the internal assessment of science investigation was the most influential factor in the teaching and learning of science investigation in this school. And it was the ‘doing of science’, and the gaining of credits, and grades that motivated their year 11 students to learn science.

6.4 Summary

The case study school was a medium size, medium decile, state coeducational school. The school valued science and encouraged student participation in out-of-school science events including science fairs, science competitions, and visits to the university organised activities.

The science department was large, offered 11 year 11 science classes and a range of other science courses, for example, human biology in year 11 and traditional science subjects in years 12 and 13. It was a highly organised department with HoDs for physics, chemistry, biology, and a teacher in-charge of year 11 science who was also responsible for organising AS1.1. The assistant HoD was responsible for junior science. The department had a well-organised management document that included unit plans for all topics for all courses at each level. Almost all teachers had their own laboratories, well stocked resources, and science technician support that showed practical work was valued.

All science teachers were well qualified to teach science. All keen, they had lesson plans, and cared about their teaching. All teachers were concerned about following the curriculum and prepared students as well as possible for assessment but had doubts about the ethics of preparation for AS1.1. Teachers had traditional beliefs about the motivational value of practical work.

Although science was valued and there was belief in practical work and support for teaching investigation, there were concerns too. Some topics in year 11 were repeats of year 10. The process for assessment of investigation was long and fragmented, taking over three lessons. There was too much training for assessment and the assessment process was unreliable.

CHAPTER SEVEN

Class Case Study

This chapter presents the results of the class case study of science investigation in year 11. Data were collected from multiple sources including the year 11 science teacher and students, and documents. Data were gathered by science teacher interviews, teacher reflection, several student surveys, student focus group interviews, conversations with the students, classroom observations, and the school data base. Detailed information about access to the school, the study class, and the development of instruments is described in Chapter four. Results contribute towards answering the research questions from the study class teacher's perspective, students' perspectives and researcher's interpretation.

The results of one year 11 science class are reported chronologically by school term in 2006 as follows:

- School term 1 (Teaching and learning of investigation)
- School term 2 (Assessment of investigation)
- School terms 3 and 4 (Teaching and learning for the rest of the year).

7.1 School Term 1 – Teaching and Learning of Investigation

Term 1 began on 7 February 2006 after a six-week summer break. The study class teacher invited the researcher to attend the introductory lesson but formal weekly observations began on 16 March 2006 after all consent forms had been received. Twenty-four out of 31 students participated in the study. Teacher reflections were taped and the first formal interview with the teacher took place on 7 February 2006. The first focus group interview was held on 13 April 2006. The school term ended on 14 April 2006 for Easter holidays.

7.1.1 Observations, running records and teacher reflections

The researcher visited the class every Thursday as this was the day the teacher specified as being the most likely day when the students did investigation. The study class teacher taught in a shared laboratory and carried materials needed for the lesson. Basic laboratory equipment was available in the laboratory and chemicals in the preparation room at the back. The laboratory was clean and attractive with student work and posters on the wall. The school's code (a list of school expectations of behaviour and work expected from all students) and a periodic table were prominently displayed as was a poster describing the levels of achievement for the National Certificate of Educational Achievement and what each level required for Achieved, Merit and Excellence grades with specific examples for science achievement standards. The students undertook practical work in nine groups of three and one group of four. Groups six and eight were not observed as they included students who were not participating in the research. Students worked in the same groups throughout the year.

Outline of lessons observed

In term 1 six lessons were observed, the first being the introductory lesson. The formally observed lessons are outlined. In the first formally observed lesson students investigated metals and metal reactions, the second lesson involved separating a mixture of chemicals. In the third lesson study class teacher returned a test the students had done earlier in the week; the fourth lesson was an exploration of energy changes and required the students to plan an investigation. The final observed lesson was a "complete investigation" carried out in one lesson. An observation schedule was used, a completed sample classroom observation and running record is included (Appendix 21). The study class teacher was asked to audio-tape her/his reflection at the end of each lesson. These reflections were transcribed and checked by study class teacher for accuracy.

The introductory lesson was on 9 February 2006. The study class teacher invited the students into the laboratory and introduced the researcher to the class. They appeared to be a lively class. Students were seated alphabetically and were attentive for the first half of the lesson doing a ten question general science quiz and then going through the answers. The teacher emphasised the importance of the year in terms of National Certificate of Educational Achievement assessments. She/he talked about her/his expectations of behaviour, standard of work and rules about homework. This was followed by an exercise reminding the class about safety requirements in the laboratory. The lesson ended in an orderly manner.

In the first formally observed lesson on 16 March 2006, students carried out an investigation. The task was to investigate the reactivity of different metals. It involved investigating the reaction of magnesium, zinc, copper, and iron with oxygen, water, and dilute acid. Students worked in groups of three and sat at long tables. They followed the method set out in the workbook to carry out the investigation (Abbott et al., 2005). The materials required were collected by one member of each group from the teacher. Students were not required to plan the investigation; they followed the task set out in the workbook.

Half of the class was interested and got on with the investigation but others did not:

> Even though it was a practical lesson and students had the opportunity to investigate, half the class was not engaged for most of the time and three students sitting next to me did not do any work for the entire lesson. (Observation notes, 16 March 2006)

The three students that sat next to the researcher were kept in at the end of the lesson and spoken to by the teacher:

> Teacher: You are behaving like year 9 students. The quality of your diagrams is not very good. When it comes to exams no-one will look at squiggly diagrams. Twice you have used offensive language. Will you get NCEA?
>
> Ken: I will try. (Observation notes, 16 March 2006)

When the lesson concluded most students had not completed the set task.

In the following lesson (23 March 2006) students carried out a practical activity that required them to separate a mixture of chemicals. The lesson started with a quiz of ten questions which included names and formulae of common chemical compounds. Students were attentive and engaged in the task. This was followed by individual students planning an investigation to separate the mixture provided. Students were to make copper salt crystals from copper oxide using an acid. The task was not out of the workbook this time. Through questioning, the class worked out the process for this investigation. The students then carried out the investigation.

> Even though a third of the class were away on a fieldtrip for another subject, student engagement in the activity was low. At times almost the whole class was off task. (Observation notes, 23 March 2006)

In the third formally observed lesson (30 March 2006) the teacher returned a test which was done earlier in the week and provided feedback:

> They did not perform well at all, 26 students sat the test, 19 Not Achieved, seven Achieved, which is really shocking. So the lesson began with going over the test, handing them out, going over them, after I had given a bit of a lecture if you like, following the poor performance. (Teacher reflection, 30 March 2006)

According to observation notes:

> As the lesson progressed the students became less and less attentive. By the end of the lesson, only students in the two groups at the front were still listening to the teacher. (Observation schedule, 30 March 2006)

The teacher's impression of the observed lesson three was:

> Towards the end there was some tendency for students to drift off task. A couple of boys at the back on the left, Harry and Henry certainly, and Jeff I should say, certainly weren't following their own work, they were probably not listening either, but apart from that most of them followed that activity through. (Teacher reflection, 30 March 2006)

When the observation and teacher reflection for this lesson were analysed, there was a mismatch between the teacher's and researcher's observation of student engagement, participation, behaviour, and learning. The reasons for this may be that the researcher's expectations of a year 11 science class, both in terms of learning and behaviour, were probably higher than that of the teacher. The other, more likely, reason could be that the researcher had her full attention on observing and recording and therefore noticed aspects that the teacher may not have because of the class management responsibility, distribution and setting up of equipment, managing safety issues, as well as focussing on teaching and learning.

In the next two observed lessons, four and five held on 6 and 13 April 2006, students did a practical activity and a science investigation respectively. The activity was an exploration of energy transformation and for science investigation students were to plan and calculate their power when running up a flight of stairs.

Selected practical activity: exploring energy changes

The fourth observed lesson was selected for an in-depth look for two reasons. Firstly, of the observed lessons in term 1, this practical had the highest level of student interest and engagement. Secondly, in the first half of the year this was the only practical activity that was identified by the teacher as an investigation and was not a fair testing type of investigation like the others that followed.

The teacher arrived early and set up 11 stations of energy transformation activities and put instructions at each station for students to follow. The task was one from the workbook. The teacher had photocopied pages from the workbook for those who did not bring their books to class. Students were to do the 11 activities that were set out around the laboratory and record their observations in a table in their workbook. They also had to identify the energy change that took place in each situation. The stations included a steady stream of water to turn a wheel, solar panels to convert light energy into electrical energy, a mouse trap to move a toy vehicle, and the use of wind from a hair dryer to move a ball.

The students listened to the instructions and chatted at the start of the lesson but once they started on the task they moved from one station/activity to the next. Of the eight groups of three students each, seven were engaged and on task throughout the lesson. These 21 students appeared interested, talked to each other and asked questions. In the last quarter of the lesson the teacher asked them to share their observations and conclusions with other members of their group. The eighth group had four students – Harry, Henry, Ken, and Jake – who did not have their books. Two of them made an effort to get a photocopied sheet from the teacher but did not do any activities. For the other students, the on-task chatter and the manner in which the students carried out the tasks demonstrated that they were interested in the activities:

> There was a buzz in the class as the students moved around and talked about what they were doing and learning. (Observation notes, 6 April 2006)

The following information about learning is from an audio-taped conversation with students while moving around the laboratory. When students were asked about their work they said:

> Pip: This is fun. I got to do the practical myself.
>
> Jessica: It is fun because we did not have to do just one thing for the whole hour. There were lots of different things we could do.
>
> Bob: Yeah there was variety.
>
> Simon: I can remember the science …. (the teacher) tells us when I can see it work before my eyes.
>
> Ed: We did not have to do heaps of writing, that's so boring. (Transcript for observed lesson, 6 April 2006)

Of the nine students asked, there were seven who were able to identify energy changes accurately. For example:

> Researcher: What is this activity about?
>
> Bob: The solar cells change light energy into electrical energy.
>
> Researcher: What have you learnt from doing these activities?
>
> Mili: I have learnt all sorts of energy changes like a mouse trap can change elastic potential energy into kinetic and sound.
>
> Jessica: Light bulbs change electrical energy into light and heat and heaters change electrical energy into mostly heat but some light. (Transcript for observed lesson, 6 April 2006)

Two students who were not engaged were asked as to why they had not done the activity and what they had learnt? One said "not much really", while the other, Ed, said:

> Ed: Because I already know the answers.
>
> Researcher: Can you tell me what energy changes are taking place when water is dropped on the wheel?

> Ed: Gravitational potential energy into kinetic energy, just like in the hydro dams. This is dumb, we did it in year 9. (Transcript for observed lesson, 6 April 2006)

An interesting aspect was that during the second focus group interview nearly six months later (14 September 2006) when talking about the investigations they had done during the year, students remembered this energy exploration practical as one they had enjoyed the most and were able to tell what they had learnt from it.

In the teacher's view:

> This investigation they all seem to like and get a lot out of every year. It is good to see the cogs ticking over as they think about the energy changes. (Teacher reflection 6 April, 2006)

This practical was not directly linked to assessment or preparation for assessment of science investigation. Students applied their observational skills to gather information and draw conclusions about the energy transformations taking place in each case.

Selected investigation: Body power

Body Power was the fifth lesson, and was the first investigation that the students learnt to carry out in this class and the only investigation carried out in term 1. The task was set out as in the National Certificate of Educational Achievement "template" in the workbook. It required the students to plan the investigation, gather, process and interpret primary data, and write a report.

This lesson started with playing "hangman" (a word game using science vocabulary in this case) until all students arrived. The students had to measure the amount of power they could develop climbing stairs. The class was asked to take out their workbook and look at identified pages. The teacher talked the students through the aim of the investigation, which variables needed to be controlled, and which they would change. Students collected the stop watches and went outside:

> Today when the class arrived they were very noisy and did not settle down. The teacher tried to give them instruction above their noise. The activity involved students going outside and running up and down the stairs. The teacher moved between the laboratory and outside. By the end of the lesson there wasn't enough time to go over their results. (Observation notes, 13 April 2006)

Students were required to plan the investigation and work out how they were going to gather the information. As soon as the teacher finished with the instructions the students left the class to work out how long it took them to run upstairs. Then they could use the information to calculate the work done and the power used. One student had taken the measuring tape so he could measure the height from the top of the stairs to the ground floor. It appeared that he shared this information with the other students. There was lots of excitement and noise. When some of the students came back it was observed that at least two groups had done several trials. Four groups had nothing written down, so there was no evidence of the data they had collected. By the time most students came back there was little time left for them to process the data and work out the results:

> One group of students had worked out who in their group had been able to run up the stairs fastest and declared that they had most power without doing any calculations. (Observation notes, 13 April 2006)

At the end of the lesson, the teacher was disappointed that the investigation did not go the way it was intended. This was evident in the following comment in the teacher reflection of the lesson:

> I thought that this planning task would be straightforward but getting the students to work out power was probably complicated. (Teacher reflection, 13 April 2006)

Considering that this was the first “complete” investigation that students carried out in the year, it was a big step up from the energy exploration in the previous week. Although the teacher took the class through the planning stage, it appeared that there were students who had prior knowledge of the investigative process and these were the students who decided they could do the investigation and ran outside to collect the data. They carried out multiple trials. The rest did not appear to understand the process and relied on the others to give them the information. At the end of the lesson the class did not have the time to complete the investigation. Most complete investigations, as required by the National Certificate of Educational Achievement, take three or four lessons. So there was insufficient time for a complete investigation. The other aspect that the students were required to do was to calculate power. For the limited time they had for learning about “work” and “power”, most in the class appeared not to have enough theoretical knowledge to be able to do so. This was reflected in the teacher’s comment above. According to notes from the review of student workbooks:

> In nine out of eleven workbooks handed in for marking Body Power investigation has not been completed. Two students Jessica and Bob have nearly completed the task but neither had done the calculations required. (11 May 2006)

The learning from this investigation was therefore limited.

Student engagement

Table 7.1 shows a summary of student engagement during each of the observed lessons in term 1. The data were collected on the observation schedule. In each quarter of the lesson, student engagement was recorded by counting the number of groups on task. This information was then compared with the running record to determine what was happening in the class at the time. An iterative process was used to check the accuracy of the recording. The number with a negative sign indicates the number of groups that were not engaged during that period.

Table 7.1: Student engagement in year 11 science class in Term 1

Student engagement in each quarter	**Student engagement in lessons 1-5**				
	1 **Investigating metals** 16 March	**2** **Separating mixtures** 23 March	**3** **Feedback on test** 30 March	**4** **Energy exploration** 6 April	**5** **Body power** 13 April
First ¼	All	Most	None	All	None
Second ¼	All	Less than half - 3 groups	Less than half	Most -1 group	Half class
Third ¼	Most - 2 groups	Most (During Practical)	Less than half 4 groups listening	All	All During practical
Fourth ¼	Most - 2 groups	Most	Less than half	Half	None

Note: No data are reported about groups 6 and 8 as these groups had students who did not participate in this research.

By the end of the term, based on the observations and records, it can be said that there were some students who were attentive and picked up what was needed by reading instructions or listening to the teacher. As the term progressed, students were less attentive at the start of the lesson and less than half were engaged in the last quarter of the lesson. Sometimes, their chatter made it difficult for the teacher to get the instructions across and some of the students at the back who did want to listen were not able to do so. It was evident the teacher tried hard to manage their behaviour and keep them moving forward. The following reflection describes the teacher's concerns:

> Even after keeping the class behind a couple of minutes, mainly because they had been too talkative earlier in the lesson, less than half of them would have actually calculated the power correctly, so never mind, we will revisit that next time … and the issue of Ken swearing out loud, I'm going to turf him out for the next week. (Teacher reflection, 13 April 2006)

There was inconsistency between the teacher saying that some students had calculated "power" correctly and the analysis of student workbooks which showed that none of the students had calculated it correctly. This could be because not all students handed in their workbooks for marking and the researcher did not see the workbooks of the students who were not participating in the research. The teacher's comments could be based on her/his observation of students not involved in the research.

The running record and observations showed that more students were on task and engaged when they were doing a practical activity or investigation, irrespective of when the practical was done in any lesson. A similar pattern emerged from the record of student enthusiasm during the lesson. Some students who sat in the front two rows were engaged in at least half of the lesson, and sometimes more.

7.1.2 First interview with the study class teacher

The first formal interview with the study class teacher took place on 7 February 2006 in the science department workroom, lasted 55 minutes and was audio-taped. During the interview the study class teacher was asked questions about her/his philosophical beliefs, what s/he thought a science investigation was, and in her/his perception what effect the introduction of the National Certificate of Educational Achievement has had on the teaching and learning of science in general and investigation in particular. The results of each interview were written after reading the transcripts several times and identifying the key messages for each response. An iterative process was used to check key messages against the responses. All effort was made not to lose the essence of each interview.

The teacher's philosophical beliefs about teaching science were:

> Encouraging children to be curious and to find out what the world around them is all about, how things work. Importance of making what we do at school as real as possible. Try and create a spark in the kids. The only way to do that, or one way to do that is to make sure that you connect them with reality as frequently as possible and to carry out a decent quantity of practical work. (Study class teacher interview, 7 February 2006)

In terms of teaching science investigation the teacher said that it was important to let the students think about how they would investigate given a particular scenario and added that students needed to be taught how to do this. The teacher explained:

> The ability to plan, to complete the fair test thoroughly, understanding of the variables and what they have to measure, what they have to keep fair, appropriate handling of the equipment so that they are doing their measuring accurately and safely and cooperating with each other it has to be said was a factor as well of course and then analysing the data on a straightforward interpretation level, plotting a graph without making too many blunders along the way, writing a conclusion which links what they have learnt with the science behind it and evaluating, we also ask them to evaluate, you know, what went wrong, what can we do next time and, I think that's probably about it. (Study class teacher interview, 7 February 2006)

The details offered by the teacher indicated that s/he wanted the students to be able to do what was required of them to do a fair testing type of investigation. The teacher in this instance said that students should be able to link the findings of their investigation with the science they have learnt and evaluate and explain the anomalies in their results. However, there was little evidence of this in the investigation that the students carried out in class. The teacher would have liked students to work cooperatively and said that the practice of teaching science investigation has not changed due to the introduction of the National Certificate of Educational Achievement but added that most teachers were probably doing more complete investigations. The teacher stated that in her/his school the students buy workbooks that have National Certificate of Educational Achievement type templates and activities so teachers did not have to come up with tasks, and students do not waste time writing out the method and can use time for thinking.

During the interview, the teacher described how s/he carried out formative assessment to gauge student learning formally and informally (going around the class). With her/his year 11 science class s/he did at least one written formative task before the summative assessment of science investigation. The teacher's view about the National Certificate of Educational Achievement was that Level 1 National Certificate of Educational Achievement was easier than the previous form of assessment for School Certificate Science. Students doing science were expected to get at least an Achieved, and further:

> The struggle is to get the children to set a higher goal for themselves. It's a battle to stop them thinking that it's OK to be mediocre. (Study class teacher interview, 7 February 2006)

The teacher did not think that the internal assessment of science investigation had changed the way teachers taught students to investigate, but added:

> On balance it probably has increased the coverage of investigations by teachers overall, I think that's probably occurred, because of 1.1, and also because it's internal and you can give the kids quite a bit of instruction leading up to it, the level of attainment of that achievement, getting to Achieved level, is quite high, higher than it is in the external exams. (Study class teacher interview, 7 February 2006)

The teacher reported that in her/his school they were teaching students to carry out a fair testing type of investigation in years 9 and 10. The teachers got their students to do a trial AS1.1 at the end of year 10. Although the department had considered using the grade from this mock practical assessment as the grade for AS1.1, as a department they decided against doing so. The end of year "mock AS1.1" would carry on as preparation for year 11. The implication was that those students who had an Achieved or better grade would not have to do AS1.1 in year 11. However, making use of the grade in year 10 students would have to be formally enrolled to do AS1.1 in year 10. It was also likely that students who had an Achieved grade for AS1.1 in year 10 may want to improve their grade in year 11.

One positive aspect of the National Certificate of Educational Achievement that the teacher was excited about was the expectation of having to teach critical thinking skills and noted that "students are asked open-ended questions so they have to be quite good at explaining concepts and discussing concepts, actually explaining perhaps two different issues and comparing and contrasting them". The teacher said that as a consequence teachers had to adapt their teaching to make sure that they had covered critical thinking skills. This comment was in relation to the National Certificate of Educational Achievement requirement for Merit and Excellence grades which require students to "explain" and "discuss" their results.

During discussion with the teacher s/he mentioned that it was school policy that students should set goals for their learning and achievement for the year. The teacher asked students to write down their goals in the second week of the first term. Students had to state what National Certificate of Educational Achievement grade they were going to aim for in the internal assessment and for the external standards. For internal assessment (AS1.1), 10 students were aiming for the Achieved grade, eight for Merit, and six for Excellence. For science externally assessed standards, 11 students wanted an Achieved, 10 a Merit, and three an Excellence grade. The students wrote these goals on paper and handed them to the teacher. After getting student consent to share the goals with the researcher, the goals were provided to the researcher. Although students had set the goals, neither the students nor the teacher talked about the goals in any of the observed lessons.

7.1.3 First student focus group interview

The first focus group interview took place on 13 April 2006 in a school meeting room, with six students participating. The interview was audio-taped and transcribed. The focus of questions in the first interview was on eliciting what science investigations the students had done, what they learnt from these investigations, and whether they enjoyed investigating and if so why? Conversely, if they did not enjoy an investigation what were the reasons?

Jake remembered heating an iron rod and learning that metals expand when heated. He also remembered that a bimetallic strip bends when heated "because one metal expands more than the other". Another student mentioned running up stairs, the investigation they had carried out on that day, finding how much power they used. Simon said:

> I liked the running up the stairs one, because it was, I don't know, because it was physical and there wasn't too much writing involved and it applies to yourself, like you learn something about yourself. (Simon, 13 April 2006)

Ed remembered one about hot water in cups of different materials that was about retaining heat. Pip added, "the main one I remember doing is making hokey-pokey". She knew the ingredients, heat "triggers" reaction, while others added that it was a chemical reaction. Bob said "a gas comes off that causes frothing", but none could remember which gas. These were practical activities and investigations the students had carried out in the previous years.

Simon said that one of the investigations that they did (separating mixtures) was boring. Jessica said, "I don't really mind it, like I'd prefer to be doing that than just writing stuff down". Ed who had not enjoyed this investigation (Body power) said he already knew the answer and added "It's boring, like it's just kind of copying stuff off the board and a lot of it you don't take in cause it's just straight writing it down". When reminded that they did not have to write much down for Body power investigation, he said, "but a lot of the time we do". Students reported that they did not mind writing small amounts but find lots of writing boring especially if they were just copying. They would rather be doing hands-on practicals. In general, according to Jake, they liked investigations that involved using Bunsen burners:

> There's always something to do with heat, it seems because you're always using the Bunsen burners. (Jake, 13 April 2006)

In the class it was observed that Jake liked playing with matches (he used up all the match sticks in the box when they did the metals investigation).

These students remembered practical work carried out in the previous years. Some were able to identify what they had learnt. However, it appeared that they could not tell whether it was a practical activity or investigation.

7.1.4 Summary of term one science investigation

The first term was about learning science and learning to investigate. The teacher provided the opportunity to investigate on one occasion and this was of the fair testing type. Through the investigation the teacher wanted the students to develop skills needed for fair testing. Although the teacher thought that getting an Achieved grade in the National Certificate of Educational Achievement was easier than passing School Certificate, a positive aspect of the National Certificate of Educational Achievement was that the Merit and Excellence questions require higher order thinking than in the past. This also meant that teachers had to teach critical thinking skills. In the teacher's opinion, the use of workbooks meant that teachers were able to spend more time teaching rather than writing tasks and students no longer had to spend time on copying out the method from the board, allowing them to spend more time on learning. In the teacher's view, more teachers were now teaching complete investigations.

It is noteworthy that students enjoyed and appeared to have learnt most from exploration of a series of short practical activities set up as work stations. Students explained their enjoyment in terms of the variety offered as opposed to doing one investigation for the whole hour. Other reasons offered for enjoyment were doing the activity and not having to write too much about it. A few students did not participate in these activities and appeared to waste their time. They said it was because they already knew the answer. It was interesting that students in the focus group collectively could remember a number of investigations that they had carried out in previous years and what they had learnt from them. However, some of these appeared not to be investigations, rather they appeared to be short practical activities. Students did not appear to distinguish between an 'investigation' whether fair testing or another type of investigation, and other practical work. From the observations, a trend emerged that with each observed lesson students were engaging less and less with the task on hand. Students had set goals as required by the school policy about the grade they wanted. Many wanted to achieve highly in science and for AS1.1, but most did not appear to be working towards these goals.

7.2 School Term 2 (2006) – Assessment of Investigation

After a two-week break, the second term started on 1 May 2006. The focus of this term was preparation and assessment for AS1.1. Just as in term 1 the study class was observed weekly, observations starting on 4 May 2006. Audio-taping of study class teacher reflections continued. The second formal interview with the study class teacher took place on 26 July 2006. There was no student focus group interview in this term as there were disruptions such as two weeks for mock examinations and school celebrations. However, the second student focus group interview, which was carried out on 14 September (term 3) is reported here because it relates to the activities of this school term. The results of student Questionnaire One, administered on 15 September, are reported here for the same reason. The results of the science laboratory environment inventory are also presented. The second school term ended on 30 June 2006.

7.2.1 Observations, running records, and teacher reflections

Six lessons were observed in term 2 – two of these involved the investigation used for formative assessment or "trial run" for AS1.1. One lesson was used to administer the two versions of the science laboratory environment inventory. The sixth, the carrying out of science investigation for AS1.1 was also observed and is reported.

Outline of lessons observed

The first observed lesson for this term, the sixth formally observed lesson (see Table 7.3), started with the teacher reminding students that they would be doing the assessment for AS1.1 (4 May 2006). The students planned and carried out an investigation, "rolling a marble down a slope". Students investigated the effect of different types of surfaces on the distance travelled by a marble. A metre ruler was used as a ramp. This task was similar to the task used for AS1.1 later. The students had to plan and carry out the investigation in one lesson and were required to write the report for homework.

The next two lessons observed (7 and 8), held on 11 and 18 May 2006 respectively, were part of a formative assessment in preparation for AS1.1. This formative assessment involved investigation of heat retention in cups made of different materials. This investigation took three lessons: first lesson (observed lesson 7) to plan the investigation; the second (observed lesson 8) to carry out the investigation; and the third to write the report (this modelled the timeframe students would have for AS1.1 assessment). The third lesson was changed to a day earlier than the set observation day and was not observed. At the start of the second lesson the teacher returned the marked plan to the students and gave feedback:

> I have marked your planning but have not said what level of achievement you are at. To get an Achieved you need to get everything on page 35 right. To get a Merit needs more. (Observation notes, 18 May 2006)

This investigation is described in detail in the section below.

In the observed lesson 9, students completed both actual and preferred versions of the science laboratory environment inventory (25 May 2006). The teacher was on leave and they suggested that the class would have a relief teacher and that it would be a good day to do the inventory. In the fifth observed lesson (10), the teacher returned to students the formative assessment task and pointed out aspects they needed to improve for their final assessment (1 June 2006). Then the class moved on to a new topic on micro-organisms. Students set up agar plates to incubate micro-organisms. On 6 June, lesson 11, data gathering for As1.1 was observed.

The formative investigation: Heat retention in cups of different materials

This investigation was selected to look into in depth because it was the investigation to prepare the students for final assessment. The teacher wanted to familiarise students with the process they would have to follow. It took three lessons just as the assessment would. In the first lesson (11 May 2006) students planned their investigation. In the next lesson (18 May 2006) students carried out the investigation and collected data and on the following day, in the third lesson, they wrote their report. The first two of these lessons were observed. Some data from the second focus group (14 September 2006) are included here because they are relevant to this investigation.

The task in the first of three lessons was to design a fair test on the insulating properties of different materials as was described in the workbook (Abbott et al., 2005). In this lesson, the teacher wanted students to understand the language used in assessment tasks through asking the following questions:

> What is the dependent variable here?
> What is the independent variable?
> Which ones would you need to control? (Observations notes, 11 May 2006)

The class were very noisy and took eight minutes to settle down when the teacher said that they would be staying behind during lunchtime. The starter quiz took 11 minutes. A third of the lesson was over before the students started the task:

> Between four and five groups engaged with the investigation they were to do. The rest talked, wandered and were not engaged. At no time during this lesson were all students on task. Ed moved to sit next to me. (Observations notes, 11 May 2006)

When asked where his plan was, Ed pointed to a drawing in his book. He had drawn three cups with a single line in each of them. When asked if he could describe his plan, draw a table to record his results, describe how to carry out the investigation, and why he did not put all of this down and that he could get a good grade for all he knew, he said:

> This is dumb, we did it for NCEA assessment last year. (Ed, 11 May 2006)

According to the teacher, towards the end of year 10, students carried out a mock AS1.1 (See section 7.1.2). It seemed that Ed thought that his grade from last year still counted. During the lesson the teacher moved around the class and helped students to write down their plan asking questions and providing direction.

In the following observed lesson (18 May 2006), students received the marked plans from the teacher so they could proceed with the investigation. As the students were gathering data it provided the opportunity to move around the class and observe closely. First, a group of students who appeared to be on task:

> This group had set up three cups made of metal, glass, and polystyrene with hot water in each and were taking readings at one minute intervals. They had the table set up in their workbooks and were recording their reading. Interestingly, they took the thermometer out from one after taking the reading and immediately putting it into the other and taking the reading. They were not aware that this would affect the accuracy of their readings. (Observation notes, 18 May 2006)

Then there was a group sitting at the back. When asked why they were not doing the investigation, Henry said that he knew which would keep the heat in "so what's the point?" The teacher had given a photocopy of the pages from the workbook to those who did not bring their workbooks. Henry's group sat and talked and at the end of the lesson they had no data to record. Another group of students claimed that they had finished but had not written anything down:

> Researcher: What are you doing?
>
> Ken: I am thinking.
>
> Later Ken was seen copying the method from his neighbour's book.
>
> (Observation notes, 18 May 2006)

Mili had collected all her data. When asked:

> Researcher: What did you learn from this investigation?
>
> Mili: That metal is the best, the tin.
>
> Researcher: Is the best what?
>
> Mili: It's an insulator.
>
> Researcher: What else did you learn?
>
> Mili: That the water cools fastest in the metal cup.
>
> (Observations notes, 18 May 2006)

Clearly, Mili did not understand that if metal was an insulator the water would take longer to cool own. Later, this investigation was discussed in the focus group when several students gave their reasons for not engaging:

> Jessica: I think the one about the cup and hot water and stuff, we did something really similar last year and that was kind of boring.
>
> Jake: Cause it was just like three days and it wasn't interesting, cause you already know that technology's out there and it's nothing new.

Simon: They've already invented thermoses and things and they all seem to work pretty much the same.

Pip: And usually if you have hot water in your cup you're going to drink it pretty fast, you're going to use it soon.

(Focus group, 14 September 2006)

According to the focus group students, they already knew the science concepts they were to have learnt through doing this investigation. Their responses indicated that they had not considered that this investigation was to prepare them for their final assessment. The teacher's purpose for doing this investigation was to give students an opportunity to practise an investigation and learn its terminology to become familiar with the process they will need to follow for the assessment. The students did not pay attention to the teacher and the researcher moved around the class listening and occasionally asking questions about what they were doing.

When students in the focus group were asked how this investigation helped them to prepare for the assessment, the following discussion took place.

Bob: It showed us the lines which we had to follow to write out the method. How to use our time?

His response helped the others to remember doing this investigation:

Pip: And what we were looking for when we were doing it.

Researcher: Do you remember your teacher marked and returned your plan? Did anyone use that feedback that the teacher gave you?

Bob: No.

Researcher: Why?

Jake answered instead: I tried to, but I didn't improve my mark, but I'm still happy because I passed.

(Focus group interview, 14 September 2006)

Through this investigation the teacher supported students' learning by giving them time to think what they had to do for their assessment but the teacher remained concerned that so close to the assessment some students were still struggling:

> Quite a large proportion of the students in there are you know at the sort of Achieved level or I have to drag them up to that sort of level, I thought well OK, they need a fair bit of structure still, even ten days out from the assessment and so I actually gave them the purpose, but the independent and the dependent variable, I led them towards that, rather than giving that to them and in fact still it turned out that there were a few, who didn't know what the independent variable was or the dependent variable. Most of them have, had cottoned on I felt but there were a few who hadn't, so it was good to prise that out of them rather than just give it to them and not have them think about it. (Teacher reflection, 28 May 2006)

This investigation was designed to give students the opportunity to find out what they needed to do for their formal assessment. However, a third of the class did not put in the effort perhaps because some of them had already done this investigation in year 10 for a trial run. Only 11 students had handed in the planning task for this formative investigation and some reported that they did not use the teacher feedback to improve.

It would appear that the students see the investigation as identifying science knowledge (finding 'the answer'). They appear to not appreciate the point of investigation as learning a process for finding out science knowledge and ideas.

The assessed investigation: Watch that Car Go!

'Watch that car go' was a moderated task available on the Ministry of Education website (TKI, 2005). Students were given the following information on a handout for this assessed investigation.

> **Background Information:**
> Watching children play with their toy cars, students noticed that the cars seemed to travel at different speeds depending on the slope they were released on.
>
> **Task:**
> In this investigation you are to plan, collect, process and interpret information, and present a report to find out how the slope of a ramp affects the distance the car goes along the flat (table or floor). This investigation is a "**fair test"** investigation. The emphasis is original. (Study class teacher, 2 June 2006)

Students had to plan the investigation during one normal class lesson, which was done on Friday 2 June 2006 before the start of the mock examination week. The teacher marked the planning task. (This lesson was not observed.)

Data gathering took place during the mock examination week on 6 June 2006 in the college hall. (This lesson was observed.) Along the side of the hall, 30 desks were set up so that students could do a written science mock examination for the externally assessed achievement standards. In the middle of the hall 30 two-metre long carpet strips were placed so that 30 students could carry out the data gathering. Other equipment placed next to each carpet strip included one-metre long pieces of wood to be used as ramps, three 10 cm blocks of wood to increase the height of the ramp, a toy car, a metre ruler, and a stop watch.

The teacher returned the marked plan to the students to use for carrying out the investigation. They divided the class into two groups and gave the following instruction:

> People, this is the last talking you do today. Group one, you will sit at the desks along the side and do the mock exam for the first hour. Group two go and sit next to one of the carpets set out in the middle. (Waits for the students to sit next to a station set out.) Group two you will carry out the practical investigation. The paper you are writing on will be collected and returned to you in class. You will be drawing graphs in the next lesson. After one hour you will swap over. (Study class teacher, 6 June 2006)

Six students were absent when the class had done the planning task. The teacher had organised for them to come and complete the planning task an hour before the assessment on 6 June 2006. They were put in group one and the teacher marked their plan while they did the mock examination. As their plans were workable none of the students were given the plan the teacher had to give to those who did not have a workable plan and so would have been disadvantaged.

> All students had come up with a plan so I did not have to give them a dummy one. Mel and Harry's plan was a bit dodgy but it looked like they had worked out what to do. (Teacher reflection, 6 June 2006)

According to an observation record the researcher noted that:

> It is pretty easy to work out as the students sitting on the side doing the mock exam could look at what the students in the middle were doing. Two who were sitting on the side watched Bob and when it was their turn followed what he had done. This was different to what they had put down in their plan. (Observation notes, 6 June 2006)

Students processed the data and wrote the report on 12 June 2006 in their science class, a week after they had collected the data and after mock examinations were over. The papers were marked and moderated:

> Because we have done this task for the first time we will moderate it on Monday at the department meeting. Use guinea pigs to do that. (Teacher reflection, 6 June 2006)

The assessment was returned to the class in the last lesson before the start of the school holidays on 30 June 2006.

Students goals for AS1.1

Following the school policy, students had set goals for science achievement and achievement in AS1.1. Table 7.2 shows student grade goals for AS1.1 and the grades they achieved.

Table 7.2: Comparison of students' grade goals with grades achieved for AS1.1

Possible grades		Students' grade goals (%)	Students' grades achieved (%)
Excellence	(E)	25	0
Merit	(M)	33	17
Achieved	(A)	42	70
Not achieved	(NA)	0	13

The students' results were far lower than the goals they had set for themselves. None were graded "Excellence" (whereas 25% had set that goal), 17% were graded "Merit" (33% had set this grade), 70% were graded "Achieved" (only 42% had set this minimal goal). A further 13% did not achieve the standard, a disappointment for students as none had expected a "Not Achieved" grade.

Student engagement in term 2

Table 7.3 shows student engagement during each observed lesson in term 2. The science laboratory environment inventory was administered in observed lesson nine (25 May 2006). The students did both forms of the laboratory environment inventory (SLEI), "Actual" followed by "preferred" while the teacher was on leave. The inventory was administered by the researcher and most students completed each version in about 20 minutes. Engagement during this inventory is reported in lesson 9.

Table 7.3: Student engagement in year 11 science class in term 2

Student Engagement in each quarter	**Student Engagement in Lessons 6-10**					
	6 **Rolling marbles** 4 May	**7** **Planning heat retention (Formative)** 11 May	**8** **Data gathering heat retention (Formative)** 18 May	**9** **Science Laboratory Environment Inventory** 25 May	**10** **Culturing Micro-organisms** 1 June	**AS1.1** **Watch that car go** 6 June
First ¼	None	Half - groups 4 and 5	Few - groups 3,4 and 5	All	None	All
Second ¼	Half class	Half - groups 4 and 5	Few - groups 4 and 5	All	Half class	All
Third ¼	All During practical	Few	Few - groups 4 and 5	Most	All During practical	All
Fourth ¼	None	Few	Few Most finished and very poorly behaved	Few after completing the inventory	None	Most finished and restless

Note: No data are reported about groups 6 and 8 as these groups had students who did not participate in this research.) The groups identified in the table with a negative sign indicate the groups in class that were not engaged during that period of the lesson.

Towards the end of the term the researcher observed that:

> The noticeable difference is that students are taking a lot longer to settle down at the start of the lesson. Today, the teacher has decided to continue to talk over their noise to give instructions. (Observation notes, 1 June 2006)

However, the group of students that sat in the front two rows were continuing to focus on the task.

7.2.2 Second student focus group interview

The interview was held on 14 September 2006 in the school meeting room in the first week students were back after the holidays. It was audio-taped and took 50 minutes. The purpose was to find out specific assessment related information. The limitation of this interview was that it was done 14 weeks after the completion of AS1.1 which had implications for the reliability of data. Students were reminded that normally in their class they work in groups to do practical work. They were asked how they found the assessment where they had to plan and carry out the investigation by themselves.

> Bob: Even though I prefer doing it by myself it was kind of interesting going from being part of a group to doing it by myself because you had to see everything through by yourself, instead of having someone else's ideas.
>
> Jake: It was different. It wasn't better or worse it was just different.
>
> Ed: I think that people who are less dominant might have problems with that. But it was pretty (good) for the most part.
>
> (Focus group, 14 September 2006)

Students were asked how they found the process of doing the investigation in the hall having half the class doing the written examination and the other half carrying out the investigation. This is how Bob described his experience:

> I think it was actually a good idea, because if you had everyone doing the exact same thing at the exact same time it could be a bit confusing. When I got up I was like one of the first to get down, but it was kind of free because you were standing in the middle of a hall and no-one else. Looking around and no-one else is moving. But it's a lot easier because you have all your stuff that you need laid out for you, and no-one else is trying to take it, so there's far less people to worry about and you can just get on and do it. (Bob, 14 September 2006)

Jessica, who did the written mock examination, first said:

> I thought I'd be a bit distracted by everyone else getting up and doing their thing. But I wasn't, I just sort of tuned them out and got onto what I was doing. (Jessica, 14 September 2006)

Students were asked if they were worried about the assessment while they were doing the written examination. Simon said:

> It was kind of like the practical is worth credits. It's first priority. Do that, you know. (Simon, 14 September 2006)

When asked if it was about credits, Jake said "Pretty much"; the others laughed and agreed. Ed added "I didn't even know the other was just mock". They were probed about what they had learnt from doing the assessed investigation. Pip, who said that she does not remember much science, commented she remembered this investigation: "I guess it stuck better because it wasn't theory, it was practical. It was easier to remember". When they were asked how they could have prepared themselves better for the assessment, Jake and Bob said:

> Jake: Well I'm just glad I passed really. I don't think I could have done anything really better than I did, well me personally, Yeah.
>
> Bob: Yeah the answers were simple really, you just had to revise them all and know what you were going to go into.
>
> (Focus group, 14 September 2006)

They were told that they did not have to share their results but asked if they were satisfied with what they had got? Two students said they did not remember what they got, one said he was happy. Jake said "Anything over an Achieved is good". Bob's response was unexpected:

> You cannot complain from passing, if you wanted an Excellence or whatever. If you're passing you're still getting the credits or whatever, so it doesn't really matter in the long run. (Bob, 14 September 2006)

Jake said "It's not if you pass its how you pass". This is interesting as in class Jake is easily distracted and often off task and Bob is focussed, always keen to answer questions, having the right answers. His response was uncharacteristic. In the focus group he was the only one who described seeing a relationship, a pattern in the data during the assessment:

> It was great, every time I put another block to raise the height of the ramp 10cm the car travelled 30cm more. I did this many times and each time the same thing happened, how good is that? (Bob, 14 September 2006)

He was disappointed but accepting of his grade and added:

> And I got what the person marking the sheet thought I should have got, and I'll respect what they think. I think I maybe should have got something a little bit better. But if that's what they thought then that's what they thought, it's up to them, they're marking it. ... I think I was a bit too distracted really. I didn't really do my best. Maybe if I was a bit more prepared, and a bit less worried and everything, I would have done quite a bit better. (Bob, 14 September 2006)

In the focus group interview, when students were asked what they had learnt through doing this investigation, all their responses were about the science concepts rather than the process of investigation. Two responses illustrate this:

> Bob: How gravitational potential energy turns into kinetic. How friction goes against it?
>
> Jake: Depending on the different surface that you're rolling them on it depends on how far and how fast it (toy car) will travel.
>
> (Focus group, 14 September 2006)

Students were asked if they could remember the goals they had set at the start of the year about their achievement in science and in AS1.1; they did not. They were given a copy of the goals they had set at the start of the year. They were surprised.

> Jessica: Well, I don't know what I got for achievement standard 1.1 but here I've got to get an Excellence grade. I know this year for science, I have fulfilled it which is alright to get one Excellence grade*.
>
> Pip: I also picked to get an Excellence grade, but I didn't get it.
>
> Simon: I wanted to get an Achieved grade and I did which was really good. So yeah I'm pretty happy with that.
>
> Jake: I picked to get an Excellence, but I didn't.
>
> Simon: What did you get?
>
> Jake: Merit.
>
> Ed: Um, I failed all the mock exams that we've just done, but I got Achieved for AS1.1.
>
> (Focus group, 14 September 2006)
>
> *Note: Jessica was talking about the mock examination in which she had scored one Excellence grade.

In this second interview, the students were comfortable in talking openly and trusted that what they shared would not be shared with the teacher or other students. They were spontaneous in their responses and did not put each other down. Their responses suggested that they were honest about their preparation or lack of it. Bob was clearly disappointed with his result for AS1.1 but did not blame the teacher or the process. Ed was his usual self; he knew he had not worked and was a bit lucky to get an Achieved. He shared with the group that he had failed all other standards but tried to put across that he did not care. Interestingly, though pass and fail are not in the National Certificate of Achievement grades, students were still talking about passing or failing if they achieved or did not achieve.

7.2.3 Student Questionnaire One: Internal assessment and motivation

This questionnaire was administered in term 3 on Friday 15 September 2006 (not the usual observation day) by the researcher after the AS1.1 assessment had been completed and students had received their grades. Students were not asked to write their names on the questionnaire. The students took 20 to 25 minutes to complete it. The purpose of the questionnaire was to focus on the assessment of investigation for National Certificate of Educational Achievement level 1. The questionnaire was designed to ask students about their preparation for assessment, learning, and actual assessment as well as to find out what aspect of the process motivated them to learn. For that reason it is reported here. Of the 24 research participants in the class, 22 completed the questionnaire (Appendix 7). The data were coded and analysed by hand. One comment was coded for each response to open-ended questions except for question 3.

Preparation for internal assessment (Question 1)

Students were asked to identify up to three investigations they had carried out and tick a box on a four point rating scale to indicate their preparedness (Table 7.4).

Table 7.4: Student preparedness for AS1.1

Investigation	Respondents (n)	Scale			
		Very well	Well	OK	Not very well
Rolling marble down a ramp	22	2	13	6	1
Comparing the power of different students running up a flight off stairs	13	0	3	6	4
Comparing how well cups made of different materials could keep heat in	14	0	3	4	7

The students were then asked why they had chosen the response they did. Most students reported that the first investigation in term 2, rolling a marble down a ramp, prepared them well or very well for assessment (15 of 22). Not all students wrote a comment. Some students found it useful because it was the same as the one they did for the assessment (3), easier to carry over ideas (1), find out how surface area affects speed (6), and how variables affect outcome (3). Five students found the body power investigation helpful but did not elaborate, and two found it helpful for remembering the formula (for working out power).

Explaining why they had chosen the response for the formative assessment investigation carried out on 18 May 2006 about heat retention by cups made of different materials, students identified what they had learnt from it, such as different materials retain heat differently, and black things keep heat in (6). Others said they learnt or practised skills like measuring, graphing, and writing up experiments (3). Negative responses overall were few and included: they did this last year for assessment/did it in year 10 (4); it was boring (1); and they already knew what would happen (1).

Usefulness of formative assessment (Question 2)

Of the 20 students who answered this closed question, two found the formative assessment very useful, eight found it useful, and eight said it was somewhat useful. Two indicated that they did not find it useful at all. The two students who found formative assessment very useful said, "It reminded me that my plan should be really clear so someone else could follow it and do it (the investigation)" (Respondent 16). One student who found formative assessment useful said, "Formative assessment told us all the things like variables and stuff we have to control, like having same amount of water, same temperature and things" (Respondent 19).

Helpfulness of teacher feedback for formative assessment (Question 3)

Question 3, an open-ended question, specifically asked how teacher feedback was useful in preparation for the formal assessment for AS1.1. Two student responses were coded for this question. Not all students responded to this question. Most responses reported the feedback useful (19). Some found the feedback helpful in terms of writing the report (5); some found it helpful to have the template and what they needed to put in each section (5); some found the feedback on planning useful (4); others said they gained confidence when the teacher told them that they had done well in the formative assessment (2).

The second part of the question asked about the usefulness of formative assessment for learning science. The students did not say how the feedback helped them with their science learning but said things specific to assessment that included: the feedback helped them to improve their report writing; the assessment improved their understanding of what they needed to learn; it helped them to focus on learning. Although only 11 students had handed in their formative task (18 May 2006) for marking and received feedback, the question allowed inclusion of other feedback useful in preparation for the formal AS1.1 assessment.

Student satisfaction with internal assessment, AS1.1 result (Question 4)

This question was to determine student satisfaction with the results. It was a 4-point rating scale on which students had to indicate their response. Only one student was completely satisfied, eight said they did as well as they could, six said they could have done better, five were not satisfied and two did not respond.

Students' views about improving their result for AS1.1 (Question 5)

Responses to what students themselves could have done to improve their grade for AS1.1 indicated that they were aware of how they could have achieved a better grade. The most common response was that they could have studied or revised (10); some said they could have written a better report (3); others thought making repeat trials (2) and drawing a graph would have been useful. Two students said they should have tried harder (2).

Enjoyment in doing the science investigation for AS1.1 (Question 6a)

Students were asked about their enjoyment of the investigation they did for formal assessment. Responses included: getting credits (2); passing (2); playing with the toy car during the actual assessment (2); it was not too hard (3); they had all the gear (2); everyone could do the work (1); and it was quieter (1). Negative responses included: I would rather do chemistry (1); I don't like physics (4); and I don't like science and don't enjoy any aspects of it (1). No comment was given by six students.

Aspects of the science investigation for AS1.1 not enjoyed by students (Question 6b)

The purpose of this question was to find out aspect(s) of the investigation for formal assessment that they did not enjoy. Two students indicated that they enjoyed it all. Others said: having to do it (2); writing the discussion (4); "it was a test so you had to get it right" (Respondent 19); the fact that it involved math (1); they did not know everything, and they had to understand what was going on (2); experiments were boring (1); and everything in science is boring (1).

Understanding science ideas through the science investigating for AS1.1 (Question 7)

In this question students were asked about how science investigation helped them understand science ideas learnt in class. Eighteen out of 22 students responded to this question. One student said they found it very helpful, eight found it mostly helpful, nine said it was somewhat helpful, five did not find it helpful and four did not respond. Their responses showed that most students found this investigation helpful to some degree in their learning of science.

Eight of the 18 students provided comments. They indicated that it helped them to understand the formulae they needed and how to write an evaluation. Others provided general comments such as: helped me to learn; made it easy because when they got to "do" the investigation it helped them to remember; and "because it lets me see the concept rather than having to 'see' it in my head" (Respondent 8); and because investigation "proves the ideas and actually show them" (Respondent 13). All five of the students indicating investigation was unhelpful gave comments which included: “cause it was stupid, if a ramp is steep something will go faster” (Respondent 17); because the class mucks around (2); because they learnt more out of the book work than in the investigation (1); and “I already knew this from year 9 and 10” (Respondent 3).

Learning about Investigating through Assessment of AS1.1 (Question 8)

Students were asked how they had learnt about investigating through doing AS1.1. There was no response from eight students. The others said they learnt how to write up an investigation (4); because it is repetitive ‘it gets it in your brain’ (Respondent 6); showed them the process to follow. One said it was fun and another said they don’t know what an investigation was.

Ways in which assessment of AS1.1 was unhelpful in learning to investigate (Question 9)

Students had the opportunity to say if they found AS1.1 unhelpful in their learning of science investigation and if so, to describe it. It appears that some students misread the question as one said it made him confident, two said it was fun and one found it interesting. Those who answered the question about how it was unhelpful said it was boring, one said it has decreased their interest in science, and one said “I don’t like science and after doing this investigation my opinions haven’t changed” (Respondent 15).

Effect of assessment of AS1.1 on student interest in investigating (Question 10)

Students were asked if doing the assessment for AS1.1 had increased or decreased their interest in doing science investigation. Fourteen students did not respond and the eight who did said that it did not interest them, they rarely take in what is taught, it is repetitive, and that “it is all boring” (Respondent 15).

Summary of questionnaire results

Most students remembered the investigations they had done. More remembered the investigation of rolling the marble down a ramp than other investigations. Rolling the marble down the ramp was very similar to the one used for assessment of AS1.1 where the students had to roll a toy car down a ramp. The difference between the marble and toy car investigation was that in the marble investigation they investigated the effect of surface on the distance travelled by the marble whereas for the toy car they investigated the effect of increasing the height of the ramp.

Most found the formative assessment and the feedback provided by the teacher useful or somewhat useful. The reasons why they found the feedback useful were mostly about the reporting or skills aspects of investigation. Less than half the students were satisfied with their results and some attributed it to lack of effort on their part.

7.2.4 Second interview with the study class teacher

The second formal interview with the study class teacher took place on 26 July 2006. Although this interview was conducted in term 3, it is reported here as the main topic, assessment took place in term 2. The purpose was to find out the teacher's view about the progress of the class in the first half year, terms 1 and 2, what challenges the teacher was facing, and how that was being managed. It was also to find out the teacher's views about student motivation and assessment of science investigation that had been the focus of teaching and learning in term 2. All quotations are from the second interview when the teacher reported:

> I find this a challenging group because of the range of ability and the fact that at the top end of the group there are about five students that I might be able to get up to a Merit level and the rest are achieving, and there's lots that are going to really struggle. (Study class teacher, 26 July 2006)

At the time of assessment (in June) the teacher thought that only a few might gain a Merit and some would gain Achieved but most would find it hard to gain an Achieved grade. The teacher reported that in the past, when s/he had a similar class, her/his strategy was to teach at a slower pace to ensure student understanding. Overall, the teacher thought that the class was making progress. When asked how s/he would manage a similar class in future, the teacher said:

> Next year we're actually going to design, have two courses …, as well as the alternative and we're going to have kind of a middle course which is mainly the achieving standards class. For biology we might actually put unit standards in there but we'll try to put the kids, try to set up classes where there's students and the teachers can focus at perhaps looking at the Merit level and then another, it's kind of a broad band really, students… who are likely to go to Achieved and not higher, ….cause more than half the kids are failing the achievement standards externally and you know there's got to be a better way than that, we must be able to improve on that. (Study class teacher, 26 July 2006)

At this point the teacher said that some students should not have been in this class. Her/his solution was to create a class where the students would only be expected to get to an Achieved level.

When asked how experiences of science investigation are related to student motivation to learn, the teacher said:

> ...ideally, what we teach, has to focus on the skills that are identified in the curriculum. It is not too difficult to do that because these students enjoy practical work. An open-ended problem or an open-ended question allowing students to choose investigation they want to do I find is more motivational. You can make it as open as you want, how do you solve this problem? How do you plan to thoroughly go about doing that? How do you then design your experiment to gather the data? Then actually gathering it, processing it properly, discussing it, and then very importantly, what does it all mean? How could you improve on it? So it's a very important process. (Study class teacher, 26 July 2006)

Commenting on how assessment through AS1.1 relates to student motivation the teacher first talked about change in teacher practice and then about motivation. S/he said:

> I think that having AS1.1 in there as an achievement standard is probably forcing all of us to focus more on what kids need to do to get the standard, put more time into that...we are all doing that. To answer your question, motivation is there but it is to get the credits. The students want to do the practical but I believe it is the internal assessment credits that they really want. (Study class teacher, 26 July 2006)

The study class teacher said that other teachers did investigation in years 9 and 10 that motivated students.

> ...students got a buzz out of something they have more control over that they can choose to investigate. It is more motivational when they can go off at a bit of a tangent and try out their own ideas. The year 11 assessment made teachers put more effort into teaching for assessment.... Assessment is not hugely motivating. (Study class teacher, 26 July 2006)

This question led to asking the teacher for her/his thoughts about AS1.1 and how it had impacted on teaching and learning. The teacher reported that s/he was doing three full investigations to prepare students for assessment. With one of these s/he focused on planning (marble rolling down a ramp), two on gathering and processing information (body power); the third, insulating properties of materials (heat retention) that s/he used as formative assessment to get the students used to the process followed for assessment of investigation, AS1.1. The teacher reported that each of these investigations took three lessons. (It was observed that only one of these investigations took three lessons.) One of the others took two lessons and a homework task and the third were done during one lesson.)

The teacher said that it was a challenge to find out what the students could do and what their weaknesses were. Practice was also needed to familiarise students with the language of assessment.

The task that their school used for AS1.1 was "Watch that car go!" (see 7.2.1) Students investigated the effect of the height of the ramp on the distance covered by a toy car. In the previous year the school used a chemistry task “Bubble trouble”, also available on TKI. The teacher said that they had changed to “Watch that car go” for the following reasons:

> The students found out what was done in the past years. Secondly, the moderators now want students to do their own dilutions rather than being given acids of known strengths. I think year 11 students are not capable of doing their own dilutions. The students achieve well in “Watch that car go”. While it seems very contrived, it is difficult to come up with a task for assessing how good these students are at carrying out an investigation. One is limited in the kinds of things that can be done with a class of thirty students. (Study class teacher, 26 July 2006)

The next question asked the teacher about her/his thoughts on organising and administering assessment of AS1.1. This assessment was carried out in the school hall where two classes did the assessment at the same time. S/he believed that this process worked well but could only be done once in the year during the mock examination week. The students did this assessment in three parts and they did not complain about it:

> I was there in the hall thinking, oh my goodness, you know, this seems crazily basic, it did seem contrived, cars rolling down a ramp in a hall like that, but you know, if you’re going to assess kids’ ability to do an investigation, you have to do what works. (Study class teacher, 26 July 2006)

When asked would they make any changes for next year, the teacher said:

> No, I don’t think so, we’ll rotate the task every few years but I think we’ll do the same one next year. Actually I’ve just been looking at the results today; the level of achievement is about the same but there are fewer kids, a lot fewer kids have got Excellence than with bubble trouble. (Study class teacher, 26 July 2006)

The teacher explained why s/he thought this was and how more students could achieve a higher grade:

> The kids aren’t going on and talking about the science behind the investigation. Yeah, we wanted reasonably in-depth evaluation of the practical, but they would have had to have talked about energy transformation to get the Excellence and that’s what stumped them, but what will happen I would guess, next year, is that the kids who do it next year will have conversations with the kids who’ve done it this year and they’ll, more of them will pick up that that’s what’s needed and so I would expect that for the same task the results will actually go up slightly for next year. (Study class teacher, 26 July 2006)

To summarise, the teacher believed that in spite of having a challenging class that did not have very capable students, the class had made progress. S/he had taught students to investigate, given them plenty of practice to learn the process, provided the opportunity for formative assessment, and had given feedback. In her/his view, the students found assessment of science investigation and the way it was assessed satisfactory though it was difficult to have 30 students doing the assessment at the same time. The level of achievement was about the same as the previous year but fewer students got an Excellence grade. The teacher believed that students would get more Excellence grades in future when they talk with former students to find out what they had to do to get an Excellence grade.

7.2.5 Science Laboratory Environment Inventory

As described in section 4.6.5, the SLEI has two versions. The actual version requires students to select responses that indicate what they experience in the science class, whereas in the preferred version they are asked what they would like the environment to be. Both actual and preferred versions of this inventory were administered by the researcher on 25 May 2006. Students took approximately 25 minutes to complete the actual version and about 20 minutes for the preferred version. The students selected from five scoring options 1 (low) and 5 (high). The negative items were reversed before adding the responses for the five scales (see Table 4.2). A paired sample t test was applied for both actual and preferred items on each of the scales (see Table 7.4). The five scales used were open-endedness (items 2, 7, 12, 17, 22, 27, 32); material environment (items 5, 10, 15, 20, 25, 30, 35); integration (items 3, 8, 13, 18, 23, 28, 33); rule clarity (items 4, 9, 14, 19, 24, 29, 34); cohesiveness (items 1, 6, 11, 16, 21, 26, 31). Open-endedness items relate to student control over the design and implementation of practical work, the choice they had or would like to have had in investigating what they wanted to investigate. Material environment items were related to the physical aspects such as whether they had the equipment available to do the practical work and if it was in good repair. Integration items were about the relationship between the concepts they had learnt and the practical work they were doing. Rule clarity was about the parameters within which they had to work, how they understood the safety requirement. A cohesiveness scale was related to the human dimension of working together, helping each other. The results show a just significant ($p < 0.5$) difference between the actual and preferred option for open-endedness. The open-endedness scale is particularly relevant as it measured student preference for the science investigation they carried out. The actual score (3.14) was higher than the preferred score (2.98), which indicated that they did not want the laboratory environment to be more open-ended. It can be concluded that they wanted less choice in deciding what to investigate and more teacher direction.

The material environment actual score (2.81) was significantly lower ($p < .001$) than preferred score (3.62) and is indicative of their preference for more equipment that worked, a less crowded laboratory and a comfortable and attractive place to work.

On the cohesiveness scale, the environment was significantly ($p < .001$) less cohesive (2.70) than they would have preferred (3.88), indicating that they would have liked to get along with each other and preferred to be able to help each other. Rule clarity was high (3.37) and this was preferred (3.40), demonstrating students wanting to have, and having, a clear understanding of the classroom rules and guidelines. Integration was seen to be high (3.35) and it was preferred (3.83), indicative of the close relationship between theory and practical integration in their class. The results are presented in Tables 7.5 and 7.6.

Table 7.5: Paired sample statistical results for Science Laboratory Environment Inventory

	Environmental factors	Mean	Standard deviation
Pair 1	Open-endedness (Actual)	3.14	.24
	Open-endedness (Preferred)	2.98	.21
Pair 2	Material Environment (Actual)	2.81	.42
	Material Environment (Preferred)	3.62	.70
Pair 3	Integration (Actual)	3.35	.65
	Integration (Preferred)	3.83	.76
Pair 4	Rule clarity (Actual)	3.37	.40
	Rule clarity (Preferred)	3.40	.77
Pair 5	Student Cohesiveness (Actual)	2.70	.91
	Student Cohesiveness (Preferred)	3.88	1.18

Table 7.6: Results of paired sample t test

	Environmental factors	t	df	Sig. (2-tailed)
Pair 1	Open-endedness (Actual) - (Preferred)	2.395	16	.03
Pair 2	Material Environment (Actual) - Preferred)	-4.573	17	.00
Pair 3	Integration (Actual) - (Preferred)	-1.969	20	.06
Pair 4	Rule clarity (Actual) - (Preferred)	-.160	19	.86
Pair 5	Student Cohesiveness (Actual) - Preferred)	-4.308	21	.00

7.2.6 Summary of term 2 science investigation

The focus of this term was on assessment. The teacher prepared students by doing two investigations. The emphasis of the first investigation was on planning, the second on gathering data and processing information and reporting the results. The third investigation (heat retention) was the formative assessment (trial run) that modelled the process that would be followed for the formal assessment for AS1.1 and was carried out in three lessons. The teacher marked and provided feedback to the students for this formative assessment. Student engagement was high during the practical part of the lesson. Students liked doing small practical activities compared to investigation. Some liked the variety rather than doing the same thing for a whole hour. As the term progressed, students still engaged in practical work whether it was within an investigation or by itself. Other than that student engagement decreased as the term progressed.

The practical investigation carried out for AS1.1 was a physics task, “Watch that car go”, which involved finding out the effect of raising the height of the ramp on the distance travelled by a toy car. One investigation that students had carried out in class was rolling a marble down a ramp to investigate the effect of surface on the distance covered by a marble. The final assessment was similar to this task.

“Watch that car go” is a moderated task available on the Ministry of Education website (TKI, 2005). According to the teacher, it was a task that students could achieve, which was backed up by the results where only three students in the class got a Not Achieved grade. Four students got a Merit grade. The teacher was concerned that no one gained an Excellence grade but thought that this was not a very capable class.

The assessment of AS1.1 was carried out in three parts. Planning was done in the laboratory, data gathering was carried out in the college hall during the mock examination week, and the processing and report writing was done under examination conditions in the laboratory in the following week. Neither the teacher nor the students had any concerns about this compartmentalised “complete” investigation.

Students could remember the investigations that they had done and said that they had been adequately prepared for AS1.1 assessment. Most found the formative assessment useful, but a few students were negative about every aspect of the assessment. The students in the focus group were accepting of their grades and said that if they had done more preparation they would have got better results. These students had set goals as was the practice in the school but none of them could remember what these goals were and when reminded of the goals they found that they had not achieved what they had set as goals. The teacher and students agreed that practical work was motivational. In the teacher’s view, the kinds of investigations they had been doing were not as motivational as open-ended investigation. In the science laboratory environment inventory students did not prefer openness, they wanted direction. In the students' view, doing any practical was better than writing for the whole lesson. Both agreed that getting credits was motivational.

The student survey results demonstrated that almost all students (21 out of 22) found rolling the marble task helpful in preparation for AS1.1 as compared to the formative assessment tasks, heat retention (7 out of 14) and the body power task (9 out of 13). Students were ambivalent about the usefulness of formative assessment; half found it useful or very useful and half only somewhat useful or not useful at all, though they found feedback useful. They enjoyed the 'hands-on' activities and getting credits. It also showed that students did not succeed in AS1.1 nearly as well as they would have liked, but like the focus group, they blamed themselves for not preparing well enough. The formal assessment in itself was not seen to help the students in their learning or promote a positive attitude to science. Students saw science learning through investigation as learning science ideas, not learning the investigation process due to teacher emphasis on substantive rather than procedural understanding.

The environment inventory results showed that laboratory work was sufficiently integrated with the theory and provided sufficiently clear instructions, even though they would have liked a more mutually supporting and a more 'comfortable' environment.

The teacher was satisfied with the set-up of assessing AS1.1 and did not see any reason to change. A few students in the class were off task all the time and their comments in the survey reflected this.

7.3 School Terms 3 and 4 – Practical Work in Science

School holidays were a much anticipated break in the middle of winter and having completed the internal assessment for year 11 both students and teachers welcomed the holidays. Term 3 started on 17 July 2006 and continued to 22 September 2006. It included the second mock examination for external standards. Term 4, for year 11 was a very busy time and included revision in preparation for the imminent external examination, school prize giving and associated practise times, study leave, and examination in mid November. This reduced the opportunity for data collection in term 4 and therefore data for terms 3 and 4 are combined.

This section includes data from classroom observations (schedules, running records) of eight observed lessons that included some practical work (two revision lessons although observed are not included as they did not include any reference to investigation or practical work and did not contribute towards the focus of this research), teacher reflections of observed lessons, the third student focus group interview (2 November 2006), the third science teacher interview (9 November 2006), the second student questionnaire (18 October 2006), document analysis, and student external and internal assessment results.

7.3.1 Observations, running records and teacher reflections

The teacher started the term reminding students of the need to prepare for the examination of external achievement standards. The summary of the eight lessons observed, selected practical work and investigation, and summary of student engagement are presented in this section.

Outline of lessons observed

Term 3 observations

In the first lesson, observed lesson 12 (20 July 2006), for term 3 and 4, the teacher had planned an expert jigsaw activity. A jigsaw is a group work strategy where students assemble in 'expert groups' and read information and summarise it. Then they regroup in 'home groups' where one member from each expert group shares the information they have learnt. The lesson involved learning about bird flu that was a current issue and relevant as they were studying the topic of micro-organisms:

> Students were working in teacher selected groups and have to read and summarise the resource material provided. They were all engaged for the entire lesson and completed the tasks. When students were presenting their information to the rest of their group those students who almost never pay attention were attentive. This has been an interesting lesson where students were motivated and their presentations showed that they had learnt from doing this task. (Observation notes, 20 July 2006)

Observed lesson 14 (3 August 2006) involved exploration of "dry ice". The tasks were set up around the laboratory as stations with instruction cards and associated equipment. Students moved from one activity to the next following the instructions on the cards at each station and recording their observation. This activity is described in detail in the next section.

In the next observed lesson, lesson 14 (10 August 2006), students made models of alkanes using 'sticks and balls'; most managed to make methane and ethane. At the start of the lesson, some groups settled down faster than in any other observed lesson. But this did not last beyond the first 10 minutes.

> Ed, Harry and Ken are away today so the others are less distracted. (Observation notes, 10 August 2006)

In the second half of the lesson, the teacher set up equipment to demonstrate fractional distillation of crude oil. The students were asked to go to the front of the room.

> Only six students went up, the rest are sitting and chatting, oh no the fire alarm has gone off. (Observation notes, 10 August 2006)

We left the room to assemble outside for the fire drill. When we came back it was lunch time.

Observed lesson 15 (17 August 2006) involved investigating the energy content of different fuels. It was an investigation from the workbook that involved planning and carrying out the investigation within one lesson. This is described in detail in the next section.

The next observed lesson, lesson 16 (31 August 2006) was the first lesson on the topic of genetics. For part of the lesson the teacher demonstrated extracting DNA from a cauliflower. This was followed by an activity to learn about punnet squares which involves working out probability of inherited characteristics. At the start of this activity most students were interested and participated in it. Once they had worked out how the counters could be used to make punnet squares they lost interest and while the teacher helped those who needed support the rest of the class very quickly went off task. For the groups in the front it was a good learning experience:

> It is easy to learn like this. I can see it works and I can do it myself. (Emily, Observation notes, 31 August 2006)

The students were to do a task using a pedigree chart. Phil and Emily were working through the worksheet and completed the task. Like most of the class, Harry was sitting and chatting:

Researcher:	Why are you not doing this task?
Harry:	It is too hard.
Researcher:	You have just been doing the other task. You can do it.
Harry:	No I can't. I won't pass anyway.
Researcher:	Why do you say that?
Harry:	I still need 66 credits. Would have to achieve in every achievement standard. And I don't need science anyway.

Ed who was sitting in front turned around and added:

> Ed: I don't need science either miss, I want to be an actor. You only need English for that.
>
> (Observation notes, 31 August 2006)

This lesson was the first indication that while some students were learning and gaining confidence, others were seeing it as a hopeless situation as they realised they would not do well in the external achievement standards. It appeared that Harry and Ed had lost all motivation to learn and were looking for reasons to be off task. The following week students were to sit the second mock examination which would assess all the external achievement standards.

Term 4 observations

Term 4 started on 9 October 2006. In the first observed lesson, lesson 17 (12 October 2006), the teacher returned the papers for the second mock examination for the year. This assessment included all external achievement standards and paralleled the formal final examination which was only a few weeks later. The teacher went over the answers but except for the two groups on the front benches the rest of the class did not pay attention. In the last 15 minutes the teacher showed them a video to which the class paid more attention. A notable aspect of the feedback given to the students was that:

> While going through the answers of the mock exam paper the teacher tells the class what they could have written to get an Achieved and in two questions what was required for a Merit. They did not say what the students needed to write to get an Excellence. (Observation notes, 12 October 2006)

This was also highlighted in the following teacher reflection of this lesson:

> I think there are about eight students who could get a Merit. Jessica could possibly get an Excellence. More are likely to get an Achieved. The mock exam results have been good and I will be giving them coaching to help. (Teacher reflection, 12 October 2006)

In the second observed lesson in term 4, lesson 18 (19 October 2006), students explored electrical circuits. In this school, electricity was taught in year 10. According to the teacher, it only needed revision and extension in year 11 because there was considerable overlap between the years 10 and 11 content (see Appendix 17). The task in this lesson was for students to make series and parallel circuits. The teacher used the analogy of a ski slope to explain the ideas of current and voltage. The students had electrical equipment and the task from their workbook. Some played with the equipment making up circuits and Harry was determined to work out how to blow the bulbs. The teacher was helping the groups in the front:

> Those students who are taking interest and working through the task can explain the science ideas and draw circuit diagrams. (Observation notes, 19 October 2006)

The teacher's intention was for them to have a clear understanding of what happens to current and voltage in series and parallel circuits:

> Students grasp the concept of voltage more quickly than they do current, so the activity here involved having students set up series and parallel circuits as well as one lamp by itself, and measuring the voltage in various parts of that circuit. So students did have time during that remaining part of a lesson to take some voltage measurements but we didn't really have time to review what they found. (Teacher reflection, 19 October 2006)

In term 4, observed lesson 19 involved use of models in astronomy (26 October 2006). This lesson was the last lesson observed. The following week was to be used for revision before students left on study leave. The students were not focused at all and the teacher had them working on tasks from the text book. The teacher then used an overhead projector to demonstrate day and night. Students were to come up and use the model to see for themselves but only a few were interested:

> There's certainly a lot of raw interest in astronomy, so some students who had been less engaged during some of the other topics, are certainly showing more of an interest at this point but there's still a few that are not doing as much work as I would like them to be doing, for sure. (Teacher reflection, 26 October 2006)

When the noise level increased, the teacher said:

> If you continue not to pay attention, I will add extra time and you will make it up at lunch time. (Observation notes, 26 October 2006)

This quietened the class down for long enough for the researcher to thank the class for their input in this research and to wish them luck for the examination. There was a mismatch here between the teacher reflection and researcher observations. Perhaps this was because the teacher was focussed on those few who were willing to participate and the researcher was able to observe the whole class.

Both the electricity and astronomy topics provided opportunities for students making or investigating models but there was little evidence of this. Where models were used level of engagement was low.

Selected practical activity: Exploration of dry ice

This activity was selected as an illustrative activity because in year 9 students had done similar exploration of dry ice and it demonstrated that those who remembered the science ideas either did not engage or treated it as play. The activity was set up as stations around the laboratory like the energy exploration the class had done in term 1. Students were told that they would be doing dry ice activities if they paid attention in the first part of the lesson. The teacher gave them instructions after doing a recall quiz for the first ten minutes of the lesson. The activities were set up around the room with instructions about what they should be doing:

> There is a lot of excitement and students are going around and doing the activities. The noise level is getting higher and higher. Bob and Sarah are not engaged which is unusual. Sarah is quietly reading a fiction book. (Observation notes 3 August 2006)

Bob came and sat down next to the researcher, which was an opportunity to find out what he had learnt and why he was not doing the activities:

Researcher:	What did you learn?
Bob:	How to be an idiot and muck around (Points to those being silly)
Researcher:	What did you learn about dry ice?
Bob:	I learnt nothing new.
Researcher:	Can you tell me a science idea for each of these activities?
Bob:	Dry ice changes from solid to gas, does not turn to liquid. It sublimates. Carbon dioxide is heavier than air so it can blanket a fire and put it out. So we use it in fire extinguishers.
Researcher:	So carbon dioxide puts fires out by having a chemical reaction with the fire?
Bob:	No it cuts off oxygen by making a blanket over the fire. Fuel needs oxygen to burn.
Researcher:	What else did you learn about dry ice?
Bob:	When it dissolves in water it makes it acidic. Blue litmus turns red. That rude noise it makes is because, when you press down with spoon is because it is sublimating and trying to escape and you're putting pressure on it. If you push it along the table top it glides like a hovercraft.
Researcher:	How did you learn all this?
Bob:	We learnt this last year and in year 9. (Transcript of informal audio-taped conversation, 3 August 2006)

After the above exchange, Bob went back to his seat. The rest of the class continued to play with dry ice until the end of the period. There was no time for the teacher to close the lesson and find out what they had learnt.

Selected Investigation: Measuring energy content of fuels

This lesson was selected because it was a fair testing type of investigation, but for most students this was new learning. It was one of the lessons where there were glimpses of a 'wow' element. Students in the focus group remembered and talked about it so it was a memorable event for some. The purpose of the investigation (17 August 2006) was to compare the energy released by different fuels. Students were asked to use the templates in their workbook to plan this investigation and then to carry it out. They talked about dependent and independent variables. The teacher walked around the room to check.

> Students except for the two rows in the front are making no effort to get started and are wasting time. It appears they have no idea as to what needs to be done. Basically they need to put 50 ml of water in a test tube and put it on the retort stand. Measure the initial temperature of water. Then collect some fuel in a bottle top. Put it under the test tube and light it. When it stops burning they have to measure the final temperature of water. Repeat this with each fuel and compare rise in temperature each time. (Observation notes, 17 August 2006)

The teacher went through safety reminders. Students were interested and keen to get started. There was a lot of excitement in group 3 in the front when they burnt diesel and saw bits of carbon and a lot of smoke coming out. The three groups that almost always got on with the task did the task as requested and worked out which fuel released most energy:

Researcher:	What did you find out?
Susan:	Miss, you can't see when alcohol and kerosene burn.
Researcher:	Then how did you know they burnt?
Susan:	The temperature went up. It went up a lot, alcohol was the hottest.
Researcher:	The hottest?
Susan:	It heated the water and it made it boil.
Researcher:	And which fuel gave the least energy?
Susan:	Definitely diesel, and look at the test tube it is all black and yucky.
Researcher:	And why was that?
Susan:	Diesel does not burn cleanly, we should not use it, it pollutes the air.

(Transcript of audio-taped casual conversation, 17 August 2006)

Another student Harry had set up the equipment. He was about to light the fuel that was placed under an empty test tube with a thermometer in it. When asked why he was about to heat an empty test tube he said, "that is what Ken is doing". When probed further it became clear that Harry had not read the instructions or listened to the teacher. He just decided to copy what his friend was doing and had not noticed that Ken had water in his test tube.

The bell rang and the lesson ended. There was no time to sum up the lesson and ascertain what students had learnt. The teacher asked the class to tidy up and kept two students in to do some writing, "which the whole class deserved" (observation notes, 17 August 2006). In their reflection of this lesson the teacher said:

> There was a little bit of a disappointing uptake with this experiment in that certainly the group at the back consisting of Andy, Susan, Linda I think, Harry, didn't get into it, in fact they didn't even set anything up at all, which is disappointing. Earlier in the year and with a different experiment which had less hazards, I would have put more pressure on them, but my priority really was to maintain the safety factor of those who did choose to participate. (Teacher reflection, 17 August 2006)

7.3.2 Student engagement in terms 3 and 4

The teacher continued to do practical work and investigation through terms 3 and 4. The summary of student engagement in the class is presented in Table 7.7.

Table 7.7: Student engagement in year 11 science class in terms 3 and 4

Student Engagement in each quarter	Student Engagement in Lessons							
	12 Jigsaw 20 July	13 Dry ice 3 August	14 Fractional distillation 10 August	15 Energy released by fuels 17 August	16 Extracting cauliflower DNA 31 August	17 Mock exam review 12 October	18 Electrical circuits 19 October	19 Astronomy models 26 October
First ¼	Most - group 5	Most - group 5	Some - groups 3,4,5	Few	Most - group 5	Few	Some - groups 3, 5, 7	None
Second ¼	All	All	Few	Few	Few	Few	Some - groups 3, 5, 7	Few
Third ¼	Most - group 5	Few	Few	None	Few	Few	Some - groups 3, 5, 7	Few
Fourth ¼	All	None	None	None	Some - groups 3, 4, 5, 7	Some - groups 3, 4, 5, 7	Some - groups 3, 5, 7	Most - group 5

At the start of term 3, students engaged with the work in the first week and worked for almost the entire lesson but from the following week a trend appeared where students were less and less engaged as each lesson progressed. Most lessons ended with students leaving without tidying up. No data are reported about groups 6 and 8 as these groups had students who did not participate in this research.

Another notable point was that in each observed lesson the students had undertaken practical activity but the lessons ended without summing up and finding out what students had learnt. It would appear that the engagement had been about doing an enjoyable activity.

7.3.3 Third focus group interview

The last interview took place on 2 November 2006, just before the end-of-year examination. All six participants came to the interview. They were asked questions about their learning, science experiences outside the classroom, who they asked for help, what they enjoyed about science, and if they had the freedom that they would like to investigate. First, they were asked to give some examples of science ideas that they had learnt through investigating this year:

> Jake: Probably one where we burnt different fuel, different products of crude oil like octane and kerosene. And people rant on about how certain chemicals like diesel are more toxic because they produce more fumes but you don't get to see it that much. But when you actually see smoke and soot, what actually happens when it burns, like the difference between octane and kerosene or diesel and that, you can actually see, or in some cases smell the difference. (Jake, 2 November 2006)
>
> Researcher: Which one of those gave out more smoke and smell?
>
> Bob: Oh definitely kerosene, it's heavier.
>
> Ed: I had fun catching the carbon that was floating in the air.
>
> Pip: My favourite was probably the electrical one about parallel circuits, the way current divided and completed a circuit. You don't really know if that's true or not but then when you do it you see how the light changes and all that.
>
> Jeff: Yeah I know that, because when they tell you you're not too sure if it actually does but when you get to investigate you can actually see it happen before your eyes.
>
> (Third focus group interview, 2 November 2006)

The others could also name their favourite investigation and what they had learnt from it. Next they were asked what topic in science they enjoyed the most and why? There was agreement that they all liked chemistry best. And why was that?

> Because I had (the teacher's name) again this year, and because I had (them) in year 9 and I understood (their) way of teaching and stuff. (Teacher) is so knowledgeable in chemistry and can explain things. (Simon, third focus group interview, 2 November 2006)

When asked about what other science they had done that they had really enjoyed, Jeff, Bob, and Jessica remembered visiting Victoria University of Wellington:

> Bob: It was free. It was great because we learnt about radioactive materials and we actually got to see firsthand. They had samples of radioactive materials that produce quite a bit of radiation and we were able to measure how much radioactivity was being pumped out by all these things.
>
> Pip: We got to use different instruments that we don't have at school.
>
> (Third focus group interview, 2 November 2006)

Students were asked what they would like to investigate if they could do anything they liked. Pip wanted to do fieldtrips. She had loved going to the rocky shore in primary school and being able to explore. Others agreed that fieldtrips were great even if all you saw was a cow (on a recent geography trip). Jessica wanted to investigate gun powder:

> If I was allowed to do it, legally, you see I do shooting… so we have to load our own bullets with different gun powders for different ranges. And I was thinking well maybe since the bullet… maybe you can make different grades of gun powder and test how powerful it is, how much kick it's got behind it. That is what I would like to investigate. (Jessica, third focus group interview, 2 November 2006)

This suggests that Jessica understood about investigating, she had a question and proposed a way to answer it.

Here is what Bob, who expressed real interest in science, wanted to explore:

> Probably jump in a rocket and go around the solar system. Wanting to prove, because we learn about how there's all these different things out there, but you don't really know. I just want to prove, not to anyone else, just to myself that it is true and they exist. (Bob, third focus group interview, 2 November 2006)

Overall, this group of students had participated in science (to varying degrees) and they had all appeared to have learnt some science through investigating. Most were curious and knew what science they would like to do if given the opportunity. It appears that even though AS1.1 promoted a narrow view of science investigation, the focus group understood what an investigation was, the students articulated what they wanted to investigate and knew how to find the answers to their questions.

7.3.4 Results from Questionnaire Two: Learning and motivation

Students completed this questionnaire towards the beginning of term 4 during a lesson when the teacher was on leave (18 October 2006). This was not the usual observation day but the opportunity was used to collect the data. The questionnaire was administered by the researcher; it took less than 15 minutes to complete, and 23 students out of 24 responded. Although this lesson was observed it has not been reported as students revised for an end of topic test and they were supervised by a reliever. The purpose of the questionnaire was to gather students' views about their science learning and motivation to learn. Coding and analysis were conducted by hand.

Most enjoyable aspect of science lessons (Question 1)

The most enjoyable part of the science lesson for most students was when they were doing practicals (10), doing experiments (6), and learning new topics (2). For other students it was the end of the lesson/leaving (4), and talking (1). The reasons offered by the students for enjoying the aspects of the lesson they found enjoyable were that it helped them to understand or learn science (8), because they liked to do things and they learn better by doing it themselves rather than being told (5), because liked to work with their friends (3), and because they liked blowing up things and it was fun (2). Others said because they did not have to write for the whole period (3), and got to pack up and leave (2).

What students did when they had difficulty in understanding a science idea or task (Question 2)

Most asked the teacher for help (10), some asked their friends or people sitting next to them or those in class who were 'brainy' (6), looked in their books (2), and "I think and then ask the teacher" (Respondent 9). Others said they gave up and stopped doing the task, moved on to the next question, doodled, and drew a picture.

How students know they understand a science idea (Question 3)

Students said that: they knew they understood when they could answer the question without help and could do the task (6); they could explain to their friends (4); "that is pretty obvious, I can do it!" (Respondent 21); "I keep trying until I can figure it out" (Respondent 1); they could answer Merit questions (1); and they were not confused (1). Three said they never understand science. There was no response from nine students.

Understanding a science idea when they were not in the class (Question 4)

This question asked the students what they did when they were not in class and could not understand a science idea. The students said that: they asked the teacher in the study period (5); asked mum or dad (2); asked other family members (2); rang their friends (3); searched on the internet (2); looked up in their science book (3); and came up with their own science explanation (1). Others: did not care (2); did nothing or skipped the question (1); "asked a nerd" (Respondent 21); and "I get kicked out and sit in the sun" (Respondent 3).

Summary of second student questionnaire

Most students said they enjoyed doing the practical aspects of science. Their reason for enjoying the practicals was that they learnt or understood the science by doing it. Others enjoyed the 'doing' because they did not have to do the written work or they could work with their friends. Some enjoyed it because it was fun. When they did not understand a science idea in class, most asked the teacher or their friends. A few looked up their books. Out of class, when they needed help in understanding: they asked the teacher during the study period; they asked their parents or other family members; a few rang their friends; and some looked for the answer on the internet or in their books. In their response to how they knew that they understood something they said: they could answer the questions; were not confused; or could explain it to their friends. Five students in the class no longer cared about learning science or understanding it and their answers were negative for each of these questions. It appears that they did not see the links between learning and understanding science ideas and investigation.

7.3.5 Third study class teacher interview

In the last interview (9 November 2006) which took place in the science department workroom, the focus was on gaining an insight into the teacher's views about issues related to student learning, motivation to learn, and how in the teacher's perception students were likely to perform in the examination. At the start of the year, in the teacher's opinion, a number of students should not have been in the class. In response to a question about the characteristics of these students and why the teacher thought they should not have been in her/his class, the teacher said:

> Well there were some students that I'd taught before, and I knew as soon as they walked through the door, I thought, oh they ought to really be in the alternative science group. Thinking of Harry, Ed probably, certainly Henry and in hindsight one or two others, Ken, probably Len and ….. What were their characteristics? Well for Harry and, for Henry particularly, just academically I knew that he was quite limited in the conceptual level of difficulty that he was going to encounter, it was always going to be quite challenging for him. Ed is a bit of sort, he's one out of the box really. I think, you know, just laziness in the past couple of years has characterised how he's been. Lack of a willingness to really engage in the work that matters in terms of passing the assessment, although in his case I think he probably will get quite a lot out of the year but in different ways. (Third teacher interview, 9 November 2006)

According to the teacher, none of these students were likely to achieve any standards and the teacher had not changed her/his opinion about these students over the year. When asked how the class had progressed over the year, the teacher said:

> I've found them a challenging class to deal with, partly because of having, teaching them on the opposite side of the school to where my sort of base is, they don't come to me and so I can't build up the sort of rapport with students as they come into the class but I have to trek over to there, you know, just some of the personal contact was lost a bit. There are quite a number of students in there who are really not well motivated, so it was a challenge to help them through … I would say that if you take them individually, half to – two thirds of the class have progressed well, a third not as well as I would have liked. (Third teacher interview, 9 November 2006)

As the teacher had found the class challenging, in a follow-up question s/he was asked what changes s/he would make to address this issue. The teacher said:

> On a big picture level we are actually structuring the year 11 course such that around about twenty percent of the kids who do the regular science course will actually be channelled into a slightly slower paced course, so I suppose that would take care of a bunch of those kids. They will be picked

> on their performance in year 10. So fifty, approximately out of 220 students are going to be taking a slightly slower pace, but not as slow as the alternative science. (Third teacher interview, 9 November 2006)

The teacher was concerned about the behaviour of some students and their motivation:

> I mean self motivation is a factor there for some of them, the behaviour or core behaviour of some of them influenced some of the others I think, the environment that they were surrounded by, I think Nikki is probably one there that if she'd been in a situation where she'd been surrounded by more motivated kids I think she would have got more out. (Third teacher interview, 9 November 2006)

When asked about the teaching strategies that the teacher used, her/his response included doing 10 questions at the start of the lesson, doing practical activity as often as possible, giving a short test every Friday to tie down the learning of the week, and keep the class settled. The expert jigsaw and the exploration investigation both of which had a high level of engagement were not mentioned which, according to class observation notes, had been the most successful teaching strategies in terms of student engagement, learning, and motivation.

The study did not focus on the achievement of Māori students. However, there were five Māori students in the class (school record). In response to a question about how in her/his view Māori students' learning could be optimised in science and especially in science investigation, the teacher said:

> I think Māori student learning in general can be optimised by having a reasonable proportion of group work with perhaps discussion of ideas, feedback within groups, groups giving feedback to the class perhaps, and in science investigations, well perhaps …, they'd do best if they're following that logic, if they're working with other people. (Third teacher interview, 9 November 2006)

In the teacher's view there was a difference in the learning needs of Māori girls and boys:

> Well the boys are particularly, I think, work better in a group. I'm thinking in that class with Mili, I mean she was actually very motivated, certainly later on, during the course of the year but I think for both girls and boys, they really do need to have a strong rapport between the kids and the teacher and frequent one-to-one work with the teacher. (Third teacher interview, 9 November 2006)

The teacher held a position of responsibility and was asked what challenges that brought with it?

> ...huge factor, because certainly you've got on a day-to-day basis my responsibilities are torn between those two areas and certainly the amount of energy and focus that I can put into my teaching is compromised. I find, it's a big difference compared to when I was just doing the teaching and perhaps focussing more on a bit more planning or whatever it might have been. (Third teacher interview, 9 November 2006)

The teacher said that s/he had been given time and adequate remuneration but "really the biggest challenge for me is to balance the whole, that enormous workload and family life, there is room for improvement. I think really, in the answer to that, the balance isn't really there at the moment". Referring back to the workload and assessment issues, the teacher said:

> Don't let anyone tell you that NCEA has been here for a while and there are no workload issues. The administration is a huge workload on teachers and those who have management responsibilities. (Third teacher interview, 9 November 2006)

7.3.6 Student workbooks

The students used a workbook (Abbott et al., 2005) in science. The workbook comprised a set of booklets one for each science achievement standard in National Certificate of Educational Achievement Level 1. These workbooks were set out like the AS1.1 templates and often used the terms investigations, experiments, and practical activities interchangeably. Student workbooks were collected by the teacher and were sighted by the researcher twice during the course of the year. Non-participating students were taken out by the teacher before passing on the set to the researcher. Each time, only 11 or 13 booklets were handed in for marking. The rest of the class had either lost their workbook or did not bring it to school on the day.

Workbooks were checked the first time on 11 May 2006. In six of the 11 workbooks handed in all tasks covered at that point in the year, were complete, and reports were written for each practical task and investigation. The rest (5) were partly complete, and mostly the part of the task done in the class was written in four work books, but the work they were asked to complete for homework was not done. In one only, the data tables were completed.

Workbooks were checked for the second time on 12 October 2006 when 13 workbooks were handed in to check. The standard of work and completion of tasks was better for the six students who had completed all tasks when the books were checked the first time. Five had incomplete tasks and in two almost all tasks were started but none were finished.

The workbooks provided easy-to-use tasks which were set out in the AS1.1 template format. They use the vocabulary that, according to the teachers, students need to learn. Workbooks provided ample opportunity for students to practise and learn the assessment format. However, they use the terminology investigation, exercises and practical interchangeably.

7.3.7 Study class National Certificate of Educational Achievement level 1, results for internal and external assessment

The students and school had given consent and access to the National Certificate of Educational Achievement results for these students for achievement standards assessed internally and externally. The school offered physics, chemistry, biology, and astronomy achievement standards. In the year of the study they also offered the organic chemistry achievement standard to students taking science. Practical investigation in the school was assessed through science AS1.1. Students were able to choose which external achievement standards they wanted to enter.

The results for internal and external assessment showed that students performed better in the internal assessment of science investigation with four students achieving a Merit grade, 17 an Achieved grade and only three did not achieve. None of the students received an Excellence grade. Only Jessica and Phil achieved in all standards and Harry and Linda did not achieve in any of the standards they entered. Seven students – Jeff, Craig, Len, Ken, Ed, Mili, and Henry – only Achieved in internal assessment. Overall, over half the students attained fewer than 12 of the 24 credits offered (Table 7.8).

In the study year (2006), the national and study school average for Achieved or better grade for AS1.1 was 83% (New Zealand Qualifications Authority, 2006a). The study class average for AS1.1 was slightly higher at 88%.

Table 7.8: Study class internal and external assessment results for NCEA Level 1

Achievement Standards	Science					Chemistry	Total
	AS1.1 Science Investigation	**AS1.3** Biology	**AS1.4** Chemistry	**AS1.6** Physics	**AS1.7** Astronomy	**AS 1.7** Organic Chemistry	
No. of Credits Internal/External	**4 Internal**	**5 External**	**5 External**	**5 External**	**2 External**	**3 External**	**24**
Jessica	M	A	M	M	M	A	24
Andy	A	A	N	A	N	N	14
Bob	A	N	A	A	A	A	19
Jeff	A	N	N	N	N	N	04
Craig	A	N	N	N	N	N	04
Amy	A	A	A	A	A	N	21
John	A	N	N	A	N	N	09
Len	A	N	N	N	N	N	04
Ken	A	Y	Y	Y	Y	Y	04
Jake	M	N	A	N	A	N	11
Emily	M	A	A	A	A	N	21
Phil	M	A	A	A	A	A	24
Nikki	A	N	N	A	N	N	09
Simon	A	A	N	A	N	N	14
Dan	A	N	A	A	A	N	21
Susan	A	A	A	N	A	N	16
Ed	A	N	V	V	N	V	04
Mili	A	N	N	N	N	N	04
Robin	N	N	V	A	N	N	05
Linda	N	N	V	N	N	N	00
Jamie	A	N	A	N	N	N	09
Pip	A	A	A	N	N	N	14
Harry	N	N	N	N	N	Y	00
Henry	A	N	N	N	N	N	04

Key: A Achieved, M Merit, N Not Achieved, V not appeared, Y not entered.

7.3.8 Summary of terms 3 and 4 science investigation

In terms 3 and 4, the teacher continued with practical work including investigation but in the lessons there was no closure to find out what students had learnt. Student engagement declined over the terms, but was variable depending on the activity. Sometimes, they did not engage because they said they already knew the answer and found it pointless. One investigation that excited the students was burning different fuels to determine which released more energy. The reason offered during the focus group interview was that they could 'see' the carbon floating in the air and they could make the connection to diesel being an atmospheric pollutant.

In the teacher's opinion, this was not a very capable class and s/he identified several students who in her/his view should not have been in this class. The department proposed setting up a class in the following year that would have students who would work towards an Achieved grade only.
The teacher understood the importance of building relationships with the students but said that s/he found it difficult because s/he was not teaching in her/his own laboratory and had to carry the equipment around and ended up setting up at the start of the lesson rather than engaging with the students. The teacher said that Māori students learnt through group work and presenting their work orally to the class but there was no evidence of this taking place.

Students preferred doing practical rather than writing. In the second questionnaire, students said they asked the teacher when they did not understand something. Out of class when they did not understand something, they ask their parents or friends, looked at the internet or looked up in their books. Five students no longer cared and their comments were negative.

The results of AS1.1 showed that only three students did not gain an Achieved grade for AS1.1 and the class exceeded the school and national average by 5 percentage points, suggesting a possible observer effect. Only half the students in the class managed to get 12 or more credits out of the 24 offered in science, most achieving more credits in the internal assessment than expected.

7.4 Chapter Summary

This was a lively class of 31 students with an experienced teacher. Twenty-four students participated in the study, 16 boys and 8 girls. The teacher believed in making science interesting and relevant to the students' lives and included practical work in their teaching for more than half of the observed lessons throughout the year. Most students appeared to be engaged when they were doing the hands-on component of practical work irrespective of the placement of the practical work within the lesson. The purpose of the practical work differed from lesson to lesson. Sometimes, students explored and learnt science concepts through doing activities.

At other times, they carried out an investigation. The types of investigation taught were mostly of the fair testing type, for example, investigating heat retention and energy released by fuels. Other types of investigations included exploring (energy changes and dry ice), pattern seeking (investigating the relationship between height of the ramp and distance covered by a toy car), and using models (exploration of day and night through using a projector, making models of alkanes). It can be said that these investigations were not ideal open-ended investigations as the students did not come up with the question to investigate and other than the fair testing investigation were not required to plan the investigations to answer their own questions. These investigations were teacher directed and sometimes like 'recipe practicals' where the students mostly followed the directions in the workbook. The teacher's description of science investigation was what was required for assessment of AS1.1.

Students preferred doing small practical activities compared to investigation that sometimes took up to three lessons. Some liked variety in the lesson rather than doing the same thing for the whole lesson. The teacher said that s/he believed that students enjoyed practical work, and having open-ended investigation where students had more freedom to choose what they wanted to investigate was motivational and they got a 'buzz' out of doing such investigation. However, students did not have the choice as all investigations were teacher or workbook directed. The results of the science laboratory environment inventory showed that the students did not want more open-endedness.

In term 2, the focus was on following the requirements of internal assessment of a fair test. The teacher gave students several opportunities to learn the terminology needed for AS1.1 and familiarised them with the format to be used for assessment.
One investigation the students said prepared them well for AS1.1 was very similar to the one done for the final assessment. The students had a formative assessment as a trial run and those who handed in their books found the feedback useful for preparation of AS1.1. The teacher said that s/he believed that AS1.1 was making her/him and other teachers do investigation in year 11 even though there was too much content to be covered.

Assessment of AS1.1 was organised in the college hall. The students did the planning in class in one lesson. They carried out their investigation during the mock examination week and wrote the report in the following week. The students did not complain that this 'complete' investigation was carried out in three parts. Even though some students were surprised with their lower than expected results, they were accepting of them and said that they needed to have revised and studied if they wanted a better grade. Only three out of the 24 students who participated in this study did not gain an Achieved or better grade for AS1.1. Contrary to teacher expectation, four of the five students s/he thought would not gain an Achieved grade did so. However, no student gained an Excellence grade and only four a Merit grade.

Student engagement and behaviour was of some concern to the teacher. Two students were constantly sent out of the class for poor behaviour. There were five or six students who seldom did any work and often managed to distract other students. As the year progressed, these students engaged less and less and it was observed that the teacher occasionally dealt with the issue by either keeping one or two students in during lunch time to speak with them or get them to do some of the work they had not done. Through talking with students who did not engage in class, two points emerged: one that some of the practical work the students were doing they had already done in the previous year; and the other that results of the investigation they were being asked to do were so obvious that some students did not see any point in doing them.

Students said that they learnt science concepts through investigating. Students were able to answer questions about what they had learnt but whether they had learnt it in this class or it was prior knowledge was not clear. The class was offered help with science during their study class and in out-of-class revision lessons by the study class teacher and could attend the revision lessons offered by other science teachers. A number of students reported that they asked the teacher for help. The teacher also helped these students during the lesson while the rest of the class chose to engage or not engage in the task on hand. Most of these students achieved a grade of Achieved or Merit in AS1.1. However, overall less than half achieved 12 credits out of the 24 offered in science. The internal assessment had a higher achievement level than the external assessments. The results of AS1.1 for the study class were better than the school and national results for AS1.1.

The students reported that the most enjoyable aspect of science was doing the practical work. They enjoyed it because it helped them to understand. Students enjoyed working with their friends and in response to the second questionnaire they said they asked their friends for help. The results of the science laboratory environment inventory also showed that the students preferred more cohesiveness and an opportunity to support their peers. A number of these students did not participate in activities and, according to the teacher, these students were not motivated.

On the students' part, as the year progressed, some could see that achieving was no longer within their reach and gave up. The teacher said that when the class walked in at the start of the year s/he saw a group of students who in her/his view did not belong in this class and should have been in an alternative science class. This view was based on having taught these students in year 9 when s/he had found these students had limited ability in understanding science concepts. The teacher's view about these students' ability did not change over the year.

Both students and the teacher believed that the National Certificate of Educational Achievement credits were the motivator for learning science investigation in this class. The teacher's solution for classes like this was to change the policy of having just one alternative science class – s/he would have a class for those students who would work towards getting an Achieved grade only.

This chapter presented the results of the class case study. Chapter eight discusses the themes that have emerged from the integration of results of the regional science teacher survey, the school case study and the class case study.

CHAPTER EIGHT
Discussion

This chapter draws together the results reported in Chapters five, six and seven to construct a case study of the phenomenon of school science investigation in year 11 in New Zealand. The overarching aim of the research was to understand the connectedness between motivation to learn, learning, and assessment of science investigation within year 11 school science. The research involved studying the phenomenon from the perspectives of teachers and students and by direct observation. The resulting data were integrated, analysed, and interpreted. The following ten themes emerged from the integration of the results.

8.1 Science Investigation as a Linear Process

Teachers saw “science investigation” as a sequence of steps. Regional year 11 science teachers’ responses to the questionnaire identified features of science investigation that best supported students’ learning to include, most often, conducting “experiments” or carrying out the “scientific method”, less often undertaking “fair testing”, and rarely “topic-based investigation”. The common aspect of each of these responses was the inclusion of a sequence of focussing, planning, data gathering, processing, interpreting, and reporting, in part or in its entirety. During the study school science teachers’ interviews a further insight was gained into teachers’ understanding of science investigation which showed that some teachers were able to reconcile different perspectives on science investigation.

Most regional science teacher responses described “experiments” as trying things out, gathering information or interpreting it, and in the interviews teachers used the term experiments for any practical work done in science. This is consistent with McNally’s (2006) and Wellington’s (1998) findings that teachers often did not understand clearly what they meant by experiments. The results of this study do not suggest that generally “students can understand the characteristics of a scientific experiment” as required by *Science in the New Zealand Curriculum,* Nature of Science, Achievement Objective 1 (Ministry of Education, 1993a, p. 36). Teachers themselves may not have a clear understanding of what an experiment is. *Science in the New Zealand Curriculum* does not define an experiment.

Some teachers interviewed considered experiments as an activity to confirm a theory; for example, when a piece of magnesium ribbon is burnt the theory of oxidation would be confirmed. The notion of an experiment as testing to confirm a theory is in congruence with Abrahams and Millar's (2008) description of experiment as "a planned intervention in the material world to test a prediction derived from a theory or hypothesis" (p. 1947).

"Scientific method" as described by the regional teachers involved students starting with a hypothesis, writing a method, gathering information, writing results, and coming to a conclusion. The emphasis is on a linear and sequential process. According to Tytler (2007), emphasising the scientific method leads to thinking that science investigation is a linear process where steps are followed to get the right answer. However, Millar (2004) and Hodson (1993) argue that there is no one scientific method and that scientists follow many different methods when investigating.

According to Windschitl et al. (2007, p. 942), as implemented in school classrooms in the US "the scientific method [includes] … testing of predictions rather than ideas" and suggests that models could be used for testing ideas. Windschitl et al.'s key criticism of the scientific method is that it is a procedure and "not a way of thinking" (p. 947) and that in school science students may be able to follow the process and complete the investigation without engaging with the underlying science ideas or being challenged to think and reason scientifically.

The use of scientific method persists in year 11 science as evident in the regional science teachers' responses that identified the scientific method as a feature of investigation. The reason for this may be as suggested by Lunetta et al. (2007) who attributed the persistent use of the scientific method to a lack of confidence and limited understanding of the science ideas on the part of the teacher, while Windschitl et al. (2007) argued that scientific method enables teachers to manage practical work in overcrowded classrooms.

Fair testing was identified in the regional teachers' responses, and some teachers interviewed described investigation as fair testing. These teachers described fair testing as part or all of a linear process of planning, gathering, processing and interpreting data and reporting information. Critically, it includes identifying and controlling of variables. This understanding of fair testing investigation is frequently referred to in *Science in the New Zealand Curriculum* and is the type of investigation used for assessment through the National Certificate of Educational Achievement's AS1.1.

In contrast to the regional teachers' predominant views, only a few teachers cited a problem-based or topic-based open-ended process as a feature of investigation that best supported student learning and thus had a contemporary view of investigation. However, two teachers when probed during interviews clearly distinguished their understanding of investigation from the fair testing they taught for the National Certificate of Educational Achievement assessment. They described investigation as an open-ended and iterative process. This contemporary view has been theorised by Millar (2004) and in essence, involves identifying a problem or a question that needs to be addressed, as well as planning an investigation, experimenting to evaluate the process, gathering, processing and interpreting information, and reporting results. Millar (in press) says students may have some choice in selecting the question but this is not a defining feature of science investigation. In his view, critical evaluation of both process and findings is an essential component of an investigation. It is not linear and does not always lead to the right answer. Roberts (2009) in the United Kingdom and Tytler (2007) in Australia are in agreement with this view.

Teachers' understandings of investigation involve the processes of planning, data gathering, processing and interpreting, and reporting in part or collectively. This may be indicative of the influence of the curriculum, though the curriculum statement's concern with initial "focussing" and "problem-solving" are far less evident in teachers' views. Teachers' understandings have more to do with the National Certificate of Educational Achievement approach where the investigation begins with a purpose or aim and neglects concern with "focussing" and "problem-solving". The National Certificate of Educational Achievement approach requires the manipulation and control of a variable and is limited to a fair testing type of investigation. However, the most common terms used by teachers to express features of investigation were the traditional experiment and scientific method, which have a low profile in the curriculum and assessment documents. Despite this traditional understanding, investigation is mostly taught as a fair testing type of investigation and is discussed in the following theme.

8.2 Investigation in Practice: Fair Testing

Regional year 11 science teachers, when provided with a list of types of investigations, more often selected fair testing as the type of investigation they did with their class than any other type of investigation. All study school teachers interviewed said that they taught the students to carry out a fair testing type of investigation. For example, they talked about the need for students to "control variables” or correctly use “the template” which is designed for assessment of this type of investigation. The frequency of selection of “fair testing” regionally was closely followed by pattern seeking and classifying. However, in the study class, pattern seeking and classifying types of investigation were not observed and the study school teachers did not mention these in the interviews.

In the study school, students experienced the fair testing type of investigation before the National Certificate of Educational Achievement AS1.1 internal assessment. According to the teachers in the study school and as observed in the study class, teachers introduced exploration and use of models after the assessment was over. Experiencing fair testing in year 11 science is in agreement with Hume and Coll’s (2008) case study findings in New Zealand.

Regionally, and in the study school, more fair testing investigations were carried out when teaching physics or chemistry topics than biology or astronomy topics. According to Tytler (2007), such an imbalance occurs because it is easier to control variables in physics and chemistry. Evidence from this study suggests that in a “fair testing” investigation as practised in year 11, the design aspects of scientific investigation (planning) were reduced to the notion of variable control where the student was making a comparison between two options and controlling variables to test a hypothesis. In Lunetta et al.’s (2007) and Tytler’s (2007) views, investigating in mostly physics and chemistry contexts is problematic as potentially it could lead to students thinking that investigation is only done in these subjects.

Fair testing is specified in *Science in the New Zealand curriculum* through achievement objectives in the Developing Investigative Skills and Attitudes integrating strand (Ministry of Education, 1993a). The controlling of variables is an objective in the Making Sense of the Physical World contextual strand and thus is likely to have led to a teacher focus on fair testing. There is similar “over-heavy” emphasis on fair testing in the United Kingdom national curricula (Watson, Goldsworthy & Wood-Robinson, 2000). However, Wellington (1998) reported changes in the United Kingdom so that there is less emphasis on controlling variables that led to less fair testing even though there continues to be one “template” model for science investigation.

The study school science department documents reflected the implementation of the curriculum where the examples cited in the unit plans specified teaching of fair testing. Other types of investigation also required by the curriculum, such as pattern seeking (Ministry of Education, 1993a, p. 82) and classifying (p. 100, 118), were not mentioned in the school documents. Abbott et al.'s (2005) workbook emphasises fair testing but includes some tasks requiring other types of investigation, for example, exploration. The resources provided for the teachers on the Ministry of Education website also have more fair testing types of investigation than other types. This emphasis on fair testing in the study school unit plans is consistent with Hume and Coll's (2008) finding that the decision to focus on fair testing is made at the departmental level.

A particularly influential factor for fair testing, being the main focus for students' learning of how to investigate in science, is that the assessed investigation for National Certificate of Educational Achievement Level 1 is a fair testing type of investigation. Fair testing is therefore required to be taught and not surprisingly is found to be the focus of teaching and assessment. Although other types of investigation, including pattern seeking, classifying and exploration are included in the curriculum, they are not specifically assessed for National Certificate of Educational Achievement. The issues this raises are that if other types of investigation are not formally assessed they are less likely to be taught. More importantly, if students mostly experience fair testing they are likely to have a limited view of science investigation. The following theme highlights how the students learnt to carry out only the fair testing type of investigation.

8.3 Training to Investigate

The regional survey results, the study class teacher interview, and study school science teacher interviews showed that year 11 science teachers focused on training their students to undertake the fair testing type of investigation in preparation for internal assessment of science investigation. The approaches the regional teachers said they used included "repetition", "doing tasks similar to those assessed" and "practising fair testing". This approach was also taken by the study school science teachers who said they were "training" their students to investigate and "getting them to go through the hoops". Some of these teachers reported an emphasis on students learning the skills needed to investigate. Thus procedural knowledge rather than procedural understanding and conceptual learning were deemed appropriate preparation for AS1.1. Science teachers in the study school said that this was contrary to how they would ideally teach science investigation but in the interest of students' achievement and because students had to be assessed they were pragmatic and continued to teach "what would be assessed" and the view was that there was no choice. These results were supported through observation of the study class where students carried out several fair testing types of investigation and practised the skills of planning, repeatedly learnt about controlling variables and gathering and recording data. This training was reinforced by constantly using the template designed for AS1.1. Cleaves and Toplis (2007) similarly found students in the United Kingdom were trained to investigate and further, that the students were aware of this practice. They said, for example that their teachers told them to find anomalous results and explain them to get a better mark. This was also found by Toplis (2004), Keiler and Woolnough (2002), and Wellington (2005) in their research in the United Kingdom.

Some teachers in the study school said that prior to the assessment of investigation they stopped the biology topic they were teaching and gave students practice through doing formative assessment (mock examination) in a physics context that was very similar to the assessed task. The teachers then provided feedback to the students on how they could improve. This they justified by saying that they were ensuring that their students were not disadvantaged because they were doing a biology topic whereas the assessment was set in a physics context. However, in the regional survey “identifying alternative conceptions and gaps” was a reason for undertaking formative assessment.

Training for assessment involved an emphasis on what the students needed to write to achieve a particular grade, a practice noted also in the study by Cleaves and Toplis (2007). The National Certificate of Educational Achievement grades require a student to be able to describe their investigation to get an Achieved grade, explain their answer to get a Merit grade, and discuss their results to get an Excellence grade. Constant reinforcement by teachers of what students should do to achieve led to students wanting to know what they should learn and write to get the credits and better grades.

In the study school, revision lessons were offered to students at lunch time. According to the teachers, large numbers of students (up to 20 or more each time) turned up to these lessons of their own volition demonstrating “strength of will” to promote their success (Corno, 1992). The focus for the students to achieve, and the support for performance goals (Covington, 1998), was so much the part of teacher thinking in the study school that some teachers described students as the “Merit and Excellence kids” and the study class teacher said that there were “no Excellence students” in her class. Most students who wanted to do well in the National

Certificate of Educational Achievement and achieve a good grade were willing to attend in order to achieve Merit or Excellence. However, in the study class, those students who had not experienced success in the learning tasks and thought they could not gain an Achieved grade gave up. It appeared that there was little support for these students.

According to the student focus group, learning to investigate was largely memorisation. In the study class this was also observed; when the teacher asked questions the students gave “rote learnt” responses (although they may have understood but were not observed). This is contrary to the philosophy that underpins the curriculum and promotes learning for understanding. The study class teacher regularly opened the lessons with a quiz but did not build on any feedback to implement a constructivist teaching approach (Baviskar et al., 2008) which is promoted by the science curriculum (Ministry of Education, 1993a). There was limited evidence of finding out what the students already knew to address students’ alternative conceptions. One fair testing investigation that the study class carried out as formative assessment was the same task that the students had done in year 10. Some students resented having to do it when they had already done it in the previous year.

In Abrahams and Millar’s (2008) view and according to research findings by Roberts (2009), both conceptual and procedural understandings are needed to carry out science investigation. Instead of developing these two kinds of understandings to investigate, students in this study were trained to perform in the assessment of science investigation. In the next theme other changes in teacher practice relating to teaching science investigation since the introduction of the National Certificate of Educational Achievement are discussed.

8.4 Changes in Teaching Practice after the Introduction of NCEA

Teaching of science investigation to year 11 changed after the introduction of assessment of practical investigation for National Certificate of Educational Achievement Level 1. Of the region’s year 11 science teachers who had taught before the introduction of the National Certificate of Educational Achievement, 83% reported a change in their practice of teaching science investigation since the introduction of the National Certificate of Educational Achievement. Prior to 2002, when the National Certificate of Educational Achievement was introduced, assessment in year 11 science was norm referenced, but it is now standards based. According to Biggs

(2003), in standards-based assessment learning outcomes are defined and state what the learner has to do to achieve that standard. In this type of assessment all students can achieve if they have reached the set standard (L. Leach et al., 2003). The other significant change that took place for year 11 science was the introduction of internal assessment of practical investigation for National Certificate of Educational Achievement Level 1 science. Prior to the introduction of the National Certificate of Educational Achievement, there was no practical assessment of science investigation in year 11.

Some regional teachers reported that since the introduction of the National Certificate of Educational Achievement, they had changed the number of investigations they did in year 11 science. Of those teachers in the survey who reported this change in practice, a small number (n=8) said they were doing more investigations, more teachers (n=22) said they were doing the same, and a slightly larger number (n=24) reported doing fewer.

Teachers offered several reasons for the change in practice as being due to a change in assessment policy which required internal assessment of science investigation. Whether they did more, the same, or fewer investigations the main reason offered for the change in practice was due to assessment requirements rather than student learning. Another reason they gave was that complete investigation, a requirement of assessment, was time consuming and took up to three lessons. According to Roberts and Gott (2006), teachers in the United Kingdom had also raised concern about the time it took to carry out a complete investigation and consequently they did fewer. Other teachers in the United Kingdom said that the course was too full and there were management issues in carrying out more investigations, including lack of technician support and resources. Similar findings were reported in the United Kingdom in terms of Sc1 which is similar to AS1.1 in New Zealand (Donnelly, 2000).

The change in practice after the introduction of the National Certificate of Educational Achievement in the study school was that in the first half of the school year, before the assessment of science investigation through AS1.1, more time was devoted to teaching fair testing types of investigation. In the second half of the school year, after assessment, teachers said they reverted back to their pre-2002 practice of committing less time to fair testing and more time to other types of investigation and practical activities. This was observed in the study class where the teacher gave students the opportunity to explore, investigate, and use models.

Study school teachers highlighted two related changes in practice: one, they emphasised that students should learn the vocabulary required for AS1.1, for example “independent” and “dependent variable” and the “reliability of data”. These are crucial ideas to understand for investigation but they were perceived as the words that needed to be learnt rather than for the student understanding of these ideas. Wellington (2005) refers to building the bridge between “knowledge that” (observed phenomenon)", “knowledge what” (remembering facts) and “knowing why” (understanding the reason for phenomenon occurring) (p. 107). In this instance, students learnt that they needed to repeat the trial several times but did not know why they should be doing so. The second change which study school teachers said was made in response to pressure to improve student performance was training the students to become familiar with the template used for AS1.1. In the study school the template was used from year 9. One limitation of this template approach for learning investigation more broadly was that it was designed for fair testing types of investigation.

Most teachers followed the complete investigation process as outlined in AS1.1, which is linear and sequential (see 8.1). Complete investigation is defined in the curriculum, but the difference from the complete investigation for AS1.1 is that the curriculum sets out a recursive process where the student goes backwards and forwards as the investigation progresses and solves problems as they arise.

A noteworthy current assessment practice for over 75% of the region’s teachers and all the school case study teachers was to carry out formative assessment in the form of a mock examination or trial run, a practice also observed in the study class. Teachers said they saw advantages and disadvantages in using formative assessment of this kind. They reported that students valued the feedback that would help them to improve their performance. Teachers saw this as outweighing the disadvantages of workload, marking, administration, and management because it was helpful to students. Formative assessment in the form of a mock examination also helped teachers determine if the intended learning outcomes were met. Teachers in the study school and the study class teacher said that they gave feedback to students about what they could do to get an Achieved, Merit, or Excellence grade. Formative assessment, as applied by these teachers, was different to that described by Bell (2005) and Bell and Cowie (1999), which is assessment of learning “during learning” and “relies on teachers developing in their pupils an orientation towards learning as distinct from performance” (Cowie, 2005, p. 3). The view of performance taken by Cowie is a narrow view related to performing in a set task. However, teachers said they were providing feedback to the students, which is an element of formative assessment.

According to Bell and Baker (1997), “the curriculum is dynamic, for even though the curriculum document may remain the same for 10 years or so the planned, taught, learnt, assessed and hidden curricula are in a state of constant change” (p. 2). At the school level, in response to the assessed areas of the curriculum required for the National Certificate of Educational Achievement, such as the science investigation from 2002, significant changes were made in the way the curriculum was planned and taught in the study school. In the year of the data collection (2006), the study school offered achievement standards for physics, chemistry, biology, astronomy, and organic chemistry (externally assessed) as well as carrying out a practical science investigation with direction (internally assessed). The changes made to the teaching programme reflected the influence of this assessment at the departmental level. The unit plans that set out the content to be taught no longer integrated achievement objectives from different strands of the curriculum as was the practice before. Topics were named after the achievement standards, for example, Chemistry AS1.4 and Physics AS1.6, and only fair testing types of investigation were identified. Other practical work was referred to by workbook page references. Students learnt physics, chemistry, biology, and astronomy. Geology was no longer taught in year 11 as it was not assessed. Science investigation was mostly focused on fair testing which students learnt in physics, chemistry, and biology but were mostly assessed in a physics context. The very open curriculum was thus constrained by assessment requirements.

The following theme discusses the approaches teachers took in implementing science investigation.

8.5 A Pragmatic Approach to Investigation

Teachers responded to the assessment requirement of science investigation by taking a pragmatic approach and tailoring their teaching and assessment process to their specific needs. Task selection for teaching and assessment of science investigation (AS1.1) appeared to be dependent upon the availability of resources, manageability, and ease of administration. Resourcing needs included science technician support, physical resources including access to the laboratory, the equipment needed to carry out the investigation, the consumables, and access to text books which were sometimes shared between classes, as seen in the study class. Manageability aspects included teaching time, class size, and being able to manage difficult classes. Administration related issues included the ease of administration of assessment for a large number of classes, the timetable constraints of the examination week, setting up the assessment venue for all classes to be assessed, and supervision reported in science teachers' interviews.

In the study school and for half of the teachers responding to the survey, students purchased workbooks, mostly authored by Abbott et al. (2005). In the study school students purchased these workbooks which transferred the cost to the students thereby reducing the photocopying cost to the school. The study class teacher always had a few photocopies for those who forgot to bring their books to class. The type of investigation selected by the teachers sometimes depended on the tasks for learning set out in the workbook. A consequence observed in the study class was that the teaching of investigation became limited to the tasks offered in the workbook. This limitation of the teaching practice is similar to Lunetta's (2003) research in the US which found that teachers' assessment practices can be influenced by the "orientation of the associated laboratory guides, worksheets and electronic media" (p. 49).

The manageability of tasks with large groups of students and the related safety issues was a factor evident in the study class where, for example, the teacher was dispensing a variety of fuels to the students for an investigation. Her/his focus was on safety issues; consequently s/he was unable to get around the entire class to support all students' learning through investigation. Lunetta (2003) suggests that teachers spend too much time on managerial functions rather than on ways of teaching that challenge students' thinking. Another significant consideration for regional survey respondents for choice of task for AS1.1 was the convenience of having tasks available on the Ministry of Education website. The availability of moderated tasks reduced the prolonged process of writing a task and getting it externally moderated.

In New Zealand, McGee et al. (2003), during the curriculum stocktake, found that teachers reported lack of resources, time restraints, inadequate facilities, and little technician support to repair and maintain equipment and set up laboratories, as reasons for not using an investigative approach in their teaching. Further, in relation to National Certificate of Educational Achievement levels 1 and 2, secondary teachers in the stocktake reported that they found resourcing of their science programmes challenging. According to McGee et al. the issue is not just resource availability but a lack of time for teachers to adapt a resource to fit their requirement.

The main considerations in the choice of task for assessment, and AS1.1 in particular, were expense and helping students understand concepts. Teacher survey responses suggested that low decile schools that could not afford the resources sometimes selected tasks that were less resource intensive. Teachers, however, identified many competing reasons for selecting a particular task for AS1.1 and it was clear that the final decision would have required careful balancing of priorities.

Teacher workload and cost were the main disadvantages associated with formative assessment as identified by the teachers surveyed. Teachers in the study school used formative assessment as a trial run or a mock examination for students to become familiar with the AS1.1 format and to get a feel for the actual assessment (see 8.4). Regionally, teachers said there were many disadvantages in undertaking formative assessment which included added workload in terms of marking, preparation, organisation and management. Some teachers said there was a financial cost to the use of formative assessment as a trial run in large schools. Nevertheless, 78% of the teachers surveyed carried out formative assessment.

Although some assessment tasks are very resource intensive, for example, “Bubble trouble” requires complex individual equipment, such tasks are commonly used for assessment. Bubble trouble was most frequently used by the survey participants for AS1.1 and the second most frequently used by participants for formative assessment. It is possible that the popularity of this particular task arose from its use in national professional development when AS1.1 was introduced in 2002. A physics investigation, such as “Watch that car go”, the second most popular task for AS1.1, is less resource intensive requiring only one class set of materials, approximately 30 for an entire cohort; resources can be re-used for several years. Choosing a simple pendulum, the third most common formative assessment task used regionally is also less resource intensive. The fact that simple harmonic motion is neither required to be taught in year 11 by the curriculum nor assessed through the physics achievement standard, has not discouraged teachers from using it for formative assessment of investigation. Donnelly (2000) found that teachers in the United Kingdom also made resource dependent choices and said there was insufficient time and inadequate technician support.

Administration issues impact on the assessment choices made by the teachers. In large schools with many year 11 science classes, administration of AS1.1 is a logistical exercise. The teacher in charge of practical assessment in the study school pointed out that within the constraints of the examination timetable, competing demands on technician time and resources, selecting "Watch that car go" as the assessment task for AS1.1 was a pragmatic way of managing and administering the assessment in the school hall.

Lunetta (2003) in the US reported challenging factors for managing teaching and assessment of science investigation as large classes, inflexible timetables and perceived focus on the examination, which is similar to the issues reported by participants in this study. The next theme presents issues related to the assessment reliability and validity of assessment that arise from the choice of task and assessment process, including issues with assessment of practical investigation.

8.6 Reliability and Validity Issues with Assessment of Investigation

Assessment reliability is about consistency or accuracy of results across assessors and over time (Harlen, 2005; Hall, 2007). For assessment of investigation high "reliability would entail students getting the same results all the time irrespective of when the assessment is carried out and who marks it" (Harlen, p. 246). Training the students to achieve in assessment (section 8.3) may enable students to rewrite the same answers and get the same result if the same assessment task is used under the same conditions. This would not be an appropriate indicator of student understanding of science investigation and may compromise the validity of assessment. Some teachers in the study school said that even though a student may get an Achieved grade for AS1.1, they could not say if that student was capable of achieving it in a similar assessment. Hume and Coll (2008) in their case study found students who had been able to carry out a fair test involving rates of chemical reactions were unable to carry out an investigation in a physics context of simple pendulums although this is not in the curriculum. Reliability can be increased by doing five to ten assessments of investigation in different contexts and taking an average (Gott & Duggan, 2002); however, this is not a realistic option in New Zealand as it would be too time and labour intensive and could mean the curriculum would not be covered. Reliability can be increased by using a template and tightening the criteria (Gott & Duggan, 2002; Hodson, 1993); both are features of investigation used for AS1.1. Very easy or very difficult assessment tasks are likely to be less reliable (Kraska, 2008). The high level of student achievement in AS1.1 in the study school and nationally (both 83%) suggests that the assessment task was comparatively easy for students in year 11 and possibly not sufficiently reliable.

Another explanation could be that it was poorly implemented because students were trained and given plenty of direction.

Although the criteria have been tightened, the implementation it appears does not reflect this change for the most commonly used tasks for AS1.1. Both the task and marking schedule are available on TKI and are easily accessible to students. According to the study class teacher and New Zealand Qualifications Authority statistics, the same tasks have been used nationally for over eight years. Potentially, students can find out what the task is and prepare for it and write the expected answers indicated in the marking schedule to get an Achieved, Merit, or Excellence grade (see Appendix 20). Further, the study class teacher suggested that students would talk to other students and find out what they need to write to get an Excellence grade. In the study school where assessment took place in three lessons spread over two weeks, students had ample time to find out specific information required and use it in their report before marking and feedback had occurred.

Validity is an essential criterion for the worth of an assessment. Assessment validity is about how well the task(s) assesses what it is intended to assess (Harlen, 2005). A valid assessment provides information which is useful, appropriate, and accurate.

There are several types of validity of which face, construct, content, predictive, and consequential validity are relevant in this case. For the assessment task "Watch that car go", the judgement statement provided for the marker relates to the purpose of the assessment. Therefore, in respect of purpose, the task "Watch that car go" demonstrates face validity. Similar face validity is shown for other moderated tasks.

Construct validity is measured by aligning the knowledge and skills that the task ought to measure to what it actually measures. In the case of assessment for AS1.1, for example, the task "Watch that car go" is designed to assess students' ability to carry out a fair testing type of investigation with direction and allow for differentiation between Achieved, Merit, or Excellence. The task measures planning, controlling of variables, gathering, processing, and interpreting data and writing a report. Therefore, the assessment task is strong on construct validity for a fair testing type of investigation as defined by the National Certificate of Educational Achievement. However, the task is less valid for a fair testing investigation that includes focussing and problem-solving, as defined in *Science in the New Zealand Curriculum* or for science investigation more holistically.

The “Watch that car go” assessment task is also likely to have limited predictive validity because the results of the assessment, in the view of the teachers in the study school, would not ensure that a successful student could carry out a science investigation in a different context or carry out a different kind of investigation. For example, the strong focus on training students is likely to de-emphasize some of the higher intellectual processes that promote transfer of learning across contexts. Fair testing is only one of the many types of investigations (Watson et al., 1999). The implication is that this focus in AS1.1 leads to teaching practices that may not appropriately sample the learning outcomes required by the curriculum in the domain of ‘investigation’. These learning outcomes at level 6 include focussing, planning and carrying out a problem-based or topic-based open-ended investigation, and developing an understanding that investigations require an iterative process. Neither focussing nor iteration is identified in the fair testing investigation assessed through AS1.1 and therefore this assessment of investigation has low content validity at level 6 of the curriculum. Additionally, since fair testing tasks favour chemistry and physics and any one task can only address one science discipline (and sub-disciplines within that) AS1.1 can be said to have low content validity within the domains of science.

The assessment of science investigation as required by National Certificate for Educational Achievement and implemented in the study school has had negative side-effects, including: encouraging a surface approach to learning; providing a narrow focus on fair testing types of investigation; teachers giving students training to perform in such an investigation; and teachers’ limited use of formative assessment and feedback. These negative side-effects highlight issues of consequential validity. The assessment of investigation as prescribed and implemented may be doing harm and is therefore open to challenge in terms of consequential validity (Crooks, 1993 cited in Hall, 2007).

However, on a more positive note, assessment reliability is raised through the standardisation of requirements, practices and conditions for the administration of assessment, such as the structured template required by the New Zealand Qualifications Authority. The increased reliability does go some of the way to building the consistency and predictability that school-based assessment of student learning should aim to achieve.

There were a number of issues that influenced the validity and reliability of AS1.1 in the study school. Evidence from observations and teacher interviews in the study school showed that formal assessment of the hands-on practical phase of investigation was carried out for a large number of students at a time in a public space where each student worked in full view of other students. Some students changed their plans from those marked and returned to them by their teacher because they could see what the others were doing.

In preparation for the assessment, students in the study school received different degrees of “direction”. Direction as defined by the New Zealand Qualifications Authority means that instructions for the investigation were given in writing and all equipment was provided as was a suitably formatted template for planning the investigation (see Appendix 20). Some teachers interviewed said they gave their students two hours to plan the investigation and others one hour. Some provided the materials students needed to try out their plan before writing it up while others did not. These are practices that influence both validity and reliability.

It is clear that much of the preceding commentary on the validity and reliability of the science fair test investigation draws on themes in the relevant literature; empirical data, such as New Zealand Qualifications Authority published statistics on the validity and reliability of the science investigation are lacking. What can be fairly said is that when constructed carefully, administered appropriately, and interpreted properly, assessment of science investigation could provide an in-depth window into how students apply their knowledge and skills to carry out an investigation (Harlen, 2005). The National Certificate of Educational Achievement requirement of assessment of a single fair testing type of investigation using a tightly structured task is likely to have increased assessment reliability but places constraints on validity.

The next theme presents teacher dilemmas associated with the level of direction given to students in the implementation of internal assessment.

8.7 Teacher Unease about Their Own Practice

A concerning theme was that some teachers were uneasy about their practice of teaching investigation to assessment requirements. Nearly a fifth of the region’s teachers and several in the study school thought they were giving their students too much help. When asked to elaborate during the interview, some teachers expressed concern that the formative assessment task they concentrated upon was almost identical to the task used for assessment. They said that a week before the assessment they stopped teaching the topic they were doing (e.g., metals and their compounds) and revised “forces” as the assessment of science investigation was set in that context. Teachers said that they not only provided students the opportunity to practise the investigation which was very similar to the one assessed but told them “what to write”. Teachers said that they knew that this was unethical practice that may have affected the validity of results. Reiss (1999) argues that such a decision is a moral decision because the teachers knew that this was wrong but still decided to do it.

Ethics, says Reiss (1999), probes into the reasoning behind the moral choices we make and often these choices are based on the consequences of such action. In this case, the teachers justified their decision by saying that other teachers were giving their students even more help than this so they did not want their students to be disadvantaged. Perhaps, in some teachers’ views the consequence of not providing their students with such help would have impacted on the students’ results. The other consequence was improved school results. With the pressure on the school and teachers to improve results, teachers chose the option which they knew they ought not to. During the interview, two of the teachers were visibly upset and others were uncomfortable that the “demands of assessment” that required preparing students, organising the assessment and the pressure for their students to perform well had reduced them to doing what they said they clearly knew was not right. Øvreeide (2008) says that sometimes as a result of personal ethics some individuals make an emotional response due to what “feels right” which generates feelings of coping and success. This can change upon reflective consideration. It appears that teachers who questioned their practice were perhaps being reflective about the moral decisions they had made.

It is noteworthy that the literature reviewed did not provide evidence that science teachers in the United Kingdom are concerned about the ethics of training the students to write particular answers although it is reported that this training does happen (Cleaves & Toplis, 2007).

8.8 A Focus on Knowledge Outcomes

The outcomes-based curriculum encourages lower level learning outcomes for science investigation, in particular, knowledge acquisition. Alton-Lee (2003) argues that educational achievement is an expected outcome of school education and that learning outcomes need to be measurable and the latter is one of the roles of assessment. Being able to carry out a science investigation is an expected learning outcome for students in year 11. *Science in the New Zealand Curriculum* is an outcomes-based curriculum statement (section 2.6) that sets out achievement objectives for each level. The learning outcomes can be used as criteria against which learning can be assessed. Students in year 11 were learning to carry out a fair testing type of investigation. The National Certificate of Educational Achievement assessment of science investigation resulted in teaching and learning of one type of investigation. The constraints of this type of investigation and the limitations of the standards for each level of achievement encourage low level learning outcomes that may result in lower order thinking. To explain what is meant by low level learning outcomes the taxonomy of the cognitive domain first put forward by Bloom, Englehart, Furst, Hill & Krathwohl (1956), and more recently updated by Anderson and Krathwohl (2001), is used. This framework has six categories from the simplest to the most complex which are knowledge, comprehension, application, analysis, synthesis, and evaluation. If the assessment requirements are aligned with Bloom's taxonomy, students who demonstrate that they have met the criteria for the standard, Achieved, appear to be operating at the "knowledge" level. The judgment statements for the marking of AS 1.1 (Appendix 20) for Achieved levels require students to describe, identify, measure, record and select; unless these skills involve deeper processes than normally associated with their performance, they align with Bloom's knowledge level.

To attain a Merit the standard requires "(p)rocessing of data to enable a trend or pattern (or absence) to be determined" and "a valid conclusion based on interpretation of the processed data that links to the purpose of the investigation" (Appendix 20). This requires analysis and would be congruent with higher order thinking. However, in the "Watch that car go" assessment task, the acceptable response for Merit requires accurate measurement of distance; more than two trials and providing a valid conclusion based on the purpose of investigation such as, "(t)he greater the height of the ramp and therefore the steeper the slope the greater the distance travelled by the car" (Appendix 20, assessment schedule). The Merit grade requires higher order thinking but the actual marking schedule stipulates a simple answer that may not require a lot of thinking and best fits with Bloom's comprehension level.

Further, the Excellence level answer requires discussion based on evaluation and justification that are higher order thinking objectives. However, just as for Merit the assessment criteria require repeatable results and enough readings to allow a "valid" trend. The science idea used as an example says "The higher the ramp the more gravitational potential energy the car had and the more that was converted to kinetic energy, therefore the further the car went before it came to a halt"

(Appendix 20; TKI, 2005). If the students were working from first principles it would require proportional thinking, but the problem is that students may learn it by rote and recall it. For students who have been "trained" to perform using tasks almost identical to the assessment task, this assessment is unlikely to require higher order thinking even though the original learning may have done.

Classroom observations, including formative assessment showed that in the fair testing investigation students did in class, some memorised and wrote answers that could get them an Excellence grade. In the sample assessment schedule provided for "Watch that car go" (TKI, 2005), the criteria for Excellence in reporting says, "the final method chosen gave results that were repeatable ... this also allowed us to see aberrant data and this data could be removed from our calculations." Acceptable examples of such answers in the study school were "I repeated the trials and took an average to get more reliable results," (Harry) or explaining an anomalous result as a measurement error on the student's part (TKI, 2005, Appendix 20). However, none of the students in the study class achieved an Excellence grade but several did get a Merit. Teachers surveyed and interviewed also reported students wanting to know what they needed to write to get a particular grade, they were not asking for help to understand why they should be writing that answer. This focus on recall reduces the Excellence level answer to a much lower level of knowledge for most students, with the assessment task not requiring students to exhibit the higher order critical thinking skills. In New Zealand, Hume and Coll (2008) found that "students were acquiring a narrow view of scientific inquiry where the thinking was characteristically rote and low-level" (p. 1201).

The study school results for AS1.1 showed that Merit or Excellence was achieved by 21.8% and 6.7% of students respectively, which is high compared to grades for any other science achievement standard assessed in the school. There was little evidence in the study class of learning experiences which would help the students to meet more challenging learning outcomes. The study class teacher, when returning the marked papers for a formative task, pointed out what the students needed to have written to get an Achieved but added, "….and Merit needs more".

The next theme highlights some of the effects of low-level learning outcomes on students' learning of science investigation.

8.9 Encouraging a Surface Approach to Learning

Students in this study had a surface approach to learning investigation. According to Entwistle (2005), the learning approach is “what the students intended to learn and how they learn it” (p. 2). In a surface approach to learning the intention is to memorise facts and processes. Ideas are accepted passively, the focus is on the requirements of assessment, reflection on learning is minimal, learners fail to recognise patterns and organise ideas. A surface approach to learning is often due to anxiety and fear of failure (Entwistle & Ramsden, 1983). These were common concerns in the study class where students felt driven by the need to achieve credits for a National Certificate of Educational Achievement Level 1. Very few students in the study class showed elements of a deep learning approach “which is linked to academic interest in the subject” (Entwistle, 2005, p. 3).

The study class students when asked to set goals for their science learning and for AS1.1 identified performance goals, for example, of achieving a Merit or Excellence grade rather than mastery goals such as learning something of personal relevance or interest. The teachers interviewed reported that students wanted to get these grades and wanted to know what they needed to write to achieve them. Such goals are indicative of a surface approach to learning in contrast to learning for personal relevance or interest and are mastery goals linked with a deeper approach (Eccles & Wigfield, 2002). Conversely, some of these students may have been strategic learners who focused on what they perceived as important for assessment.

Study class observations and focus group interviews suggested that students had rote learnt science facts, such as, plastic is an insulator and metal is a conductor of heat but did not understand that hot water in a metal cup will cool down faster than in a plastic cup. Similarly, they had the skills to set up an investigation to find out which cup kept the water hot for the longest period of time. They had procedural knowledge to measure temperature and for this investigation they had learnt that they needed to measure the temperature every five minutes. However, they did not demonstrate procedural understanding that if they took the thermometer out and put it in again they needed to give it time before taking the reading. Their learning approach focused on perceived skills needed to perform in the investigation rather than understanding the application of the skills learnt.

One of the science teachers interviewed described how a student learnt the investigation they carried out for the effect of surface area on the rate of chemical reaction. This student then wrote the learnt answer without reading the requirement of a subsequent investigation that involved investigation of acid concentration on the rate of chemical reaction. Reproducing memorised information showed the surface approach to learning by this student who expected to gain an Achieved grade in the assessment.

When undertaking a fair testing investigation almost all students in the study class had drawn tables in their books and entered data showing that they had taken several readings. When asked why they needed to take several readings, a number including Harry responded “to take an average”, which they explained made their data reliable, but they could not explain what they understood by reliable data. Similarly, during another investigation a student set up a test tube to measure the energy released when different fuels burnt. The test tube was placed in a retort stand and had a thermometer in it. This student then proceeded to put the fuel he had collected from the teacher in a bottle top and put it under the test tube to light the fuel. When asked what he was doing he could not explain why he was about to heat an empty test tube. In this case the student was trying to reproduce the procedure followed by other students around him and missed the detail that these students had water in their test tube. His approach to learning was minimal as he just wanted to get the investigation completed and did not appear to think about learning from this experience.

During the same investigation another student found that all the fuels she had burnt boiled the 20ml of water she put in the test tube. Her conclusion was that all fuels released the same amount of energy. Upon further probing she said it could be because her test tube was not clean but she was unable to see that if she had used a larger quantity of water (100ml) she would have been able to measure the change in water temperature for each fuel burnt (section 7.4). The student’s response demonstrated a lack of reflection on the results which is characteristic of a surface approach to learning. The student’s response to the test tube being dirty was in agreement with Cleaves and Toplis’s (2007) findings in the United Kingdom that students had a rote response to anomalous data when they did not get the expected results.

The workbook used in the study school set out tasks in the template format required for AS1.1 like a recipe. The tasks were explained in detail and required little thinking. Students followed instructions and carried out investigation that was mostly of the fair testing type. As the same workbook was used in more than half of the region’s schools the practice may apply more widely. This risks reducing the teaching of investigation to a “cook book” approach (Roth, 1994), and learning to surface learning.

Study class students learnt the facts and the process but did not have the conceptual or procedural understanding required to do the thinking behind the doing, which is the essential component of investigation. Their learning experience as observed emphasised the planning and doing of the investigation but not critical analysis of the procedure, looking for evidence, or presenting an argument for drawing the conclusions. In previous research, Roberts and Gott (2006) found similar issues in the United Kingdom where students demonstrated a lack of procedural understanding and critical analysis. Millar’s (2004) theory that students need to form links between the domain of objects and the domain of ideas essential for understanding were not taught or scaffolded in the study class. The *Science in the New Zealand Curriculum* requirement of evaluating the procedure and findings, which encourages a deeper approach to learning, was not evident.

Teachers said and students agreed that they were motivated to gain credits and grades valued by the wider community. Teachers emphasised what students needed to learn, practise and write to get the credits and grades. These factors encouraged a surface approach to learning and motivation to perform. Science investigation in year 11 in the study class and the study school was not conducive to deeper learning of investigation.

Student learning was restricted by the concern to perform. They learnt skills as identified above and mastered content knowledge needed for investigation that would enable them to carry out a fair testing type of investigation to get an Achieved grade. Millar (2004) posits that learning from investigation takes place in the discussion that occurs at the end. There was little evidence of this in the study class. The students in the study class, and as some teachers indicated, in other classes as well, had learnt “what to write” to get a particular grade. They did not experience learning for understanding that can be achieved through doing open-ended investigation as experienced by students who participate in science fairs and CREST. The latter have ownership of the investigation, develop deeper skills of evaluating findings, presenting and arguing, and enjoying the experience of investigation (Davies & France, 2001).

8.10 Motivational Foundation of Practical Work

This theme relates to the practical work undertaken in both the practical aspect of investigation and practical activities other than investigation. Practical work other than investigation was carried out by teachers across the region as well as in all year 11 classes in the study school and included activities such as setting up circuits, measuring current or voltage, metal reactions with oxygen, water, and acid, culturing bacteria, or using models to understand phenomena such as eclipses and seasons. In the study school, teachers said that they did practical activities other than investigation after the National Certificate of Educational Achievement AS1.1 assessment had taken place, and in the study class such practical work took place throughout the year but more in the second half when AS1.1 assessment had been completed. Teachers said that the purpose of these practical activities was to help students develop conceptual understanding. Such practice has also been reported in the United Kingdom by Millar (2004) and Wellington (1998) to gain an experience of the phenomenon.

Generally, there was agreement between teachers regionally and those interviewed as well as students in the focus group and the study class that “hands-on practical work” was motivational. Teachers’ views were based on their interpretation of students’ engagement during practical work as enjoyment of practical work. Teachers provided a number of reasons for their views. The regional teachers surveyed said doing interesting, real science, having fun, and the investigation having a ‘wow’ factor were most motivating for students. Students gaining an understanding, knowing what was expected, and that it was achievable were other motivational factors. Some study school teachers said that students were interested in doing practical work and kept asking for it, and others said that they used practical work as a “carrot” to get students to do other work which included writing.

In the study class, task engagement was high during practical work whether the practical work was part of an investigation or a practical activity other than investigation. This may be explained by situational interest, which according to Palmer (2009) is short-term interest generated by a specific situation such as a spectacular demonstration, a practical activity that has a ‘wow’ factor or one that has novelty. Illustrative examples of situational interest from the study class included students doing a number of exploratory investigations with dry ice and energy changes. In the case of the study school, situational interest could perhaps explain some students’ interest in the setting up of the assessment of AS1.1 in the school hall as exemplified by the focus group students who said that the gear was set out, it was in working order and “no one was taking away your gear”.

Although the teacher and the researcher can interpret engagement or enjoyment as motivational, it is only the students who can say if practical work is motivational and for what reason. Students' reasoning for motivation was identified through focus group interviews, and from informal discussion with the researcher, as well as student surveys. Enjoyment of practical work was reported by students to arise from interest, novelty, variety, making a personal input in the way practical work was conducted, being able to work with their friends, and move around. The enjoyment of working with their friends was also a motivational reason offered by students in the focus group. The preference to "work with their friends", "help each other" and "work in groups" was evident in the statements students selected in the preferred version of the SLEI (Fraser et al., 1995, section 7.2.2). Palmer (2009) also found that students enjoyed activities that allowed them to work with their friends and to move about. Working with their friends was a reason put forward by some responses of teachers in the regional survey. On a negative note, practical work was described as providing an escape from writing, which included copying from the board and completing worksheets.

Palmer (2009) posits that students are interested in tasks that may have personal relevance. The results of the SLEI from the study class showed that students had a preference for pursuing something of personal interest. This was not often the case in the study class where all investigations and practical work were either teacher directed or tasks from workbooks. Students seldom investigated something of interest to them. There were, however, glimpses of choice-dependent interest as demonstrated by one girl who was allowed to go outside in the "Rolling a marble down a slope" investigation task, on her request, and investigate if the marble rolled further on astro-turf. This was a memorable event for her, which she shared in the focus group interview.

Palmer (2009) and Alexander et al. (1994) have reported novelty as a motivating factor for doing investigation that arouses situational interest. The influence of novelty was observed in the study class where there was a 'wow' element to the task which showed student enjoyment, for example, the excitement when students burnt diesel fuel and could see bits of carbon float through the air. In contrast, repetition can be demotivating as evident in the teaching scheme of the study school where there was an overlap of up to 90% between the practical activities in some topics in year 10 and year 11 (e.g., electricity unit plan, Appendix 17). Due to this repetition, novelty was not often experienced by the students in the study class and perhaps the study school. Some (5 to 8) students in the study class did not participate in some practical activities claiming that they were boring because they had done these before and were not of interest to them, which is consistent with Rennie et al.'s (2001) view that adolescents find science as a dull and boring subject which fails to motivate them.

Students in the study class said that they wanted to learn when they found the activity interesting. Students in the focus group reported being able to remember concepts learnt during investigation when they had enjoyed the experience and seen it "happen before their eyes" such as a bimetallic strip bending as it was heated. Similar findings in relation to memorable events were reported by Alexander et al. (1994) and Eccles and Wigfield (2002).

Teachers' beliefs about student motivation during investigation were based on the level of student engagement during the practical component of investigation and in some cases students asking the teachers if they would be doing practical work. Students' reasons appeared to be different. Students were motivated to do practical work when it had novelty; they enjoyed working with their friends; and they found practical work an attractive alternative to copying notes. There was agreement between teachers and students that National Certificate of Educational Achievement credits and grades were a strong extrinsic motivating factor.

8.11 Philosophical tensions between beliefs, curriculum, and assessment

As noted earlier (section 2.1.5), the school curriculum emphasises both constructivist and outcomes-based educational philosophies, yet there is no recognition in Ministry documents of the inherent tension between these two positions. Arguably, constructivist beliefs are more learner-centred than centrally prescribed outcomes as documented in the curriculum and the National Certificate of Educational Achievement assessment standards. Most teachers in the study school aspired to a learner–centred approach to science teaching but due to assessment requirements most had a content-driven approach as viewed by Denessen (1999). In relation to teaching investigation, teachers in the school said they provided opportunities for the students to engage in investigation but this was not ideal (see 8.5). Some said that their approach to teaching was to provide students with the materials and allow them to find answers for themselves. The philosophical beliefs that underpinned their teaching practice, although not articulated as constructivist, supported a constructivist theory of learning. In New Zealand, science teacher education programmes promote a constructivist theory of learning, which perhaps is an influence of the Learning in Science Project of the 1980s at the University of Waikato (Hipkins et al., 2002). *Science in the New Zealand Curriculum* is an outcomes-based curriculum. The expectation is that the teacher plans learning for students so that they achieve the expected learning outcomes. The study school documentation reflected that the planned curriculum set out the learning outcomes for each unit of work taught in year 11. According to Hall (2005), outcomes-based education is generally, a “relatively closed system of education” (p. 244). This is because it is prescriptive, which puts further constraints on teachers with a learner-centred teacher identity.

According to the teachers interviewed, most believed in following the curriculum, some said that they wanted to encourage students to think and ask questions and others thought it was important for the students to be curious and wanted to make learning fun. However, when it came to practice, nearly all were focussed on teaching the content and ensuring that their students achieved credits and grades they were expecting to achieve.

Schwab (1958) argued that “exercises presenting no problems of choice and application were education appropriate for the nineteenth century” (p. 376). Yet in the twenty-first century the constraints of the assessment of investigation was making the teachers employ highly structured methods of teaching that included practical tasks and investigations set out in workbooks and students writing their answers into highly structured templates. Schwab favoured collaborative inquiry methods of teaching that would allow the learners to understand the problem they were to investigate and solve the problem as a group. Although some teachers believed that students should be able to work collaboratively there was little evidence of this in the study class. Hume and Coll (2008) found that in one of their case studies students were allowed to plan the assessed investigation in groups, gather their data collaboratively but wrote individual reports. This was not the case in the study school in the present study where all students planned, carried out, and reported their investigation individually.

Assessment of science investigation, as stated earlier, is prescriptive and limited to one fair testing type of closed investigation. The tension that the science teachers experienced was: between their philosophies of student-centred learning approaches; the requirement to deliver an outcomes-based curriculum; and the very narrow template approach to teaching and assessing science investigation.

Hall (2005) mapped the tensions in the New Zealand education system between the: educational goals of life long learning and knowledge creation; implementation of outcomes based education; assessment approaches that include standards-based assessment; and the philosophical beliefs of the teacher. Hall puts the institutional context and the teaching and learning context at the heart of this map. When dealing with the multiple demands on their time, science teachers in the study school appeared to be focussed on preparing students for the assessment of science investigation. They had changed their practice of teaching investigation and reduced the practical work they could do in the limited time to 'cover the curriculum'. This is in contrast to Schwab's view that inquiry teaching involves studying in-depth rather than taking a superficial approach to investigation.

In some cases, teachers went beyond their comfort zone and provided what they thought were unethical levels of support so that their students would achieve. Although they were uncomfortable in the way they taught, trained, and assessed students, it was obvious they had adopted a strategy that would give tangible credits and grades to their students. Their 'identity' as a teacher was thus continually challenged and constrained by the school environment and the assessment requirements beyond their control.

8.12 Summary of Discussion

The case study of year 11 science investigation in New Zealand revealed that science teachers saw science investigation as a procedure to follow sequentially. Their understanding of science investigation was closely aligned with the requirement of assessment rather than interpreting the curriculum in line with problem-solving and an iterative process. Teachers reported a change in their practice of teaching investigation with the introduction of the National Certificate of Educational Achievement, which became preparation for assessment constrained by the assessment process and availability of resources. Fair testing was taught and students were trained to perform in the assessment of investigation for which they were motivated to achieve credits and grades. To achieve these performance goals there was surface learning rather than deeper learning for understanding as required by the curriculum. In the teacher's view the assessment of science investigation through AS1.1 may not have been reliable and teachers thought it may not have been valid. Teachers were uncomfortable with the level of support they provided to help students achieve. While students and teachers supported the traditional view that the doing of science was motivational, students put forward a variety of reasons, including that it allowed the freedom to work with their friends and to avoid writing which they found tedious.

To sum up, it can be said that the teaching of science investigation was constrained, learning was limited, motivation to learn was largely extrinsic and reduced to achieving credits and grades.

CHAPTER NINE
Conclusion

The focus of the case study was to understand the phenomenon of school science investigation in year 11 in New Zealand. The bounded system of science investigation, the case, was explored to understand the connection between the parts as identified in the national documents, experienced by science teachers in the Wellington region and the teachers and students in the study school, and observed in the study class.

Findings of the case study are presented in relation to the research questions posed. Through the discussion of results a number of implications for policy and practice have emerged which are also addressed in this chapter. The targeted audience for the findings of the study is teachers and teacher educators, the policy makers at the Ministry of Education in relation to the curriculum, and at the New Zealand Qualifications Authority in terms of assessment. The findings of this research, towards which teachers and students have contributed, have the potential to make a difference to the teaching and learning of science investigation in New Zealand classrooms. Finally, the implications of the findings for future research are suggested.

9.1 Research Questions and Findings

The research questions posed are addressed below.

1. **How do year 11 science teachers understand "science investigation"?**

   - Year 11 science teachers understand science investigation as a linear and sequential process. They described features of science investigation that supported student learning as experiments, scientific method, and fair testing. Very few science teachers had a contemporary, open-ended view of science investigation.
   - Teachers identified "experiment" as the "doing" of science or "practical work," whether it was within an investigation or in an activity by itself.
   - The assessment of science investigation as fair testing for AS1.1 in year 11 has promoted a narrow view of science investigation as linear and sequential, and leading to one "correct" answer.

2 How do year 11 science teachers practise science investigation?

- Teachers teach science investigation as a linear and sequential process.
- Teachers' reported that their practice of teaching science investigation in year 11 had changed since the introduction of the National Certificate of Educational Achievement. They now teach the fair testing type of investigation in year 11 as required for internal assessment.
- Teachers prepared students for the National Certificate of Educational Achievement AS1.1 assessment through doing tasks similar to those used for the formal assessment, through practising fair testing and carrying out formative assessment as a mock examination. While there were workload issues, teachers used this formative assessment to raise students' grades.
- Although the *New Zealand Curriculum Framework* (Ministry of Education, 1993b) and *Science in the New Zealand Curriculum* (Ministry of Education, 1993a) are underpinned by a constructivist view of learning, there was little evidence within this case study of teachers applying constructivist approaches to teaching in year 11 science.
- Teachers trained year 11 students to succeed in the assessment of AS1.1 science investigation through repetition and this training in fair testing may have sometimes started in year 9 in preparation for year 11.
- Teachers felt constrained by the assessment regime and student, school and community expectations, and some were uncomfortable with the level of support they provided for improved student performance; this support was characterised by assessment tasks being almost identical to the final assessment.
- After the assessment of AS1.1 science investigation in school term 2 teachers reverted to their practice of doing practical work through short activities and a range of types of investigation including fair testing.
- Teachers used the template provided by the New Zealand Qualifications Authority as direction for AS1.1. The process of investigation was long and was carried out in three parts – planning, doing, and writing the report using set tasks.
- Teachers adopted a pragmatic approach to the selection of tasks based on availability of resources, manageability, and ease of administration.

- The predictive validity of AS1.1 was compromised as the task for teaching was very similar to the task used for assessment; and also a narrow training approach to learning investigation.
- Although science teachers in the study school were personally uncomfortable with the organisation and management of assessment for science investigation for AS1.1, opportunities for collective critical examination of processes were few.

3 What types of science investigation are carried out in year 11 science?

- The fair testing type of investigation was carried out in preparation for the AS1.1 assessment.
- All fair testing investigations carried out were teacher led. Students did not seek to answer a question or solve a problem that they had identified themselves. They carried out the investigation which was often set out in the workbook.
- The AS1.1 assessed task was almost always in a physics or chemistry context because it is easier to control variables in tasks within these subjects compared to tasks in biology and astronomy. Controlling variables is an essential element of the fair testing type of investigation. The investigation was linear and structured by the template intended for providing "direction".
- Other types of investigation carried out in year 11 included exploring and classifying and the use of models. These were not developed as investigation but as a collection of activities more often carried out in physics and chemistry topics than in biology, astronomy, and geology.

4 How does the type of investigation relate to students' learning and motivation to learn?

- Students and their teachers thought that hands-on practical work, irrespective of the type of investigation and whether within investigation or another practical activity, helped them learn science ideas.
- Students adopted a surface approach to learning investigation as fair testing and tended to rote learn answers to fulfil the requirement of assessment. There was an absence of evidence of learning exhibiting characteristics associated with a deeper approach to learning such as reflecting upon and evaluating the procedure.

- Assessment of the fair testing type of investigation for AS1.1 encouraged an emphasis on developing procedural knowledge (learning the steps to follow) rather than procedural understanding (knowing why they were following the steps).
- Low level learning outcomes were encouraged through assessment of science investigation as fair testing for AS1.1. Assessment requirements for the Achieved standard encouraged knowledge acquisition. Although the requirements for Merit and Excellence standards identify higher order thinking, this thinking is not necessarily used by students who commonly rote learn answers for assessment.
- Teachers and students identified the extrinsic motivation of getting an Achieved or better grade for AS1.1 as the most common motivating factor for learning science investigation. This was associated with students setting narrow performance goals for learning science investigation.
- Teachers considered that practical work within investigation and other practical activities was motivational for students.
- Students enjoyed doing hands-on practical work and were particularly interested in participating in practical work that had novelty and variety – especially the practical aspects of science investigation – regardless of the type of investigation.
- Students found report writing demotivating.
- Students found repetition of practical work, including investigations they had experienced before, demotivating.
- During practical work, including practical aspects of science investigation, students experienced opportunities to move around and work with their friends in a less formal learning environment. They found this motivational.

The findings of the case study suggest that teaching, learning and motivation to learn science investigation were overwhelmed by the requirements of internal assessment of science in year 11. This is represented in Figure 9.1.

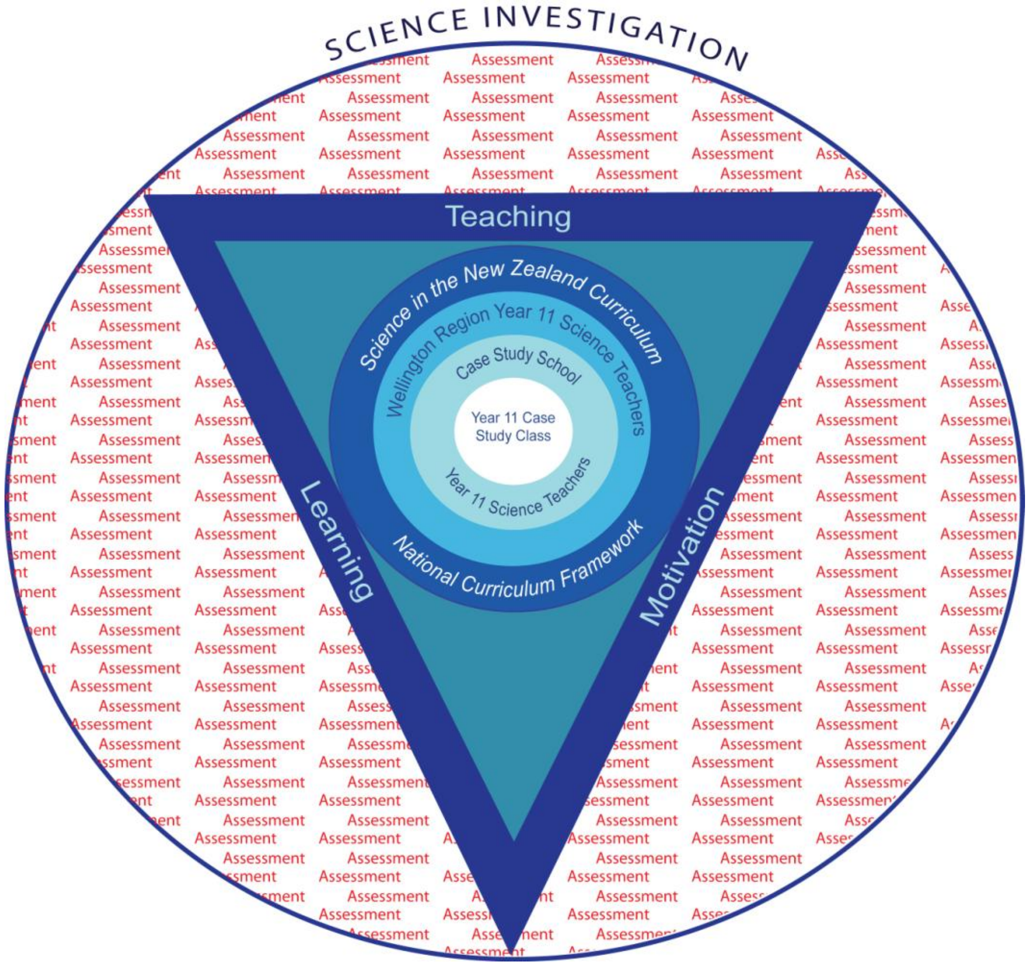

Figure 9.1: Science investigation – links between learning, motivation and assessment in year 11

9.2 Recommendations for Policy and Practice

The research findings have implications for both teaching practice and policy in relation to teaching, learning, and assessment of science investigation.

9.2.1 Recommendations for practice

The following recommendations are made to teachers and teacher educators. It is recommended that:

- Teaching of science investigation from years 9 to 11 include students learning a variety of types of science investigation such as exploring and classifying.
- Teachers carry out diagnostic assessment from years 9 to 11 in order to identify students' conceptions, and build upon these.
- Science departments develop teaching schemes with minimal overlap of investigation tasks used from years 9 to 11. This may reduce student disengagement due to perceived repetition of particular investigations.

- Science departments encourage extensive use of formative assessment, in its broadest sense, to support student learning through investigation. It is recommended that the feedback focuses on enhancing understanding as well as preparing students for summative assessment.
- Teachers provide students with opportunities to carry out investigations that respond to their personal interests, and science departments encourage and support participation in science fairs and CREST that promote open-ended investigation.
- Science departments provide teachers with the opportunity for professional development on constructing investigation tasks that challenge students to think critically, evaluating investigation methods and results, making judgement based on evidence, and developing argumentation skills.
- Teachers focus their teaching of science investigation on developing conceptual and procedural understanding rather than simply procedural knowledge. It is recommended that they consider moving away from the use of a structured template, particularly in years 9 and 10, which constrains the learning of science investigation and in its present form limits it to fair testing.
- Science methods courses in teacher education programmes provide the opportunity for student teachers to carry out a variety of types of investigation and develop an understanding of not just the management of these investigations in their classroom but the thinking behind the investigation and how to scaffold their students' learning of investigation.
- Science teacher education promotes formative assessment of science investigation not as a "mock examination" but to foster learning and deepen understanding.

9.2.2 Recommendations for policy

The following recommendations are made to the Ministry of Education, the New Zealand Qualifications Authority, New Zealand Association of Science Educators, and Post Primary Teachers' Association. It is recommended that:

- The New Zealand Qualifications Authority removes the requirement for internal assessment of science investigation in year 11 through AS1.1.
- If internal assessment of science investigation is to continue, then the New Zealand Qualifications Authority provides a variety of moderated assessment tasks that include different types of investigation in a variety of topics.

- The Ministry of Education through the science curriculum continues the requirement for teaching open-ended science investigation in secondary schools from years 9 to 11.
- The Ministry of Education provides resources for professional development of science teachers to enable them to fully implement the curriculum and teach different types of investigation.
- The Ministry of Education provides resources for professional development to foster skills to do formative assessment of investigation to enhance student learning.
- The Ministry of Education provides resources for science teacher professional development in the organisation and management of science investigation in their schools, including the writing and moderation of assessment tasks that can be used within the constraints of the resources available in the school.
- The Ministry of Education provides resources for professional development for enhancement of teacher understanding and practice of the social constructivist philosophy that underpins the science curriculum.
- The New Zealand Association of Science Educators promotes effective practice in teaching and learning of science investigation through encouraging presentation of examples of science investigation at the science teachers' conference and associated subject conferences.
- At a local level, branches of the New Zealand Association of Science Educators provide support and share examples of effective practice with their members through providing workshops for teachers on science investigation.
- The Post Primary Teachers' Association highlights the need for teacher professional development and negotiates time for teachers to engage with the resources available on the Ministry of Education and New Zealand Council for Educational Research websites so that teachers can adapt these resources to their specific needs.

A significant systemic change in education has taken place during this research. *The New Zealand Curriculum* (Ministry of Education, 2007) is being implemented in schools. This is different to the *New Zealand Curriculum Framework* (Ministry of Education, 1993b) in that the latter provided a framework and seven separate curriculum statements for each learning area including science. *Science in the New Zealand Curriculum* (1993a) provided the achievement aims, achievement objectives, learning contexts, sample learning experiences, and assessment examples. It had four contextual strands and two integrating strands: The Nature of Science and its Relationship with Technology; and Developing Scientific Skills and Attitudes (see Chapter two for details). The science learning area of *The New Zealand Curriculum* (Ministry of Education, 2007) has placed The Nature of Science strand as the focus of science learning ahead of the contextual strands. The Nature of Science strand now includes investigating in science as one of the four components.

The aim in relation to investigation is that students will:

- Carry out science investigations using a variety of approaches: classifying and identifying, pattern seeking, exploring, investigating models, fair testing, making things, or developing systems. (Ministry of Education, 2007, n.p.)

In *Science in the New Zealand Curriculum* (1993a) investigation was included in the Developing Scientific Skills and Attitudes and the aim was that:

- In their study of science, students will use their developing scientific knowledge, skills, and attitudes to: further develop their investigative skills and attitudes.

There is a significant change in the achievement aims which now require the teaching of a variety of types of investigations which in the light of the findings of this research would potentially move away from a narrow focus on fair testing types of investigation. However, the aims are not listed in the curriculum document itself and are only available in the online version of the document or on a separate foldout. In the absence of achievement aims in the hard copy of the curriculum document the requirement for carrying out a variety of approaches to investigation can be overlooked.

The achievement objectives in *Science in the New Zealand Curriculum* (1993a) were set out under the skills of focussing and planning, information gathering, processing and interpreting, and reporting. The overall expected outcome was for students to be able to carry out a complete investigation (see 2.3.2). Whereas the achievement objectives for investigating in science at level 6 (year 11) in *The New Zealand Curriculum* (Ministry of Education, 2007) are that students will:

- Develop and carry out more complex investigations, including using models.
- Show an increasing awareness of the complexity of working scientifically, including recognition of multiple variables.

- Begin to evaluate the suitability of the investigative methods chosen. (Ministry of Education, 2007, n.p.)

If the above achievement objectives are viewed alongside the achievement aim it is likely that students in year 11 will experience the variety of investigative approaches that curriculum requires. In the absence of the aims, if the planning was based on the achievement objectives listed above the focus may move from fair testing to the use of models.

Moreover, the alignment of achievement standards to the curriculum currently in progress and to be implemented in 2011 is allowing the assessment of practical investigation to continue. The Ministry of Education has retained the internal assessment of science investigation with direction at level 1 in the form of Achievement Standards, Physics AS1.1, Chemistry AS1.1, and Biology AS1.1 (Ministry of Education, 2010).

The implication of the findings of this research is that assessment of investigation through AS1.1 has narrowed the learning of science investigation to a fair testing type of investigation, which has issues of consequential validity for assessment. The continuation of assessment of investigation is not conducive to learning and requires a change in policy. It is imperative to further research the impact of continued assessment of science investigation at level 1.

9.3 Future Research

This case study was able to provide insight into teachers' understanding and practice of science investigation in one school and more generally in the region. It adds to international understanding of the practice of assessment of performance in science investigation in year 11 (Roberts & Gott, 2004a, 2006) and New Zealand (Hume & Coll, 2008). Further case studies of the organisation and management of science investigation in a range of school types and sizes, and case studies of teaching and learning of science investigation in a range of classes, are needed to add to current understandings. A national survey of year 11 science teachers would be informative.

Further research is needed to investigate the relationship between student enjoyment of practical work in science and motivation to learn. There is a need to investigate in some detail the relationship between science investigation and its effect in New Zealand where considerable resources are invested to make practical work possible. Schools have access to varying amounts of funds depending on the socio-economic background of the community where they are located. It would be useful to determine if the availability of the resources influences student experience of practical work and how it relates to their motivation to learn.

Studies into the role of the teacher in student investigation are needed for understanding the connections between wanting to learn and learning to think critically. There would be value in identifying outstanding teachers of science and studying how these teachers foster their students' motivation to learn and to think critically within the context of teaching science investigation.

Further research is needed to determine the effect of the current practice of learning and assessment of science investigation on students' decisions to continue with senior science subjects, physics, chemistry, and biology.

Constructivism underpins the *National Curriculum Framework* (Ministry of Education, 1993b) and *Science in the New Zealand Curriculum* statement (Ministry of Education, 1993a). Research is needed to investigate teachers' understandings of this philosophical base and to determine how these understandings influence teachers' practice of teaching science investigation and the assessment of science investigation. Within such research, student outcomes in terms of learning investigation and motivation to learn investigation could be explored.

Year 12 physics, chemistry, and biology require the teaching of investigation under supervision. Supervision is described by the National Certificate of Educational Achievement as providing guidance and a framework but offers less direction than that provided in the form of a template commonly used for AS1.1. Given the findings of this research, it would be useful to investigate how year 12 students are taught and assessed for science investigation in physics, chemistry, and biology.

It would be informative to research how a learner experiences science investigation in New Zealand during formal schooling. A cross-sectional study could be designed which includes a set number of observations in early childhood, primary, intermediate, and secondary schools located in the same community. Such data would provide a starting point for researching children's learning of investigation at different levels.

This research explored teachers' views about science investigation and how they reconcile the tensions caused by the curriculum and assessment requirements. The thesis has raised teacher identity as a construct relevant to the teaching of science investigation. Exploring literature on teacher identity would have been a useful addition to this thesis but is not critical to the fundamental questions asked in this research. Further phenomenological research that delves deeply into how teachers construct their views of science as a learning area as well as their role as teachers and how the current assessment regime fits with their identity of science and self, is needed.

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Appendices

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Appendix 1: Achievement Standard 1.1

Subject Reference Science 1.1

Title Carry out a practical science investigation with direction

Level 1 **Credits** 4 **Assessment** Internal

Subfield Science

Domain Science – Core

Registration date 27 October 2004 **Date version published** 27 October 2004

This achievement standard involves carrying out a practical investigation, with direction, by planning the investigation, collecting and processing the data, and interpreting and reporting the findings.

Achievement Criteria

Achievement	Achievement with Merit	Achievement with Excellence
• Carry out a practical science investigation.	• Carry out a quality practical science investigation.	• Carry out and evaluate a quality practical science investigation.

Explanatory Notes

1. This achievement standard is derived from *Science in the New Zealand Curriculum,* Learning Media, Ministry of Education, 1993, 'Developing Scientific Skills and Attitudes', pp. 42-51; and *Pūtaiao i roto i te Marautanga o Aotearoa*, Learning Media, Ministry of Education, 1996, 'Ngā Pūkenga me Ngā Waiaro ki te Pūtaiao', pp. 70-85.

2. Procedures outlined in *Safety and Science: a Guidance Manual for New Zealand Schools*, Learning Media, Ministry of Education, 2000, should be followed. Investigations should comply with the Animal Welfare Act 1999, as outlined in *Caring for Animals: a Guide for Teachers, Early Childhood Educators, and Students,* Learning Media, Ministry of Education, 1999.

3. An *investigation* is an activity covering the complete process: planning, collecting and processing data, interpreting, and reporting on the investigation. It will involve the student in the collection of primary data.

   The investigation will be directed. This means that general instructions for the investigation will be specified in writing and direction will be given in the form of the equipment and/or chemicals from which to choose. A template or suitable format for planning the investigation will be provided for the student to use.

4. Investigations should be based on situations in keeping with content drawn from up to and including science/pūtaiao curriculum Level 6. Possible contexts are given in the curriculum documents.

5. If a student enters for assessment against AS90186, Science 1.1, as well as any of: AS90156, Agriculture and Horticulture 1.1; AS90161, Biology 1.1; AS90169, Chemistry 1.1; or AS90180, Physics 1.1, the investigations must be in different subject areas. For example, if a student is being assessed against AS90161, Biology 1.1, and is also being assessed against AS90186, Science 1.1, then the emphasis of their investigation for AS90186, Science 1.1, cannot be based on biology.

6. A practical science investigation *will involve:*
   - a statement of the purpose – this may be an aim, testable question, prediction, or hypothesis based on a scientific idea
   - identification of a range for the independent variable or sample
   - measurement of the dependent variable or the collection of data
   - collecting, recording and processing data relevant to the purpose
   - a conclusion based on the interpretation of the processed data.

7. A quality practical science investigation *enables a valid conclusion to be reached. This would normally involve:*
   - a statement of the purpose – this may be an aim, testable question, prediction or hypothesis based on a scientific idea
   - a method that describes: a valid range for the independent variable or sample; a description of and/or control of other variables; the collection of data with consideration of factors such as sampling, bias, and/or sources of error
   - collecting, recording and processing of data to enable a trend or pattern (or absence) to be determined
   - a valid conclusion based on interpretation of the processed data that links to the purpose of the investigation.

8. Evaluate *means to justify the conclusion in terms of the method used. Justification will involve, where relevant, consideration of the:*
   - reliability of the data
   - validity of the method
   - science ideas.

Quality Assurance

1 Providers and Industry Training Organisations must be accredited by the Qualifications Authority before they can register credits from assessment against achievement standards.

2 Accredited providers and Industry Training Organisations assessing against achievement standards must engage with the moderation system that applies to those achievement standards.

Accreditation and Moderation Action Plan (AMAP) reference 0226

Appendix 2: Wellington regional science teachers' questionnaire

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Science Investigations in New Zealand Secondary Schools:
Exploring the links between learning, motivation and internal assessment

Year 11 Science Teacher Questionnaire 2006

Office use only

This questionnaire seeks your views on teaching and learning science investigation at Year 11, in the context of NCEA. Please answer the questions as accurately and honestly as you can. Your response is anonymous and confidential to the researcher and her supervisors.

There are five Parts to the questionnaire, Parts A to E. Please respond to questions by writing in the spaces provided or by placing a tick or a cross in a box as requested.

Please think about your year 11 science classes when responding to the questionnaire.

ID: ☐☐☐ 1-3

Part A: Teaching Science Investigation

Q 1 In your view, what features make up a science investigation that would best support Year 11 student learning? *(Do not limit yourself to AS 1.1)*

☐☐ 4-5

☐☐ 6-7

☐☐ 8-9

Q2 With your year 11 science class, which of the following types of science investigation do you do in each of the identified curriculum areas?
(Please use a tick for yes, a cross for no and NA if it does not apply)

Type of science investigation	**Physics** Forces, Energy	**Chemistry** Basic Chemistry, Metals	**Biology** Micro-organism Genetics	**Geology** Rocks, Minerals, Volcanoes	**Astronomy** Planet Earth and the Solar System	
Fair testing						☐ 10
Classifying & identifying						☐ 11
Pattern seeking						☐ 12
Investigating models						☐ 13
Exploring						☐ 14
Making things						☐ 15
Developing systems						☐ 16
Other type (please list below)						
						☐ 17
						☐ 18

Q3 . Did you teach year 11 Science <u>before</u> the introduction of NCEA?

Yes: ☐ No: ☐ *If 'No', please go to Part B, Question 4* ☐ 19

Q3 a. Has your teaching of science investigation changed with the introduction of NCEA? ☐ 20

Yes: ☐ No: ☐ *If 'No', please go to Part B, Question 4*

Q3 b. Please describe how your practice of teaching science investigation has changed with the introduction of NCEA. 21-22

23-24

25-26

Q3 c. Are you doing more, the same or fewer science investigations with your year 11 class than you did before the introduction of NCEA?

More: ☐ The same: ☐ Fewer: ☐ ☐ 27

Q3 d. Please explain why you are doing more/the same/fewer investigations.

28-29

Part B: Assessment of Science investigation AS1.1

Q4 With your year 11 science class(es), are you doing AS1.1?

Yes: ☐ No: ☐ *If 'No', please go to Part C, Question 7* ☐ 30

Q4 a. How do you prepare your students for AS1.1 assessment? 31-32

33-34

35-36

Q5 Please describe the science investigation you used to assess students for AS1.1 the last time you carried out an internal assessment?

37-38

Q5 a. Why did you choose this investigation?
(You can tick more than one box)

Students find it engaging		39
Students find it easy		40
Helps students understand a science idea/concept		41
Requires little equipment		42
Inexpensive		43
Available on TKI as an exemplar		44
Available on TKI as a moderated exemplar		45
Allows easy differentiation (Achieve, Merit , Excellence)		46
Other reason *(please list below)*		
		47
		48

Q6 Do you give your students a trial run/mock exam (formative assessment) for AS1.1?

Yes: ☐ No: ☐ *If 'No' please go to Part C, Question 7* 49

Q 6a. Please describe the science investigation you used for this trial run/mock exam (formative assessment).

50-51

Q 6b. What advantages and disadvantages do you see in doing a trial run/mock exam (formative assessment)?

Advantages:

52-53

Disadvantages:

54-55

Part C: Science Investigation, Learning and Motivation

Q7. What are the characteristics of science investigations that, in your experience, motivate or demotivate year 11 students?

56-57

58-59

60-61

Q8 What are the characteristics of assessment (summative, formative, self- and/or peer-assessment) of science investigations that, in your experience, motivate or demotivate Year 11 students?

62-63

64-65

66-67

Q9a. What other practical science related activities do you do with your year 11 science class?
(for example, making slides to view under microscope)

☐☐ 68-69

☐☐ 70-71

☐☐ 72-73

Q9b What characteristics of these activities, in your experience, motivate or demotivate students?

☐☐ 74-75

☐☐ 76-77

☐☐ 78-79

Q10a Do you use a textbook and/or workbook for year 11 science?

Yes: ☐ No: ☐ *If 'No', please go to Question 11* ☐ 80

Q10 b. Please give the name(s) of the textbook(s) and workbook(s)

Textbook(s): ____________________ ☐ 81

____________________ ☐ 82

Workbook(s): ____________________ ☐ 83

____________________ ☐ 84

Part D: Demographic data

☐ 85

Q12 For how long have you been teaching?

Up to 5 years:	6 to 10 years:	11 to 15 years:	16 years and over

Q13 For how many years have you taught year 11 Science?

Up to 5 years:	6 to 10 years:	11 to 15 years:	16 years and over

☐ 86

Q14 You are: Female: ☐ Male: ☐

☐ 87

Q15 Your school type:

Coeducational: ☐ Boys: ☐ Girls: ☐

☐ 88

Q16 Your school decile rating:

Low (1-3)	Medium (4-7)	High (8-10)

☐ 89

Q17 Your school size:

Under 500	500 - 799	800 - 1199	1200 and over

☐ 90

Part E: Other comments

Q11 If there is anything else you wish to say about science investigations for year 11 that you have not been able to say so far, please write it below.

☐☐ 91-92

☐☐ 93-94

☐☐ 95-96

Thank you very much for completing the questionnaire.

Please put the questionnaire in the stamped addressed envelope and post it to: Azra Moeed, School of Education, Victoria University, Box 600, Wellington.

Appendix 3: Study school science teachers' interview schedule

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Science Investigation in New Zealand Secondary Schools: Exploring the links between learning, motivation and internal assessment

Study School Science Teachers' Interview Schedule

Background

1. Can you tell me something about your background as a science teacher?
2. What is your senior science specialist subject?
3. What is your philosophy of science teaching and learning?
4. What do you feel were the highlights of your science teaching this year?

Teaching and learning

1. How do you feel your students' learning in science has progressed over the year?
2. What is the role of science investigation in science learning and teaching?
3. What are your goals for student learning through science investigation?
4. What have your students learned through doing science investigation?
5. How do you think science assessment through NCEA relates to students' learning?

Assessment

1. What is your approach to assessment in science?
2. How do you feel the assessment of science investigation went this year, including formative assessment with respect to AS1.1?
3. With the introduction of NCEA, has your practice of teaching science investigation changed? In what way has it changed?
4. What issues have you found in assessing/ implementing/administrating AS1.1?
5. How was your teaching affected once internal assessment of science investigation through AS1.1 had been completed?

Motivation

1. How do you think students' experiences of science investigation relate to their motivation to learn science?
2. What do you feel the effect of internal assessment of science investigation has had on students' motivation to learn science?
3. How do you feel students' motivation to do science investigation was affected once AS1.1 had been completed?
4. Thinking about your year 11 science class, in your opinion, have the students enjoyed investigating?
5. In your opinion, are your students working towards getting an 'achieved' or they are striving to get a 'merit' or 'excellence'?
6. What changes, if any, would you make to your teaching of science investigation in the future?

Appendix 4: Observation schedule

Observation Schedule: Date: Day:

Purpose: To record behaviours of teacher and students which indicate the teaching and learning of science investigation, student motivation to learn and assessment of science investigation for NCEA internal assessment by AS1.1

Lesson Overview (topic/focus, style)

Classroom environment:

Physical aspects:

- Layout
- Lighting
- Room Temperature

Start of Lesson

Uses an advance organiser

Makes links to the previous lesson

Focus of lesson: Scale: *Mostly (1) some what (2) not at all (3)*

Theory: ☐ Practical: ☐ Assessment ☐

Checks homework ☐

Teaching and Learning Behaviours

Teacher welcomes students to class			
Makes sustained eye contact			
Smiles			
Body language:	*Affirming*	*neutral*	*negative*
Student initial response (whole class)	*Positive*	*Neutral*	*Negative*

Student Behaviours

Engagement (whole class √ / individuals *)

Proportion of class highly engaged:

None	All	first ¼
None	All	second ¼
None	All	third ¼
None	All	last ¼

Quality of Engagement:

Enthusiastic: (Keenness/eager to start)	Most	some	Few
Perseverance (Carrying it through)	Most	some	Few
Attentive (Behaving within the guidelines of class expectation)	Most	some	Few
On task behaviour	Most	some	Few

Investigation:

Type: ___________________________________

Skill involved and developed:

Taught Practised Applied

Gear: Organised/ Students to find

Teacher input:

Teacher led	Demonstration	Posed as a problem	Student driven	mentor

Student interaction: Individual work/Group work/ Cooperative group work

Assessment:

Diagnostic: Oral/written Answers: from whole class/ taken in for marking

Formative: Reflective task/Through a class activity/ Test Answers: to class/ individual feedback oral/written

Feedback/ feedforward

Summative: End of Topic test/aspects of practical/final assessment

Appendix 5: Study class teacher interview schedule

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Science Investigation in New Zealand Secondary Schools: Exploring the links between learning, motivation and internal assessment

Science Teacher Interview Questions

Initial Interview Schedule (start of term 1):

Can you tell me something about your background as a science teacher?

What is your philosophy of science teaching and learning?

What is the role of science investigation in science learning and teaching?

With the introduction of NCEA, how has your teaching of science investigation changed?

What is your approach to assessment in science?

How do you think science assessment through NCEA relates to student' learning and motivation?

What are your goals for student learning through science investigation?

Second Interview Schedule (start of term 2):

How do you feel the students' learning in science progressed in term 1?

How do you feel students' experiences of science investigation related to their motivation to learn science?

What do you feel were the highlights of your teaching in term 1?

What changes, if any, would you make to your teaching of year 11 in this term in the future?

How do you feel the assessment of science investigation went in term 1, including formative assessment with respect to AS1.1?

What issues have you found in implementing AS1.1?

Third Interview Schedule (End of year):

What do you feel the effect of internal assessment of science investigation in term 2 has had on students' motivation to learn science?

How has internal assessment of science investigation in term two affected your teaching in this term?

What changes, if any, would you make to your teaching of science investigation in this term in the future?

How do you feel the assessment of science investigation work, including internal assessment with respect to AS1.1?

What issues have you found in implementing AS1.1?

How do you feel students' motivation to do science investigation was affected once AS1.1 had been completed?

What have students learned through doing science investigation?

Appendix 6: Study class focus group interview schedule

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Student Focus Group Interview Questions

This year you have allowed me to be in your class, answered questions and have done some questionnaires for me. Thank you doing that.

Thank you for coming to this interview. I have got just a few questions I would like to ask that will help me to understand what you think is the role of science investigation in your learning this year.

Questions for the first interview:

1. What science investigation have you done recently?
2. Which of these was the most enjoyable?
3. Why did you enjoy doing it?
4. Can you tell me what this investigation was about?
5. What science idea did you learn from it?
6. Which of the investigations did you not enjoy?
7. Why did you not enjoy doing them?
8. Tell me about the science ideas these investigations were about.

Questions for the second interview

1. You have recently done ...... investigation for AS 1.1 as internal assessment. What did you learn from doing this investigation?
2. How did this investigation relate to other science learning you have been doing in your science class?
3. What have you learnt about doing science investigation that will help you to do it better next time?
4. How can you prepare yourself better for this kind of assessment?

Questions for the third interview:

1. You have done a number of science investigations this year. How have these investigations helped you to understand the science ideas that you have learnt in class?

2. Can you give me some of the science ideas that you have learnt through investigating this year?

3. In what way have the science investigations you have been doing have made you choose/ not choose to study science next year?

4. If you were given the choice, what would be something that you would like to investigate and find answers to?

Thank you very much for sharing your thoughts with me.

Appendix 7: Study class student questionnaire one

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Science Investigation in New Zealand Secondary Schools: Exploring the links between motivation and internal assessment

Year 11 Student Questionnaire (1): Internal assessment of science Investigation

As you are aware, I have been observing your classes over the past term. This questionnaire is about the AS1.1 assessment that you have just completed.

Q1 You have carried out several practical tasks over the last term.
How well did these tasks prepare you for this internal assessment?
(List up to three of these practical tasks and tick the appropriate box.)

	Task	Very well	Well	OK	Not very well
Example:	To find out the effect of acid concentration on the rate of chemical reaction between magnesium and hydrochloric acid **Why did you tick this box?** It made me think about what would be a suitable range of concentrations that I could use for my investigation.		√		
1	**Why did you tick this box?**				
2	**Why did you tick this box?**				
3	**Why did you tick this box?**				

Q2 Before the final assessment you had the opportunity to have a formative assessment. How useful was the formative assessment?

Very useful	Useful	Somewhat useful	Not useful at all

Why was this?

Q3 Your science teacher gave you feedback for the formative assessment.

a. How did this feedback help you with your final assessment?

b. How did the feedback help you to learn science?

Q4 How satisfied are you with the result of your internal assessment (AS1.1)?

Completely Satisfied	I did as well as I could	I could have done better	Not satisfied at all

Q5 'If you wanted to perform better, what could you have done to improve your result?

Q6a What did you enjoy about this science investigation?

Q6b What did you not enjoy about this science investigation?

Q7 Have the science investigations that you have done helped you to understand science ideas you have learnt in class?

Very helpful	Mostly helpful	Somewhat helpful	Not helpful

Why was this?

Q8 How has this assessment for AS 1.1 helped you to learn about science investigation?

Q9 How has this assessment been unhelpful in your learning about science investigation? Please describe how.

Q10 How did this assessment increase or decrease your interest in science investigation?

Thank you very much for helping me with my study

Appendix 8: Study class student questionnaire two

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Science Investigation in New Zealand Secondary Schools: Exploring the links between motivation and internal assessment

Year 11 Student Questionnaire (2): Motivation and Learning

1. **Which part of your science lessons do you enjoy the most?**

   Why do you enjoy this part of your lesson?

2. **What do you do when you are having difficulty in understanding a science idea or doing a task?**

3. **How do you know when you understand something?**

4. **When you are not in your science class and need to understand a science idea what do you do?**

Thank you

Appendix 9: Science Laboratory Environment Inventory (actual)

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Science Investigation in a New Zealand Secondary School:

SCIENCE LABORATORY ENVIRONMENT INVENTORY (SLEI)

Actual Form
Year 11

Directions

This questionnaire contains statements about practices which could take place in this laboratory class. You will be asked **how often** each practice **actually takes place**.

There are no "right" or "wrong" answers. Your opinion is what is wanted.

Think about how well each statement describes what your laboratory class is actually like. *Tick the appropriate box.*

1	if the practice actually takes place	ALMOST NEVER
2	if the practice actually takes place	SELDOM
3	if the practice actually takes place	SOMETIMES
4	if the practice actually takes place	OFTEN
5	if the practice actually takes place	VERY OFTEN

Be sure to give an answer for all questions. If you change your mind about an answer, just cross it out and tick another.

Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.
Practice Example. Suppose that you were given the statement: "Students choose their partners for laboratory experiments." You would need to decide whether you thought that students **actually** choose their partners "Almost Never," "Seldom," "Sometimes," "Often," or "Very Often." For example, if you selected "Very Often," you would circle the number 5 on your Answer Sheet.

Remember that you are being asked how often (Almost Never, Seldom, Sometimes, Often, Very Often) that each of the following practices ***actually*** *takes place in this laboratory class.*

No.	Statement	*Almost Never* 1	*Seldom* 2	*Sometimes* 3	*Often* 4	*Very Often* 5
1	Students in this laboratory class get along well as a group.					
2	There is opportunity for students to pursue their own science interests in this laboratory class					

No.	Statement	*Almost Never* 1	*Seldom* 2	*Sometimes* 3	*Often* 4	*Very Often* 5
3	What we do in our regular science class is unrelated to our laboratory work.					
4	Our laboratory class has clear rules to guide student activities.					
5	The laboratory is crowded when we are doing experiments.					
6	Students have little chance to get to know each other in this laboratory class					
7	In this laboratory class, we are required to design our own experiments to solve a given problem.					
9	This laboratory class is rather informal and few rules are imposed.					
10	The equipment and materials that students need for laboratory activities are readily available.					
11	Members of this laboratory class help one another.					
12	In our laboratory sessions, different students collect different data for the same problem.					
13	Our regular science class work is integrated with laboratory activities.					
14	Students are required to follow certain rules in the laboratory.					
15	Students are ashamed of the appearance of this laboratory.					
16	Students in this laboratory class get to know each other well.					
17	Students are allowed to go beyond the regular laboratory exercise and do some experimenting of their own.					
18	We use the theory from our regular science class sessions during laboratory activities.					
19	There is a recognized way of doing things safely in this laboratory.					
20	Laboratory equipment is in poor working order.					

No.	Statement	*Almost Never* 1	*Seldom* 2	*Sometimes* 3	*Often* 4	*Very Often* 5
21	Students are able to depend on each other for help during laboratory classes					
22	In our laboratory sessions, different students do different experiments.					
23	The topics covered in regular science class work are quite different from topics dealt with in laboratory sessions					
24	There are few fixed rules for students to follow in laboratory sessions.					
25	The laboratory is hot and stuffy.					
26	It takes a long time to get to know everybody by his/her first name in this laboratory class.					
27	In our laboratory sessions, the teacher/instructor decides the best way to carry out the laboratory experiments.					
28	What we do in laboratory sessions helps us to understand the theory covered in regular science classes.					
29	The teacher/instructor outlines safety precautions before laboratory sessions commence.					
30	The laboratory is an attractive place in which to work.					
31	Students work cooperatively in laboratory sessions.					
32	Students decide the best way to proceed during laboratory experiments.					
33	Laboratory work and regular science class work are unrelated.					
34	This laboratory class is run under clearer rules than other classes.					
35	The laboratory has enough room for individual or group work.					

Appendix 10: Science Laboratory Environment Inventory (preferred)

SCIENCE LABORATORY ENVIRONMENT INVENTORY (SLEI)

Preferred Form
Year 11

Directions

This questionnaire contains statements about practices which could take place in this laboratory class. You will be asked **how often** you would **prefer** each practice to take place.

There are no "right" or "wrong" answers. Your opinion is what is wanted.

Think about how well each statement describes what **your** preferred laboratory class is like. *Tick the appropriate box*

1	if you would prefer the practice to take place	ALMOST NEVER
2	if you would prefer the practice to take place	SELDOM
3	if you would prefer the practice to take place	SOMETIMES
4	if you would prefer the practice to take place	OFTEN
5	if you would prefer the practice to take place	VERY OFTEN

Be sure to give an answer for all questions. If you change your mind about an answer, just cross it out and tick another.

Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.

Practice Example. Suppose that you were given the statement: "Students would choose their partners for laboratory experiments." You would need to decide whether you would prefer students to choose their partners "Almost Never," "Seldom," "Sometimes," "Often," or "Very Often." For example, if you selected "Very Often," you would circle the number 5 on your Answer Sheet.

Remember that you are being asked how often (Almost Never, Seldom, Sometimes, Often, Very Often) that you would prefer each of the following practices to take place in this laboratory class.

No.	Statement	Almost Never 1	Seldom 2	Some-times 3	Often 4	Very Often 5
1	Students in this laboratory class would get along well as a group.					
2	There would be opportunity for students to pursue their own science interests in this laboratory class.					

Appendix 11: Pseudonyms and codes used

Regional Science Teacher Survey (Chapter five)

Codes: RST 001 to RST 101 Coded in order of questionnaire receipt

School Science Teachers (Chapter six)

Codes: Pseudonyms self-selected, otherwise identified by researcher.
Stella; Beth; Lillian; Mike; Tony; Len; Mandy; Keith; Tanya; Sandra

Study class (Chapter seven)

Codes: Pseudonyms self selected by students in the focus group
Ed; Jessica; Bob; Jake; Pip; Simon

The study class teacher has been referred to as “the study class teacher”

Codes for all participating students in the study class: Pseudonyms were researcher selected except those who were also in the focus group.
Jessica; Andy; Bob; Jeff; Craig; Amy; John; Len; Ken; Jake; Emily; Phil; Nikki; Simon; Dan; Susan; Ed; Mili; Robin; Linda; Jamie; Pip; Harry; Henry.

Appendix 12: Sample of analysis of study class teacher reflection

Teacher reflection, Rolling a marble down a slope onto different surfaces (4 May 2006)

(Note: Student names changed to pseudonyms)

The **marble lesson**

OK, quarter to two on 4 May, just completed a lesson with the year eleven science class, looking at stopping distances. This is based on Thursday's lesson, bit of an introduction on forces and introduced with that concept was certainly a mention of the word friction, so they had got that background. Wednesday's lesson was all about gravity, so not related, but at the end we did then just spend five minutes discussing this particular investigation and what the purpose would be, what the variable, the independent variable would be, in other words the, so the purpose was to investigate the stopping distance of a marble having been rolled down a ramp, looking at different surfaces of the, for the marble running on after it had gone down the ramp. So the variable being changed, obviously the independent variable is the surface and the measurement being the distance travelled along that surface, using a meter ruler – distance of the marble.

Science idea *

Fair testing *

Procedural * understanding

Measurement

OK, at the end of yesterday's lesson the students were asked to complete the plan for today, which wasn't done well. Normally the homework is due all together on a Wednesday, so I suppose it was out of what I normally, you know, they normally have that expectation, so this was different. Anyhow, a little bit of the start of the lesson for them to catch up and think about variables. We also covered a different issue to do with measuring a slope of a graph that I'd identified as a weakness in the homework that had been handed in on Wednesday, or I had checked on Wednesday, so yeah, they had a few minutes to think about how to control the other variables. My thinking there was really in a practical sense, was that the students actually knew what they had to do before I let them loose with the equipment, that was realistically what I was wanting them to do. So I showed them the equipment and what they were going to use and we discussed what they would have to actually measure. We didn't discuss what they would have to keep the same, I wanted them to come up with that themselves, so I'll be checking that at some later stage.

Lesson 1 * Planning

Lesson 2 * Carrying out skill

Process

Codes: * Investigation * Engagement * Assessment
• Learning • Behaviour + management

With the class being not overly settled this morning, I decided to put the results table up on the board, which in a way, giving them a little bit more than I perhaps originally wanted but in reality it meant that I could then control the distribution of equipment by making sure that they had written that space, you know, the table, before they had actually set about it, so I suppose that was little bit of a control issue and perhaps next time I'll get them to come up with that data table. So yeah, the groups went out and I think that was a successful tactic. I sent groups out, the kids that I knew would work better, sent them straight outside, the ones that I had more suspicions about I kept them inside, but once they had produced some reasonable data I let them go outside as well and the students got on with the work well, the practical work, one group, Harry, Josh and Ed, very, very slow as usual to get anywhere but really all the other groups got on and they were, while they were doing the experiment I was happy that they were on task for certainly ten minute duration or so doing the practical so I was quite pleased with that. One of the students asked if they could use the Astroturf, which was, I hadn't thought of that, so that was a rather useful extra value for the independent variable. I also suggested to some groups to try the strip of paint on the concrete and we just on an individual basis to those groups, talked about the cyclist who was killed on the Western Hutt Road a couple of years ago when he slipped on the paint on the road, so that brought another aspect in there.

Towards the end of the lesson I wrote up what I expected the students to do next, to come to a conclusion with their experiment and my priority then was to collect the equipment, make sure it all came back, so I did that and it did all come back. Student participation at this stage was a bit mixed, some of them were getting on well with processing the data and some of them weren't but I guess that's something that I always find is the case, that once kids have done the experiment they need a little bit of a chivvy to get on with the processing, so it was pleasing that some of them did do that without any chivvying, or not much chivvying.

Student engagement *

So I then set about setting the concluding part of the experiment for them to complete for homework. Thought about setting it for tomorrow but Friday afternoons are always tricky so I generally set a test for that lesson, which is, so it's always a good time to do a bit of consolidation of the work, give them some

Reporting part for HW *

practice at NCEA questions, so we'll probably come back to this on Tuesday or Wednesday of next week and just discuss what they've found out in their interpretation and evaluation. I do quite like to look at what they have produced before we actually perhaps come back and discuss it, so yes, I think that would probably be Wednesday of next week.

Assessment

Other issues at the end of the lesson, we went over by two or three minutes, based on the fact that they were slow to stop and listen earlier in the lesson, and a question that I, having asked them to pack up, I should probably have asked them before that, I was keen to hear had they actually found anything surprising or you know, what particularly had they learnt. When I asked that they were all ready to go and I'd really lost them by that stage, so nothing of great interest came out there except that they found the grass had the most friction, so it was worth asking and getting that answer out I guess, so yeah, and then the issue of Ken swearing out loud, I'm going to turf him out for the next week and yeah, so I think that's probably about it, say for the lesson. OK, that's it for the investigation of 4 May.

Findings of investigation

Learning from investigation

Another observation, a statistic you might be interested in, on 2 May, homework check, this is the statistics for the completion of the homework set by the student teacher but reinforced by me. Out of thirty students on the roll, we had, one, two, three, four absent we had fifteen who made some attempt at the homework, of which, four did the whole lot, so that's eleven who did part of it and then eleven students who made no attempt at the homework at all. In one or two cases it's because they had not brought the book with them, but I regard that as not having completed it. Students who had completed none of the work were kept in for just about the whole of the interval, which is something I've been doing regularly, so it will be interesting to see whether there's any improvement over the year. That response of homework is probably about equivalent to what I've seen from the class right through this term really. OK, over and out for 4 May.

Concerns about lack of H.W.

[recording ends]

Appendix 13: Human ethics approval

Massey University

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

13 December 2005

Ms Azra Moeed
83A Judd Crescent
Naenae
LOWER HUTT

Dear Azra

Re: HEC: WGTN Application – 05/57
Science investigations in new Zealand Secondary Schools: Exploring the links between learning, motivation and internal assessment

Thank you for your letter dated 9 December 2005.

On behalf of the Massey University Human Ethics Committee: Wellington I am pleased to advise you that the ethics of your application are now approved. Approval is for three years. If this project has not been completed within three years from the date of this letter, reapproval must be requested.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee.

Yours sincerely

Sylvia Rumball

Professor Sylvia V Rumball, Chair
Massey University Human Ethics Committee: Wellington

cc Associate Professor Janet Davies
Dept of Technology, Science
& Mathematics Education
WELLINGTON

Dr Linda Leach
Dept of Social & Policy Studies in Education
WELLINGTON

Massey University Human Ethics Committee
Accredited by the Health Research Council

Te Kunenga ki Pūrehuroa

Appendix 14: Participant information sheet (sample)

Private Box 756
Wellington
New Zealand
T 64 4 801 5799
F 64 4 801 2692
www.massey.ac.nz

Science Investigation in a New Zealand Secondary School:
Exploring the links between learning, motivation and internal assessment

INFORMATION SHEET FOR STUDY SCHOOL SCIENCE TEACHERS

Researcher's Introduction
My name is Azra Moeed. I am a senior lecturer at Victoria University of Wellington and a part-time doctoral student at Massey University.

As part of my postgraduate study, I am interested in finding out how science teachers understand and practice science investigation at NCEA level 1. I also intend to research year 11 students' experiences of learning through science investigation. Data gathering will take place in 2006. The study will explore the links between science investigations, learning, motivation and internal assessment

My contact details and those of my doctoral supervisors are:

Azra Moeed
Victoria University of Wellington, Wellington
Phone: 04 463 9643
E-mail: azra.moeed@vuw.ac.nz

Associate Professor Janet Davies
Massey University, Wellington
Phone: 04 801 2794 ext. 6321
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Dr Linda Leach
Massey University,
Phone: 06 3569099 6947
E-mail: l.j.leach@massey.ac.nz

Project Procedures
This proposed research contextualises science investigation in one year 11 science class in 2006 in the approach to science investigation employed in the selected secondary school and the wider perspective of year 11 science teachers on science investigation at NCEA level 1. The class and the school have been selected purposively. Data-gathering from science teachers in the study school will include interviews and the collection of teaching materials relevant to year 11 science investigation.

Data from the selected science class will be gathered by observation, informal discussion and several focus group interviews with the students, analysis of student work and student grades, and from personal reflections by and interviews with the science teacher. Year 11 science teachers at all secondary schools in the Wellington region will be invited to respond to a postal survey.

Your involvement in this research would entail:
Your involvement would be in the form of an interview and would mean a commitment of up to an hour of your time.

Neither your school, its teachers or students, nor the Wellington regions science teachers will be identified in this study. All the data gathered will be stored in a safe, locked place at all times. Five years after the conclusion of the study all information collected will be destroyed.

Appendix 15: Sample consent form

Massey University
WELLINGTON

Private Box 756
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New Zealand
T 64 4 801 5799
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www.massey.ac.nz

Science Investigation in New Zealand Secondary Schools: Exploring the links between learning motivation and internal assessment

STUDENTS' CONSENT FORM

This consent form will be held for a period of five (5) years

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree/do not agree to the interview being audio taped.

I agree to not disclose anything discussed in the Focus Group

I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: .... **Date:** ....

Full Name - printed ....

Appendix 16: Regional science teacher questionnaire Question 10b

Table showing text books and workbooks used in year 11 science

Books		**Responses n=101**
Text books		55
	New directions in science (Wignall & Wales, 2003)	23
	Pathfinder series year 11 science (Hook, 2001)	16
	Fifth form science resources	9
	Newhouse physical world, material world etc.	4
	Level six science series of 4 books	2
	Making science work	1
	Revision books named as text books*	46
	Year 11 study guide ESA	16
	Form five science (Hannay, Howison & Sayes, 1995)	11
	Longmans write on notes	9
	NCEA Science Study Guide	6
	Year 11 Physics	2
	Year 11 Biology	1
	ESA Human biology guide	1
Workbooks		62
	NCEA level one workbooks (Cooper, Abbott & Hume, 2005)	37
	Workbook that goes with New Directions	12
	"Exams for you" worksheets, purchased	10
	School produced workbook	3

* Some responses identified "revision books" as text books.

Note: References included where sufficient information was provided. Some of these are old books and information is not accessible.

Abbott, G., Cooper, G., & Hume, A. (2005). *Year 11 science (NCEA level 1) workbook*. Hamilton, New Zealand: ABA.

Hannay, B., Howison, P., Sayes, M. (1995). *Form 5 science*. Auckland: ESA Publications.

Hannay, B., Howison, P., Sayes, M. (1995). Year 11 NCEA science study guide. Auckland: ESA Publications

Wignall, A. & Wales (2003). *New directions in science: NCEA Level 1*. Auckland: Pearson Education.

Wignall, A., & Wales (2003). *New Directions in science workbook Level 1*. Auckland: Pearson Education.

Appendix 17: Study school year 10 and 11 unit plan for electricity

School: Study School

Unit guide Title: Electron Power

Achievement Objective(s) codes: Physical World 5 – 1, 3, 4 (parts of each)
Planet Earth and Beyond 4 – 5

Lesson Title	Time	Learning Outcomes Purpose of Lesson	What Students Do	Resources
Getting them going	½	To produce an electron flow and measure.	H_2SO_4 and electrodes Lemon and electrodes.	Circuit boards
Using the energy	½	To be able to define/ recognise/make a circuit.	Create a circuit	Use Science Now Text
Electrical current and it's measurement		To define current. Learn to use an ammeter. Measure current.	Make a circuit. Use an ammeter in different parts of the circuit	
What else can be measured	1 – 2	Develop the idea of electrons numbers.	Be able to use an ammeter with batteries in series and components in parallel and series.	What else can be measured
Measuring the energy produced	1	To be able to use a voltameter across batteries in series and parallel.	Students carry out.	
Measuring the energy used	1 – 2	Investigate how the energy is distributed.	Design and build circuits with lamps in parallel and series. Use a voltameter to measure energy use.	
Who's ohm	1	• Develop Ohms law by investigating circuit readings. • Graph results. • Develop the idea of resistance.	• Students set u experiment and gather data. • Do simple problems • Demonstrate the effect of varying resistance on bulbs on a circuit.	
What else can we put in	1	• Be able to use successfully in a circuit, diodes, switches, nichrome wire.	• Design a burglar alarm • Do activity 1 + 2 from p.82 Science Now Book 3	

Lesson Title	Time	Learning Outcomes Purpose of Lesson	What Students Do	Resources
AC/DC	2 – 3	Investigate aspects of household electricity E.g.: • cost of electricity • safety in a home (fuses, earthing, double insulation) • safe use of electricity in the home (e.g. water, overloading).	• Wire 3 pin plug • Calculate cost • Mend a fuse • Be able to identify the energy changes which can occur.	• 3 Pin plugs • Use model generator
conservation	1 – 2	• Investigate where we get our electricity from. • Investigate how/why we should conserve out energy.	• Do graphs from p.92 Science Now book 3.	

STUDY SCHOOL YEAR 11 SCIENCE
UNIT GUIDE TITLE: Electricity
ACHIEVEMENT OBJECTIVE CODES: **PW 6.1,3,4**

Science Skills; Investigations; Science / Technology integrated through unit

Lesson Title	Time (hours)	Learning Outcomes Purpose of Lesson	What Students Do	Resources
Static / current electricity, Electricity basics	4	**Electricity.** Difference between static & current electricity. Need of a circuit for current electricity. Practice in writing circuit diagrams using correct symbols as given in prescription. Connect up simple circuits according to circuit diagrams involving resistors, variable resistors, switches, lamps, wires, ammeters, voltmeters, cells	▪ Recall prior knowledge from Yr 10 – brainstorm key points in electricity ▪ Recap static electricity, try experiments – rub vinyl strip with cloth, hold next to tap water, pick up small squares of paper, etc, demo Van der Graff generator ▪ Draw chart showing names and symbols of common circuit symbols ▪ Use analogy (eg 'ski slope model') to help explain concept of electricity, and what is meant by 'voltage' and 'current'. ▪ Set up circuits using Worcester boards, lamps in series & parallel. Include variable resistor and observe effects. ▪ Draw circuit diagrams	***NDS*** ch. 12 ***ESA*** ch.15 Workbook practical tasks. Worcester Circuit boards. ***Readings in Physics*** P. 149 – 50 Worksheet 'same / different exercise' Thinking skills: compare / contrast series / parallel circuits ICT: Crocodile Physics activities
Calculations in Electricity	4	Series & parallel circuits. Advantages & disadvantages of each. Calculations involving voltage, current, power & resistance. Calculation of electrical energy using power.	▪ With circuits connected up, include voltmeter, ammeter, record measurements and use Ohm's Law to find R for lamps in series & parallel. ▪ Practice Ohm's Law calculations. R = VI ▪ Carry out calculations involving electrical power P = V/I and energy = Pt	***NDS*** ch. 12 ***ESA*** ch.16 Small worksheet – 'Ohm's Law Questions. Worksheets 'Questions' (1-6 – current), 'electricity revision test'
Test	1	***Assessment – Practice A.S. 1.6 – 'Describe aspects of Physics pt 3 - Electricity'***	▪ Students sit end of topic test	

Appendix 18: Sample science teacher interview analysis

How do you prepare students for science investigation assessment, including formative assessment with respect to AS1.1?

Stella *Yep, great. Okay 1.1 formative assessment, what did you do with your class for formative assessment?* We also did friction on different surfaces to see how far the ball would go. Last year we did the energy on different colours of material. The cooling effect in water. What else did we do? I can't remember. But we did do quite a few of them. Oh and the one I did before the assessment was very similar to the assessment. Maybe too much help.	Did formative assessment similar to assessment Lots of other practise of Fair testing Formative similar to AS1.1 Ethical issues with practice
Beth Did lots of practical work make sure they are learning. I like to work with individual students and help them. Get them to learn things they should know like variables. You know some kids struggle with all the words My class were prepared I think but I am not sure that I should be saying this but the formative I did was so like the assessment I wonder if that is ethical. Other have said that to me too, so like it is not just me	Focus on learning Practise Fair testing Ethical issues with practice
Lillian. I'll get them to write all sorts of plans depending on the topic or an issue. If we're looking at a horse in motion, okay there's a pendulum go and investigate the length of the pendulum time period, or when we're in microbiology go and … End of tape side A ….. We're doing very much jump through the hoops as such, fair testing, what variable to control…and I'll give the kids marking schemes and I'll say well 'have you done this have you that. Grade yourself, grade your neighbours then I'll grade you, see what come up with. If you got a merit because XYZ, then you missed out on an excellence because you didn't have this point and that point.' And they can jump through hoops.	Training to go through hoops Lots of other practise of Fair testing Feedback on what to write for a grade

Mike We do a formative assessment with micro-organisms. The students are provided with a base question. They are required to create a plan of first of all what they are going to look at, determine the variables, look at what has to be controlled, how they're actually going to undertake the assessment and then sort out a suitable tabulation of obtaining meaningful and repeat samples. Using the template. And then the experiments are usually undertaken and once they've been written up they are then appropriately checked and marked. *And so for your summative for the same what do you do for the summative assessment?* Nearly the same, we usually do something that reasonably parallels, especially at year eleven, reasonably parallels what we would be using in the summative. A number of the students that we have, have a great deal of difficulty translating material from one area to another unless they are very, very close. There is always the potential of looking at it and maybe making the comment are you doing essentially a repeat of what you've done before, formative through to summative. And at year eleven with what we are doing at year nine and ten hopefully we can move away from that in the future, but currently that's where we tend to sit.	Fair testing. Using the template. Teach skills Ethical issues Use of template in year 9/10
Tony Ah we did practice several fair tests, my class muck about but I still feel I have to teach them the NCEA jargon, over a couple of lessons, did a practice that was quite similar, and I think it was using some of the same ideas may be I gave too much help but they need it. I know some other teachers do the same.	Fair testing Practice one quite similar almost identical Ethical issues
Len A lot of work, and most of the students achieved, but I had to give them a lot of help one to one mainly. I think it's a lot of work. We started with…we teach them the principle based on the 1.1 and then I give them three different mock exams and then we went onto planning the different parts of their 1.1 and still the kids need a lot of help. We practise the template. Teach them what to write to get merit and excellence but I don't have many able students	Students achieved but needed lots of help. Lots of practise of Fair testing Feedback, telling what to write.
Mandy I did three with my class. One was how different surfaces develop different kinds of friction – that was one. The second one was running up the steps the (inaudible) to see what is the work done and the distance covered and calculating the power they have (inaudible), and the third one was the pendulum one. The kids	Three formatives. Practising (All from workbook and fair testing)

are keen they want to know what they have to write to get good grades. So I say write this for merit and the… (inaudible). I don't understand what direction means. Is it ethical to give so much help?	Ethical issues
Ken *Okay how do you feel that the assessments of science investigation went for you the last time you did it, including any formative assessment with respect to 1.1?* Yea it is essential to do some initial teaching on that and to train them how to deal with an investigation, ah its actually quite difficult to teach properly and to let kids go and I guess I have some concerns in that area and concerns really lie in how much information you give them in any particular task, and how much you don't give them because I guess what I am seeing is that some of the moderation of the tasks that we have done, they were actually things we thought we could convey to the students and not be stringent on. Umm for me the difficult part is to decide exactly what they do require, there seems to be boundaries which can be quite frustrating sometimes you know that they are getting more help. The practise investigation for summative assessment is pretty much like the assessment. We try to keep it reasonably close otherwise it is pretty pointless really	Initial teaching is needed to train them up. Concern as to how much help to give Moderation issues Ethical issues Unsure what is required Formative similar to summative assessment
Tina The practical investigations. Yeah it's definitely a lot more structured than it used to be. We use the template in year 9 and 10 so may be in a year or two they won't need quite so much help. There's more of their own work, trying to get more of their own work going into it. I think there's more emphasis on the structure, and making sure that you use the template and writing it out the correct way. So I guess where we used to probably rush through a few practicals, personally I've tried to put it in the NCEA style so they'd have a lot more practice on it. My class did rolling a marble on a slope and it is similar to the assessed watch that car go they do for assessment.	Lots of other practise of Fair testing Use of template Ethical issues
Sandy I have only been in the school for this year and just ask what others are doing. The kids have to do fair testing for NCEA so I did the ones in the workbook. Student like feedback and want to do better but they just ask for what they have to write. It frustrates me but next year will be better. Our department is using the same template for year 10 so they should know the things they have to write.	Practice Fair testing Workbook Use of template

Notes: Focus on fair testing (8)
Lots of practice (8)
Use of template (4)
Ethical issues raised in relation to help offered (7)
Formative assessment similar to actual assessment (5)

Appendix 19: Integration of data from science teacher interviews

	Responses	1	2	3	4	5	6	7	8	9	10	Total
1	Engage children in science	√			√		√			√	√	5
2	Student ask the question/choose/	√	√	√	√		√			√	√	7
3	Curiosity/interest	√	√		√	√	√			√	√	7
4	Think critically	√	√	√	√		√	√			√	7
5	Fun	√	√			√		√			√	5
6	Progress/Answer questions at "Achieved"	√			√			√	√		√	5
7	Apply what is learnt	√	√	√	√		√	√	√	√	√	9
8	Follow the curriculum	√	√	√	√	√	√	√	√		√	9
9	Choice in what to investigate	√			√		√				√	4
10	Goal fair testing/AS1.1/ assessed invest.	√	√	√	√	√	√	√	√	√	√	10
11	Learning thorough doing	√	√	√	√	√	√	√	√	√	√	10
12	Scientific method	√	√					√		√		4
13	Vocabulary	√		√		√		√	√	√		6
14	Assessment after learning/learn first	√	√	√	√	√	√	√	√	√	√	10
15	Uneasy about helping/too much help/ethics	√	√		√		√		√	√	√	7
16	Assessment As1.1 (Hall) Efficient process	√	√	√			√	√	√	√		7
17	Comfortable with moderation	√	√	√	√	√	√	√	√	√	√	10
18	Change in practice	√	√	√	√	√	√	√	√	√	√	10
19	Planning ……Results	√	√	√	√	√		√	√		√	8
20	Validity	√	√	√	√	√	√	√	√		√	9
21	Practical work is motivational	√	√		√		√	√	√		√	7
22	Students just want to achieve (Most)	√	√	√		√		√	√	√	√	8
23	Assessment AS1.1	√	√	√	√	√	√	√	√	√	√	10
24	Revision/ understanding	√			√			√	√		√	5
25	Time				√				√			2

Appendix 20: Achievement Standard Assessment Task for AS1.1

National Certificate of Educational Achievement
TAUMATA MĀTAURANGA Ā-MOTU KUA TAEA

2008

Internal Assessment Resource

Subject Reference: **Science 1/1**

Internal assessment resource reference number:

Sci/1/1_CC2

Watch that car go

Supports internal assessment for:

Achievement Standard 90186 v3
Carry out a practical science investigation with direction

Credits: 4

Date version published:	April 2008
Ministry of Education quality assurance status	For use in internal assessment from 2008

Teacher Guidelines:

The following guidelines are supplied to enable teachers to carry out valid and consistent assessment using this internal assessment resource. These teacher guidelines do not need to be submitted for moderation.

Context/setting:

This assessment resource is based on planning, carrying out, processing and interpreting, and reporting of a practical investigation that is a **fair test** investigation. The teacher directs what type of investigation the students are to do and changes the planning sheets and student instructions accordingly.

Conditions:

This assessment activity is to be carried out in four parts that lead to the production of an investigation report.
The specific conditions should be stated on the student instruction sheet. e.g. equipment and materials available.

The students need sufficient time for:

- trialling and planning
- carrying out
- processing and interpreting data
- writing a report

The time allowed will depend on the particular investigation chosen. State this time on the student instruction sheet.
Any special safety requirements **must** be stated on the student instruction sheet.

Teachers need to be aware of the credit value of this standard when determining the time needed to carry out the investigation.

Resource requirements:

Students will need to be provided with the materials and equipment required for trialling and carrying out the investigation.

The Investigation

Part 1: Developing a Plan

- The student is provided with a *Planning Sheet* (included) and will work independently to complete this. The planning sheet may need to be modified, related to the task chosen, to allow sufficient space for students to write.
- The student should be given the opportunity to conduct trials to develop their method, eg. to establish a suitable range of values for the independent variable for a fair test or the sample selection for pattern seeking. A record of this trialling needs to be mentioned on the template or in the final report.
- The student uses the planning sheet and trial results to write a detailed, step-by-step method. The Planning sheet (or other check sheets) may be used to self-evaluate that the method is workable.

Part 2: Collecting and Recording Data

The student follows their written method to collect their own data. The method may be modified but these modifications must be included in their final report and indicated to the assessor.

Part 3: Processing and Interpreting Results
The student must process the data collected into a form that shows a pattern or a trend or absence. This may be achieved by averaging, using a table or using a graph.

Part 4: Presenting a Report
The student, working independently, presents the report of the investigation following the directions/format given in the student instructions.

Teacher Resource Sheet

Prior teaching will need to occur on the scientific method and how to design a practical that involves **'fair' testing.**

2008

Internal Assessment Resource

Subject Reference: **Science 1.1**

Internal assessment resource reference number: Sci/1/1_CC2

Watch that car go

Supports internal assessment for:
Achievement Standard 90186 v3
Carry out a practical science investigation with direction
Credits: 4

Student Instructions Sheet

School/Institution	
Student Name	
Teacher or Class reference	
Date of completion	

Background Information:
Watching children play with their toy cars students noticed that the cars seemed to go faster and further the steeper the slope they were released on.

In this investigation you are to develop and carry out an investigation. You will plan, collect, process and interpret information, and present a report to find out how the slope of a ramp affects the distance the car goes along the flat (table or floor) This investigation is a **fair test** investigation.

Conditions:
This assessment activity is to be carried out in four parts that leads to the production of an investigation report. This investigation must be carried out individually.

Times: Total time will take a minimum of 1 week e.g.

- trialling and planning 1 period
- carrying out and processing data 1 period
- interpreting the data and 1 period
- writing the final report 1 period

Equipment:
You have been given books, a ruler, ramp, and a car.

Part 1: The Plan

1. State the purpose of your investigation
2. Identify the key variables involved:
   - the independent variable (the variable that is to be changed)
   - the dependent variable (the variable that will be measured)
   - controlled variables (significant or relevant variables that will need to be kept the same to make your results more reliable)
3. Describe a suitable range of values to be used for the independent variable and how these values will be changed. Trialling will help you establish this range.
4. Describe how the dependent variable will be measured.

Controlled variables: (things you will need to keep the same)

1. Identify any other variables that might influence your investigation and describe how they will be controlled or kept the same to make your results more accurate.
2. Describe how you will ensure that your results are reliable and that you have enough data.

Now write a detailed **step-by-step method** that you will use.

You may change your method as you carry it out as long as you describe any changes made to the method in your report.

Part 2: Collect and Record Data

- Follow your method to collect data and record the results in a table or another appropriate way.
- Remember to record any changes to your method and reasons for the changes as you go.
- Record any difficulties with equipment, gathering your data or your method.

Part 3: Process and Interpret Results

- Process your results so that you can show the trend (or lack of) or pattern in your data. This will usually involve some calculations (e.g. averages) and/or a graph.
- Record the relevant trend or pattern; this is your interpretation.
- Relate the trend or pattern to your purpose; this is your conclusion.

Part 4: Present a Report

Present a report on your investigation. This will include your:

- Trialling and planning sheet
- detailed step-by-step method, including any changes made during your investigation
- recorded data
- processed data
- interpretation of results
- conclusion that links your interpretation to the purpose of the investigation evaluation of the conclusion in terms of the method used. In this you may comment on the
  - reliability of data (repeats / outliers etc)
  - Validity of the final method chosen.
  - Way your results reflect the science ideas related to the investigation.

Planning Sheet **Student name:**

1. Purpose of investigation (this may be an aim, testable question, prediction or hypothesis)

2. **FAIR TEST**
Which variable will be changed? (This is the independent variable)

How will the independent variable be changed?

Give a suitable range of values for this variable

3. **FAIR TEST**
Which variable will have to be measured or observed in order to get some data or information from the investigation? (This is the dependent variable)

How will the dependent variable be measured or observed?

4. Other variables that need to be controlled to make your results more accurate.

Other Variables	Describe how this variable will be controlled or kept the same?

5. How will you ensure that your results are reliable?

6. Notes from your trials.

Now use the information on this planning sheet to write a detailed step-by-step method.

Method

Changes made to the method after the investigation started.

Report Sheet

Recorded data:

Processed data:

PAGE FOR TEACHER USE

Interpretation of Data:

Conclusion:

Evaluation of the Method and Data and / or Science ideas

Assessment Schedule: Sci/1/1_CC2 - Watch that car go

Evidence	Achievement	Merit	Excellence
Report contains	Statement of purpose Eg: To see what effect the height of a ramp above the floor has on the distance travelled by a car.	(as for achievement)	(as for achievement)
Report (planning sheet and or method)	Identify range for independent variable. • *The height of the ramp above the floor. Only 3 heights chosen.* **and** • Measurement of dependent variable. Distance travelled from the ramp.	a valid method (easily followed by another student) is required that includes: • A **valid** range of the independent variable. Eg: At least 4 independent variables (height), preferably 5, is the minimum recommended range for Merit grade. Eg: heights of 5cm, 10cm, 15cm, 20cm • Description of **and** control of other key variables *Eg: same ramp, same position released on the ramp, same area of bench / floor, same car.* • Consideration of other factors *Eg: how the car released.* **and** • Measurement of dependent variable. *Distance travelled from the ramp in cm.*	As for merit

Report (Recorded data, processed results)	Collect, record and process data relevant to purpose. one investigation on each height. Distance recorded in follow able format. Graph showing trend. **<Possible results>** **Height (cm) | Distance travelled (cm)** **5 | 3.4** **10 | 12.3** **15 | 33.5** **20 | 46.0**	Collect, record and process data to enable a **valid** pattern or trend (or absence) More than two repeats (to establish validity) on chosen heights. Results correctly averaged Distance accurately measured. Averages recorded in a way that allows the **valid** trend to be shown and/or correctly labelled graph-showing **valid** trend that supports collected data.	(as for merit)
Report (Interpretation and conclusion)	A conclusion based on the processed data collected. The greater the height of the slope the greater the distance the car travelled.	A **valid** conclusion that links to the purpose. *The greater the height of the ramp and therefore the steeper the slope the greater the distance travelled by the car.*	(as for merit)

Report (evaluation)			**Evaluation to justify the method used to reach the conclusion.** One of Method The final method chosen gave results that were repeatable. This also allowed us to see aberrant data and this data could be removed from our calculations. Reliable data. We took enough reading to allow a valid trend. We repeated each trail until we got 3 recordings that were similar. **Science ideas** Example Our results supported the science idea that *The higher the ramp the more gravitational potential energy the car had and the more that was converted to kinetic energy, therefore the further the car went before it came to a halt.*

To determine the overall level of performance all judgements within a column must be met.
For each judgement, evidence can be obtained from anywhere in the report.

Appendix 21: Sample classroom observation and running record

Observation Schedule: Date: 26/5/06 **Day:** Friday

Purpose: To record behaviours of teacher and students which indicate the teaching and learning of science investigations, student motivation to learn and assessment of science investigations for NCEA internal assessment by AS1.1

Classroom environment:

Physical aspects:

- Layout
- Lighting ✓
- Room Temperature Warm

Today – Lots of teacher talk and students did not pay a lot of attention.

Lesson Overview (topic/focus, style)

- Return planning task.
- Practical, gathering data.

Start of Lesson

Uses an advance organiser ✗

Makes links to the previous lesson ✓

Focus of lesson: Scale: *Mostly (1) some what (2) not at all (3)*

Theory: ☐ Practical: ☑ Assessment ☐

Checks homework ☐ Set homework

Teaching and Learning Behaviours

Teacher welcomes students to class ✓				
Makes sustained eye contact ✓				
Smiles				
Body language:		✓ *Affirming*	*neutral*	*negative*
Student initial response (whole class)		✓ *Positive*	*Neutral*	*Negative*

Quite a lot of listening needed but they are not paying as much attention.

Student Behaviours

Engagement (whole class √ / individuals *)

Proportion of class highly engaged:

None	✓	All	first ¼	Except gr 3,4,5
None	✓	All	second ¼	Except gr. 4,5
None	✓	All	third ¼	" " "
None	✓	All	last ¼	Most not engaged

Quality of Engagement:

Enthusiastic: (Keenness/eager to start)	Most	some ✓	Few
Perseverance (Carrying it through)	Most	some ✓	Few
Attentive (Behaving within the guidelines of class expectation)	Most	some ✓	Few
On task behaviour	Most	some	Few ✓

Investigation:

Type: Carrying out investigation in preparation for assessment

Skill involved and developed:

Data gathering

26/5/06 Assessment Practise

Students present 23.

2:15 We come in and sit down
Teacher returns marked books to 11 students.
(Rest had not handed in) [Harry, Ed, Jo talking]

2:20 Class still chatty. [Ed has moved to sit next to Harry]

Teacher: "Yesterday you did well. I have marked your work but have not said what level your answer is at.
Can tell you individually later.
To get achieved you needed to get all correct on Page 35 [workbook]
To get merit some one else should be able to follow your plan. Excellence needs more".
[Len, Ken, Ed, Harry being silly]
"Next friday you will plan your internal assessment. Then in exam week you will have 2 hours to collect data.
You need to study Pages 32-53 (workbook)
One hour you will do practical, next hour do a mock exam for other standards"
"Week after that you will write your report here in class"
"You will get another practise new week.

2:30 "Now you will carry out the plan you wrote yesterday.
"Jeff I won't repeat what I have said, you need to listen to instruction
2:35 OK you can collect gear from here and get started. Take care with thermometers.
Harry, Henry & Ken sent out and not allowed to do practical.
Pip not sure what to do with the stop watch. Bob helps.
All in class get out of seat and working on →

Those who do not have books (12) Not attentive. Chatting. Ignored.

Ed wanders annoying others

side benches.

2:45 Three groups at the back not engaged.
Ed says this is dumb we did it
last year.
All need to collect hot water from the urn
and a chatting while they wait.

{Harry, no books. I offer him paper. He make a dart with it.}

Some students not sure that they need
to repeat their trials. Their tables do not
have the space.
Bob points out to their group that they
need a bigger table.
Students take thermometer out and put it
in after two minutes and read it. I said
Pip will you get the correct reading. She
said yes. Others just went along with it.

Teacher goes around the class helping.

{Most now need several readings

Group 4 break a measuring cylinder.
Teacher sweeps it up.

3:00 Class start to pack up. Teacher puts
H.W. on board.

Bell goes 3:15. All ready to leave.

① Notes: Students did not hear instruction & did not know what to do.

② Ed, Harry, Henry, Ken have decided that they will not pass.
③ students have done this investigation last year. Claimed they are bored.
④ None of the students measured temperature or Volume accurately.
⑤ most did not have a plan so did not know what to do