

Tertiary Students' Perceived Value of Practical Work as
Contributing to the Learning of Science

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ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Signed

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ABSTRACT

This thesis focuses on practical work as pedagogy in the teaching and learning of science. In particular the emphasis is on students' perceived value of practical work in science courses offered from pre-degree to final year degree level courses at a university in Auckland, New Zealand.

It seems a common assumption that the teaching of science will include a practical component. For instance, the School of Applied Sciences at Auckland University of Technology (AUT) offers a significant practical component within almost every course offered. This thesis explores the assumption that practical work should be included in the delivery of science courses. A range of views on the nature of science, the acquiring of knowledge and theories of learning are investigated, as well as the ways in which these may underpin the use of practical work as pedagogy in science education.

The research described in this thesis took the form of a case study in which students in a range of science courses at AUT were asked to complete a questionnaire and a small number of respondents were then interviewed. Questionnaires were used to gather a large number of responses across a range of subject areas and a range of levels of study. Interviews were utilised to gather more in-depth responses. The data collated from the questionnaires and interviews was analysed thematically.

Perhaps not surprisingly, the findings of this case study indicate overwhelming support by students for practical work. The dominant themes which emerged indicated that practical work not only supports learning and understanding in science, but also provides learning opportunities that classroom learning does not provide.

The findings of this thesis would seem to support and justify the continued delivery of practical work in science courses. While the responses did not reveal *how* students believe practical work supports their learning and understanding, some respondents affirmed the less explicit aims of practical work in science education, such as the development of a sense of inquiry, the ability to problem solve and the ability to think critically.

This then leads to the question as to whether practical work, as delivered in Applied Science courses at AUT, provides opportunities to potentially meet all of the aims which are expected and hoped for by students, the researcher and her colleagues. While this thesis establishes that students value highly the practical component in science courses, the need to further investigate the style of delivery of practical work to meet wider aims also emerged from this study.

CHAPTER 1: INTRODUCTION AND OVERVIEW

- 1.1 Personal perceptions on practical work and rationale for study
- 1.2 Overview of research method
- 1.3 Overview of thesis chapters

1.1 Personal perceptions on practical work and rationale for study

I can reflect on the teaching of science from my own experiences of being taught science at secondary school (my earliest recollections of learning science as a subject), at university, from learning how to teach science during teacher training, and from teaching science at both secondary school and tertiary levels.

My own experience of learning science at school and university contained much laboratory work which I believe contributed to my conceptual understanding of science and scientific concepts, and to my enjoyment of science, in particular the emulating of the role of the scientist. Although much of the practical work was “recipe book” style, and the testing or demonstration of theories, it also included investigative practical work. Whether acknowledged or not at the time by the teacher or myself, I firmly believe that the inclusion of practical work in my learning of science helped me construct my personal conceptual understanding of science.

Similarly, as a secondary school science teacher in the 1980s, my colleagues and I were also very committed to the inclusion of practical activities in science. There was collegial sharing of ideas and activities. We were supported and encouraged to perform practical science activities providing an experiential approach to learning both inside and outside of the classroom. This included not only laboratory experiments but also, for example, rocky shore studies, bush studies, and time and motion studies on the rugby field.

My lasting impressions of these experiences are ones of enjoyment and value, from both the teacher and student perspectives. During a chance meeting ten years after teaching a student in a fifth form (year 11) science class, who had pursued an arts career, I was impressed by her remembering seeing and hearing a record played through a cone of paper. She commented that although science was not “her subject”, she had enjoyed it and found many parts of it memorable. To have confirmed firsthand that the practical

component of science teaching can make learning memorable had great impact upon me.

I have now been a member of staff in the School of Applied Sciences at Auckland University of Technology (AUT) for fifteen years. During this time, there has never been a member of staff, myself included, who has questioned the content and delivery of practical work in their course/s. One could interpret this observation to mean that science lecturers fully appreciate the inclusion of practical work as a valued pedagogy in learning science. Alternatively this may indicate that the inclusion of practical work as an adjunct to science education is simply taken for granted and its value never questioned. It therefore seemed appropriate that the purpose and perceptions of practical work be reconsidered.

In my current position in the School of Applied Sciences, my responsibilities include the timetabling of lectures and practical sessions and the allocation and budgeting of resources for both. The practical component of courses contributes at least the same number of contact hours to courses as the theory component and requires significantly more resourcing. Resourcing includes specialist venues, technical staff to manage equipment and laboratory requirements, and a greater staff-to-student ratio.

From my perspective, as both a lecturer and member of the management team in the School of Applied Sciences, I need to question whether the greatest benefit to students is being gained from practical work. This issue has become more prominent recently as a result of the practical component having been reduced in papers within the same faculty for resourcing reasons.

The suggestion has been made that alternative modes of delivery of the practical component of science courses, such as virtual laboratories and simulations, replace the traditional style of practical work which is predominantly hands-on. This more economical approach may still achieve the same anticipated aims.

However, having “dabbled” with virtual laboratories and simulations and I believe that although these have a place in practical work in learning science, they are not a substitute for the many and varied purposes of traditional hands-on practical work in the

laboratory. One example of a popular aim of practical work is making phenomena more real, which is unlikely to be achieved through virtual laboratories and simulations.

In order to defend and support the inclusion of practical work and the associated resourcing costs, it is important that students perceive this aspect of their learning as being valuable, and that the reasons for saying so should be clear. It is imperative to ascertain the perceived value by students and to confirm whether students share the same beliefs about practical work as their lecturers. We, as a school and as lecturers, expect students to value and get value from practical work for educational reasons. If we discover that this is not the case, we need to question our delivery of practical work. Are we as lecturers delivering practical work in such a way to meet the school's educational objectives?

It is a concern that in annual course surveys students often rate "Value of Practicals/Field Trips in the Course" as "average". The format of this survey is a Likert scale and although there is an opportunity to add comments at the end of the questionnaire, comments are seldom made specifically in relation to practical work. When they are, they are usually of the "I enjoyed the field trips" kind which provide little insight into the value students place on practical work in their courses. Can the expense of practical work, including field trips, be justified on the grounds of enjoyment? If students are "enjoying" practical work, can it be assumed that learning is therefore taking place? As Wellington (2000) queries, "Students do practical work, but do they know why they do practical work?" (p. 145).

In conclusion, I have been led to consider the following questions:

- What is the nature of science and how do views about the nature of science impact on views about teaching and learning in science?
- What are the purposes of learning science, and what are the purposes of practical work as a pedagogy in teaching and learning science?
- What are the educational purposes of the School of Applied Sciences, and what is the role of practical work in fulfilling these purposes?
- What views of teaching and learning may underpin the teaching of science in the School of Applied Sciences?

These questions are addressed in the literature review, from which arise two further questions:

- Are we in the School of Applied Sciences teaching and using practical work in a way that best helps our students to learn?
- Do our students understand why they do practical work and do they feel they benefit from it?

1.2 Overview of research method

A case study methodology was adopted as the project was an exploration in a specific environment. It was anticipated that the findings would be informative and beneficial to the School of Applied Sciences. An assumption was also made that the findings could potentially be extrapolated and applied to similar courses in other tertiary institutions.

The data was gathered from AUT School of Applied Sciences students. The researcher is employed in a full-time position within the school, with access approved by lecturers to students across a range of science disciplines and levels within the school. Data was collected by distributing a questionnaire to students in selected courses across programmes within the School of Applied Sciences and from structured interviews from a selection of participants from the same courses.

To obtain individual opinions and thoughts of students as to how they perceived the value of practical work in the learning of sciences, both quantitative and qualitative questions were asked in this study. Quantitative questions required students to provide data on their gender, ethnicity, year and level of study and to rate attributes of practical work. Qualitative data was gathered in both phases of the research using open-ended questions to increase the depth of responses, provide more insight, support emergent themes, and to establish perceptions held by particular cohorts of students.

The qualitative data was analysed and coded for emergent themes; these themes were then discussed with respect to findings from the literature review. Data was also analysed to investigate any correlation in perception between particular cohorts of students, such as perceptions according to gender, programme enrolled in, or level of study.

1.3 Overview of thesis chapters

Chapter 2 conducts a literature review and commences with a discussion of the nature of science and the characteristics of the modern scientist in relation to the role AUT plays in the education and training of prospective scientists. It continues to investigate the ideas of knowledge and learning and learning theories in relation to science education. I then discuss the historical development of practical work in the teaching of science, what constitutes practical work, the amount of and cost of practical work in courses, and the continuing and current justification for practical work in science education.

Justification is based upon common perceptions of the purpose and value of practical work widely held in the science education community. Along with this justification arguments against the inclusion of practical work will be cited. Finally, current trends in the offering and delivery modes of practical work will be discussed. The evidence from this literature review will form the basis of the discussion of the thematic findings of this study.

Chapter 3 outlines the methodological approach, including the research tools used, data collection and analysis, and ethical considerations.

The collected data is analysed in Chapter 4, and emergent themes are identified and elaborated upon. Correlation or disparity between questionnaire and interview responses will be investigated; the anticipation being that more in-depth responses will be collected from the interviews.

Chapter 5 relates the findings from this study to the current literature in the field, and discusses the implications of the findings for the School of Applied Sciences and potentially the wider science education community.

The conclusion to this thesis, Chapter 6, presents the strengths and limitations of this study, makes recommendations based on the findings, and finally presents further research possibilities in this area of science education.

CHAPTER 2: LITERATURE REVIEW

- 2.1 The nature of science
- 2.2 The aim of science education
 - 2.2.1 Purpose of science education at tertiary level
 - 2.2.2 AUT training of technicians/technologists/scientists
 - 2.2.3 Graduate destinations
- 2.3 Knowledge and how it is acquired
 - 2.3.1 Learning theories
 - 2.3.2 Constructivism in learning science
 - 2.3.3 Constructivism as a rationale for practical work in learning science
- 2.4 The nature and purpose of practical work
 - 2.4.1 The perceived purpose of practical work in science
 - 2.4.2 Perceptions of the value of practical work
 - 2.4.3 Amount of practical work in teaching science
 - 2.4.4 Resourcing practical work in tertiary education
- 2.5 Current trends in approaches to practical work
- 2.6 Summary

2.1 The nature of science

In order to investigate the role of practical work in science education, it is important to consider what science is, and why and how we teach science.

The philosophical debate of what constitutes science is complex. Ziman (2000) states that although it is widely acknowledged that the function of science is to produce knowledge, philosophers of science have failed to come up with a satisfactory definition of “science”. The debate as to what constitutes science is very much concerned with how the body of knowledge is arrived at, agreed to and accepted by the scientific world.

Modern science, which involves experimental testing, has only existed for 300 years, since Galileo, but it has only been part of life for the general public for the last 150 (Russell, 2001). Prior to this, science primarily existed as philosophical debate within the domain of academics.

As an alternative to the complex philosophical debate about what constitutes science, Harlen (2000) provides a simplified definition: “Science is a major area of human mental and practical activity which generates knowledge, knowledge that can be the basis of important technological applications as well as adding to understanding of the world around” (p. 1). But this provides no insight into the ongoing debate as to how this knowledge is generated.

Sharrock and Read (2002) present an historical insight into the philosophy of scientific theory according to Thomas Kuhn, a twentieth-century philosopher of science whose theory will be discussed later in this chapter. They debate what constitutes scientific theory and how it is arrived at by fellow philosophers and scientists, such as Paul Feyerabend, Steven Weinberg and Karl Popper. The authors highlight the debate of science versus pseudo-science, which has vital social and political relevance both historically and currently (Lakatos, 1970, cited in Curd & Cover, 1998).

This thesis will not investigate pseudo-science, as it is “genuine” science which is taught as part of a “normal” or “regular” curriculum in the New Zealand education system. Genuine scientific theory, according to Ruse, possesses five key characteristics:

- 1 it is guided by natural law
- 2 it has to be explanatory by reference to natural law
- 3 it is testable against the empirical world
- 4 its conclusions are tentative, i.e., they are not necessarily the final word; and
- 5 it is falsifiable. (cited in Curd & Cover, 1998, p. 76)

Two major views as to the nature of “genuine” science can be identified. The positivist (or empiricist) view holds that science is value-free, derived from facts and these facts are based on observations which are free of opinion (Chalmers, 1990). The facts established by observation are the basis of the general laws of science which provide generalisations to the practical world. If these explanatory laws are to be adopted and substantiated they must be arrived at via the “scientific method”, which has three stages: observation of the significant facts, arrival at the hypothesis, and ultimately the consequences, which comprise the general law or theory (Russell, 2001). Chalmers (1990) presents the view of Kuhn (1970), on the progression of scientific theory. This involves one theoretical structure being replaced by another when a new paradigm emerges as a result of experimentation which falsifies the existing paradigm. When the

new paradigm gains the support of the scientific community, Kuhn argues, a scientific revolution has taken place.

This concept of science aligns with that described by Russell (2001), who sees science as a general body of scientific knowledge organised into hierarchies: the lowest hierarchy being facts and the highest the general laws of science that apply to the universe.

There are various processes by which these general laws may develop from facts. One is an inductive process, whereby observations generate laws, which in turn suggests that there is a “law of higher order generality” (Russell, 2001, p. 41). Then there is a deductive process, involving the hypothesising of a general law which is then tested and compared with observations. Both of these processes support the view of science being the “quest for generality” (Chalmers, 1990, p. 26) and support the scientific method as a means of arriving at the general laws of science.

The second major view as to the nature of science is the relativist view. The process of arriving at general laws utilising the scientific method – the process upheld by the positivist view – is debated by relativists. Positivists see science as based upon objective facts established by careful use of the senses (Chalmers, 1990, p. 41). The relativist view denies the objectivity of observation: perceptual experiences of the observer are influenced by the background and experiences of the observer.

The Austrian philosopher Feyerabend denies the existence of “theory-neutral facts”, and supports the idea that the science based on observable facts is relative to people, cultures and different philosophical schools (Chalmers, 1999). Feyerabend asserts that scientists should not be restricted by scientific method and objectivity as these constrain scientific development, making it more dogmatic and less adaptable. His position is that the high regard for science is playing a repressive role in society and there should be more humanitarian freedom. By removing the constraints of the scientific method, individuals would have the freedom to choose between science and other forms of knowledge (Chalmers, 1999).

A commonly accepted theory as to the process by which knowledge is obtained from a relativist viewpoint is constructivism. Constructivism holds that knowledge is

subjective and an individual constructs their own meaning of the world. This is the perspective I adopt in this thesis and believe the constructivist view should be considered in the teaching of science. This will be discussed further in section 2.2.

From the above discussion it can be seen that there is more than one philosophical argument as to the nature of science. These arguments have had, and possibly continue to have, an influence on science education in schools, universities and communities in the twentieth and twenty-first centuries. On the personal level, one's views of the nature of science influences not only one's views about science education, but also the role of practical work and the role of the teacher in a class. The aim(s) of science education and the role of practical work will now be discussed bearing in mind these alternative viewpoints.

2.2 The aim of science education

Alternative views of the nature of science unavoidably influence the aims of science education and therefore the teaching and learning of science. If science is the quest for a set of rules which explain our universe – the positivist view of knowledge – is the aim of science education to teach these rules which have already been established by scientists? Alternatively, is the aim of science education to provide opportunities for individuals to construct their own conceptual understanding of the natural world, adopting a relativist view of knowledge? This section discusses whether the purpose of science education is to meet one of these aims, both of these aims, or potentially a set of overarching objectives broader than either of these.

“Science” is recognised as an area of study in education in practically all countries of the world (Harlen, 2000). As Osborne (2003) states, science education “is something which is seen as universal value and, perhaps more importantly, an essential component of the core curriculum for all” (p. 37). One must therefore ask what the aim of science education is and why it is a required component of education.

Harlen (2000) argues that “Science plays such a vital part in our lives and the lives of future generations, it is essential that the education of the whole population, not just the future scientists, provides them with a broad understanding of the status and nature of scientific knowledge, how it is created and how dependable it is” (p. 1). Today's society

is dominated by science and technology, hence science is vital not only in the technological aspects and developments of modern civilisation, but also in societal aspects of civilisation. Doubt has been raised as to whether the science curriculum is meeting the needs of both future scientists and future citizens (Fensham, 1985, as cited by Osborne, 2003). This concern is reinforced by comments which appear in a report prepared by the Teaching and Learning Research Programme in England (2006) claiming that the science curriculum aims to create future scientists rather than future citizens.

In contrast, and perhaps in response to the concerns raised above, according to the New Zealand Curriculum (NZC) (Ministry of Education, 2007) the aim of science education is to “contribute to the growth and development of all students, as individuals, as responsible and informed members of society, and as productive contributors to New Zealand’s economy and future”. The curriculum states that these aims will be achieved by helping students

develop the skills, attitudes, and values to build a foundation for understanding the world. They come to appreciate that while scientific knowledge is durable, it is also constantly re-evaluated in the light of new evidence. They learn how scientists carry out investigations, and they come to see science as a socially valuable knowledge system. They learn how science ideas are communicated and to make links between scientific knowledge and everyday appropriate decisions and actions. (Ministry of Education, 2007, p. 28)

These aims correlate with the philosophy of science according to Kuhn’s view (1970) as described in the previous section. Science explains nature; explanations are arrived at by investigating nature; scientific revolution occurs; and finally use of knowledge and skills facilitates the contribution of individuals as citizens in society.

The aim of science education, as delivered in New Zealand schools, appears then to satisfy the requirements of both developing future scientists and scientifically literate future citizens. Likewise, reforms in science education in the United Kingdom and United States since the 1980s have seen a shift from the pragmatic training of future scientists to the developing of a scientifically literate population capable of participating in our more science- and technology-driven societies. As a consequence of reforms in the aims of science education, a rethinking of approaches to curriculum, assessment and instruction is also required (Duschl, 2008).

In the early 20th century, the philosopher Dewey recognised that “The problem was that science has been taught too much as an accumulation of ready-made material with which students are to be made familiar, not enough as a method of thinking” (cited in Bybee 2010, p. 70). He insisted that the power of science resided in its process and that students could learn this only by “taking a hand in the making of knowledge, by transferring guess and opinion into belief authorized by inquiry” (p. 70).

Views such as those held by Roth, McGinn and Bowen (1996) and Harlan (2000) maintain that science education has not changed over the last century. Roth et al. claim, for example, that “Science education remains what it has been for decades: an indoctrination in an objectivist conception of science and epistemology and a breeding ground for uncritical and scientifically illiterate citizens” (p. 455).

Harlan (2000) also notes that the positivist view of science – the teaching of science as facts and scientific activity being the application of principles and skills – is still a prevalent aim of science education. It is possible that science education at university level subscribes to the positivist view in contrast to pre-tertiary science education as described by the NZC. The aims of science education as stated in the NZC align with a social constructivist view of science education. These aims, which include attributes and skills in addition to content, provide greater potential for educating and training to enable citizens to participate in a time of “rapid growth of scientific knowledge, scientific tools and technologies and scientific theories” (Duschl, 2008, p. 270).

Reforms in the purpose of science education have occurred over the last half century, whereby the goal of science education has shifted from enabling students to think “like scientists” and a focus on what needs to be known to *do* science (Schwab, 1962, cited in Duschl, 2008) to what students need to be able to do to *learn* science: how to obtain evidence, use principles, develop explanations, and be able to make predictions that represent the natural world (Duschl, 2008).

Another pragmatic aim of science education, which may be representative of tertiary level science education, is that of training and producing specialist scientists and technologists who flow into our communities. The perceived (and identified) problem with this aim is that unless science education is for citizenship for all whereby all

members of our communities have access to, and are educated in, science, and acknowledges its role in the current social context, science education is seen as hard and unappealing (Osborne, 2003) and perhaps irrelevant. An example provided by Osborne is that of the high school student questioning the relevance of learning about the blast furnace, in comparison to current technology that is prevalent in the media. This example could easily be applied to tertiary education also. Similarly, Munro and Elsom (2000, cited by Osborne 2003) identify the problem of “science teachers marketing the advantage of studying of science as leading to a small subset of scientific careers rather than its general cultural value” (p. 45).

By the time a student enters tertiary study in New Zealand, they possibly have set goals for their future career, or at least have an idea of the field they see themselves participating in. Hence students who come into sciences have usually achieved to some extent in sciences at school and are either interested in pursuing a career in science, perhaps as a scientist, or have a science career of another nature in mind (appreciating the wide scope of science careers).

Regardless of the background of new students, it is assumed that students enrolling in a tertiary science programme come equipped with scientific knowledge, scientific skills and understanding of the scientific method. This is generally the case for students enrolling in the AUT School of Applied Science, whose levels of competence, awareness and experience in each aspect nevertheless vary widely. The education that then occurs in Applied Sciences is very traditional, primarily providing factual knowledge and practical skills and utilising lectures and practical sessions.

It is important to ask what students’ aims and expectations are with respect to continuing their science education in a tertiary programme, having emerged from science education which is philosophically relativistic; is tertiary education aimed at developing scientists, technicians and technologists or producing scientifically literate citizens, or both? The anticipated aims of tertiary science education are reflected in the programmes and courses offered, and in the pedagogies used, but are not overtly underpinned by a view or views of the nature of science as the compulsory science curriculum in New Zealand is.

2.2.1 Purpose of science education at tertiary level

Prior to the advent of science education as a formally taught subject within education, science was traditionally a philosophical quest by academics. Science education developed into formal lectures, delivered by lecturers, and practical work which was limited to demonstrations. Demand for practical work arose to meet the needs of jobs, to support apprenticeship training and to provide graduates with practical skills and the ability to perform complex experimental procedures (Boud, 1986).

The aims of science education in the NZC (Ministry of Education, 2007) currently express a broader range of objectives regarding the outcome of science education than those of tertiary curricula, which tend to focus on the practical capabilities to enable the graduate to perform in a practical scientific setting. The NZC these days does truly go beyond the “useful specialist”, which perhaps continues to be the anticipated outcome of much tertiary level science education.

The NZC, which specifies learning outcomes for students in years 1–13 of the New Zealand education system, is aimed at preparing students to develop a range of attributes *in addition to* scientific knowledge and skills. If attained, these attributes – which include a sense of inquiry, observational and problem solving skills – prepare students well for entry into university; the student has the capability of functioning with a scientific approach. This contrasts with traditional science education (Boud, 1986), which was primarily useful for providing students with knowledge and skills and preparing them to function in a specific job. The more academic students, of course, continued in education and pursued roles more representative of a scientist.

One might ask whether similar learning outcomes to those in the NZC are currently expected in tertiary education; that is, are universities expected to adopt and maintain NZC learning outcomes, or do they assume that graduates from the earlier years of science education have achieved these aims and that tertiary education should be more focused on preparing a student for a career in science, on producing scientists capable of contributing to society by utilising their specific scientific knowledge and skills.

Certainly within Applied Sciences at AUT, the curriculum is very programme- and course-specific and very content-focused, with the broader attributes of the science graduate specified in the graduate profile only.

It appears that the aims of science education in a tertiary institution have more specific purposes than that in the compulsory schooling years. The aims consist of training the scientist and the specialist, the technician or technologist. Within these aims, I believe the aims of the NZC are predicated. The attributes of the student entering university are assumed, having studied science in the compulsory years of schooling, and the role of the university is less focused on “teaching” these attributes. Tertiary science education could be seen to leverage these attributes to further the scientific capability of students.

Before investigating the role of a university such as AUT in the training of technicians, technologists and scientists, one can begin by considering the definitions of each:

- technician: a person who looks after equipment or does practical work in a laboratory
- technologist: a person who applies scientific knowledge for practical purposes; develops machinery or equipment from this knowledge; a person concerned with applied sciences (of which the definition is to bring into operation or use)
- scientist: a person who studies or is an expert in science (Compact Oxford Dictionary and Thesaurus, 2006)

These definitions imply significantly differing roles for science graduates. The implication is that for technicians practical skills are most important; there is little expectation for them to demonstrate the knowledge or wider attributes of the technologist or scientist. The technologist is expected to have the knowledge and skills and be capable integrating the two; and the scientist utilises scientific method to generate knowledge, that is, a set of generalisable rules. An appreciation of these differing roles leads to the question of the nature of the education and training provided for each role.

2.2.2 AUT training of technicians/technologists/scientists

The School of Applied Sciences at AUT has evolved dramatically from being part of a technical institute to being part of a university “for a changing world”, and this has shifted the profile of the graduate. The abridged timeline below (Auckland University of

Technology, 2012) illustrates the progression from the “technical school” it was in 1895 to the university it became in 2000:

1895 – Auckland Technical School opens in a former cabinetmaking factory in Rutland Street with 137 students enrolled for night classes in vocational education and the trades.

1906 – A day technical school opens. The institution is renamed Auckland Technical College.

1960 – The college separates into two institutions: a technical high school (Seddon Memorial Technical College) and a polytechnic division, an event described as a “major turning point in the history of New Zealand’s technical education system”.

1963 – The polytechnic division is renamed the Auckland Technical Institute (ATI) and, under the Education Amendment Act 1963, is officially recognised as offering advanced vocational education.

1964 – Introduces the country’s first full-time technicians’ course, the New Zealand Certificate in Engineering.

1989 – The Education Act marks a watershed year for polytechnics: providing long-awaited autonomy and the right to confer degrees. ATI becomes AIT, Auckland Institute of Technology.

1991 – AIT becomes the first polytechnic authorised to award a degree qualification.

1993 – AIT is the first polytechnic in New Zealand to offer the Bachelor of Applied Science degree.

2000 – AIT makes history as New Zealand’s first polytechnic to become a university, and renames itself AUT, Auckland University of Technology.

Until 1992 the School of Applied Sciences was focused on training technicians in the New Zealand Certificate in Science programme. Many of the students enrolled in the courses were in apprenticeships with industry, including the health sector and laboratories, and attended both lectures and laboratories which were vocationally oriented.

Upon the introduction of the Bachelor of Applied Science degree and the Bachelor of Medical Science degree in 1994, the focus of programmes shifted to include a broader range of capabilities, including the capability of progressing onto research. The aim of the bachelor degree programme was:

A central belief is that graduates from this programme should have developed the ability to approach problems in a logical and scientific manner utilising fundamental knowledge and available literature. These skills are of little value if they are not able to write and deliver clear and succinct reports of scientific work. (Auckland Institute of Technology, 1996).

A graduate from the Bachelor of Applied Science degree programme was expected to be capable of:

Explaining and applying skills and fundamental knowledge
Sourcing and evaluating information
Analyzing and solving theoretical and practical problems
Communicating effectively
Participating in further study and research
Planning creatively at a significantly higher level
(Auckland Institute of Technology, 1996).

Hence there was a shift from the narrow and vocationally oriented technician outcomes to broader expectations; graduates were expected to be able to apply knowledge, communicate knowledge, problem solve, analyse, and potentially advance to higher levels of study and research.

In addition, more recently the Bachelor of Applied Sciences programme changed title to the Bachelor of Science. Besides the Bachelor of Science being an internationally recognised qualification, “Bachelor of Applied Sciences” implied a more vocational qualification (i.e. a “technician” profile rather than a “technologist” or “scientist” profile), which the school wished to move away from. The school keeps “Applied Sciences” in its name to reflect the applied versus purely theoretical nature of the programmes offered. It is anticipated that graduates will be adequately prepared to utilise and apply their knowledge and skills on completion of a programme, in addition to possessing the knowledge and skills to contribute to the pool of scientific knowledge with further postgraduate study.

Given the change in profile of the AUT science graduate, one might assume that the aims of the curriculum within the university have changed to reflect this profile. Perhaps

the NZC foreshadowed this change; the institution/university has shifted its focus to broader outcomes which are aligned with the NZC.

The aims of programmes offered within the school are to prepare graduates with knowledge, skills and attributes to pursue futures as technicians, technologists and scientists, as represented by the graduate profile statement (School of Applied Sciences, 1996 & 2009).

It is important to establish, however, if the teaching pedagogies employed within the School of Applied Sciences' programmes are meeting these aims for the graduate.

2.2.3 Graduate destinations

The aims of the courses and curriculum delivered by the AUT School of Applied Sciences are designed not only in conjunction with the anticipated graduate profile, but also the job market. Education of science students must provide the knowledge, skills and attributes expected of and demanded by not only employers but also the science community. A school delivering science education should adapt curricula and pedagogies to provide such an education if it is to produce such graduates. The School of Applied Sciences' courses are described below.

Graduates of the pre-degree programmes in the School of Applied Sciences have fundamental knowledge and practical skills in a range of sciences, mathematical and communication capabilities. Most graduates use the pre-degree qualification to progress into higher qualifications.

The Bachelor of Medical Laboratory Science, a four year undergraduate degree, produces students who are recognised as laboratory technologists. Their knowledge and skills do reflect the definition of a technologist given above: one who applies scientific knowledge for practical purposes; a person concerned with applied science – the application of human knowledge to build or design useful things. This programme of study incorporates very specialised knowledge and equipment, and requires a large component of practical work. The fourth and final year of study is a clinical placement year, during which the students are placed with and work alongside trained technologists.

Graduates of the three year Bachelor of Science degree have less specialised knowledge and skills and therefore gain employment readily as a technicians, technologists,

scientific officers and research assistants. Further study, in graduate or postgraduate areas within AUT or other universities, can lead to technologist or scientist pathways. Many graduates undertake postgraduate study and pursue research careers.

Regardless of the destination of the graduate, students are progressing through programmes of study within the School of Applied Sciences gaining fundamental through to advanced scientific knowledge, and complementary practical skills to facilitate the practice of the technician, technologist and scientist.

Hence it can be perceived that the overarching purpose of practical work as a pedagogy within science programmes in this university is to provide the practical skills required to practice as a technician, technologist or scientist. Practical work also provides the opportunity to develop additional characteristics of the graduate profile, as described earlier in this chapter. It is also hoped that practical work is able to meet the broader aims and outcomes outlined in the literature discussed later in this chapter.

The role of practical work in the teaching of science at AUT, and the contribution it makes to the graduate profile, is of interest from several perspectives. Firstly, are lecturers cognizant of the wider aims of practical work in the teaching of science, in addition to teaching the required skills, or is it expected that the characteristics of the graduate evolve without specific intention and attention throughout the course of the programme? Do graduates develop the attributes associated not only with the technician, but also the technologist and scientist? And what do students feel that they are gaining from practical work? Do they perceive the role of practical work as that of simply teaching the skills required or are they aware of the additional contribution to their preparedness for a career in science?

The purpose of this study is to investigate the perceptions of science students as to the role of practical work in their education. There is a compulsory component of practical work in all papers within the School of Applied Sciences. Do students see the purpose and value of the practical component to simply learn skills? If so, one might get the impression that the focus of Applied Sciences is the training of technicians. Alternatively, students may appreciate the wider contributions that practical work can make to their development as technologists and scientists.

2.3 Knowledge and how it is acquired

In order to analyse student perceptions of the value of practical work in science education, this section will present a review of literature on how learning takes place, and the role and contribution of practical work to learning.

Theories of *how* learning occurs (how people acquire and modify knowledge, skills, strategies, beliefs, attitudes and behaviours) have evolved over the centuries, and date back to ancient Greek philosophers such as Plato and Socrates in 300–400 BC.

Philosophy, being an “inquiry into ideas, traditions, innovations and ways of thinking” (Ozmon & Craver, 2003, p. 2), has provided views on nature and society over the centuries which have influenced ideas about how learning occurs in education.

Learning theories attempt to explain how knowledge is acquired. Learning involves, but is not limited to, the acquisition of new knowledge, or the modification of existing knowledge, and there are several ways of viewing the world with respect to knowledge, including scientific knowledge. Recognised schools of thought on what scientific knowledge is include empiricism, relativism and positivism, and constructivism. Empiricism, rationalism and positivism share the realist ontological paradigm; there is a real world, a set of facts, which are independent of our knowledge (Driver, Asoko, Leach, Mortimer, & Scott, 1994, Chalmers, 1999). Constructivism aligns with both the realist and the relativist paradigms, the latter being that there is no absolute set of facts, but rather scientific concepts are constructed and validated (Driver et al., 1994).

Empiricism holds that experience is the only source of knowledge. According to Schunk (2008), “Knowledge is symbolic of nature and is built upon fundamental concepts which have not simply been developed by direct observation but by involving the senses” (p. 11). Rationalism holds that knowledge derives from reason (Schunk, 2009, p. 10). Knowledge is seen as stable; something reliable which can be known (Buntting, 2006), well defined and which does not depend on or originate from experiences or utilisation of sensory perceptions. Positivism emphasises rationality and non-problematic knowledge (Driver et al., 1994); there is a set of facts and a body of knowledge to be transmitted.

Constructivism holds that knowledge is acquired as humans develop constructs/concepts from experiences to explain the world. The constructivist paradigm requires communication of ideas within the cultural and social scientific community (Driver et al., 1994). Constructivism emphasises construction of new ideas and generation of meaning from experience in contrast to the absorbing of new ideas (Bell, 1993).

My own epistemological philosophy of learning in science is based on the constructivist view; learning involves the senses and experiences, and the processing of these experiences mentally to construct mental models which explain these experiences and the objects which exist in the real world.

The evolution of theories of knowledge and learning has helped develop and refine the way(s) in which science is taught and learnt. Anecdotally, some students entering university see sciences as subject areas in which scientific laws and theories are memorised and *perhaps* applied, whereas others see science as being a process of inquiry, learning and applying scientific knowledge in an open process which permits the opportunity for new ideas or interpretations and discovery to occur.

Educationalists over the years have developed curricula informed by an understanding of what constitutes knowledge, and of how we learn, that is, the process by which we become “knowledgeable”.

Just as there are alternative views of the meaning of knowledge, there are alternative views, which have developed into well-recognised theories, as to how learning occurs. These learning theories have also helped shape curricula and need to be considered to provide insight into the teaching and learning of science.

2.3.1 Learning theories

Underpinning the many commonly recognised learning methods in science education – e.g. problem based, inquiry based, laboratory based, discovery and kinaesthetic based methods – are three philosophical frameworks that attempt to explain how learning takes place in sciences. These frameworks are behaviourism (also referred to as conditioning), cognitivism (social cognitivism and cognitive information processing) and

constructivism and they have evolved over the nineteenth and twentieth centuries. Each should be considered for their important implications for educational practice (Schunk, 2009).

Behaviourism was a strong psychological force shaping learning theories in the early twentieth century. Learning theories prior to cognitivist theories including conditioning theories of learning are classified as behaviourist (Schunk, 2008). Behaviourism focuses on observable aspects of learning and the causes of learning are observable environmental events. According to Ozmon and Craver (2003), B. F. Skinner, an early twentieth-century psychologist, maintained that “knowing is really a case of the environment acting on people” (p. 207). Learning occurs when there is a change in behaviour due to reinforcement of a correct response to changes in environmental events. A significant difference between this theory of learning and others is that behaviourists believe that learning does not need to include thoughts, feelings or beliefs (Schunk, 2009). Learning occurs as a response to positive reinforcement of desirable behaviour. A behaviourist theory applies well to skill development and training, and competency based learning objectives, which are acknowledged aims of some practical classes. Such learning can be repeated in a process which involves positive or negative reinforcement, resulting in learning of the correct behaviour taking place.

While a behaviourist theory of learning is useful in appraising whether changes to teaching practices or procedures influence changes in student performance, this theory of learning neither focuses on how these changes come about (Duit and Treagust, 1998) nor explains the phenomena involved in the process of learning.

The cognitive theory of learning, which challenged behaviourism and in particular conditioning theories, evolved in response to work carried out in the mid-twentieth century by Albert Bandura (Schunk, 2009, p. 78) which showed that reinforcement was not necessary for learning to occur. Although both theories of learning acknowledge that the environment can affect learning, behavioural theory attaches less importance to the learner, and more to the environment; cognitive theory does the reverse.

Cognitive theory stresses the “acquisition of knowledge and skills, the formation of mental structures and the processing of information and beliefs” (Schunk, 2009, p.16) and characterises the stages of development of mental processing by age. This theory was supported by Lev Vygotsky, who contended that all higher mental functions

originated in the social environment (Vygotsky, 1962, cited in Schunk, 2009). He emphasised the role of social mediation (interaction with the environment) in learning in contrast to simply “acquisition” as the model of learning (Kozulin, 2003). This theory resonates with the constructivist view of learning.

Jean Piaget also argued that interaction with the social and physical environment contributes to cognitive development. Piaget’s work contributed to cognitive theories of learning which focus on the internal processes involved in learning (Schunk, 2009). These internal processes are described as stages of cognitive development, which relate to age.

Both behavioural and cognitive theories acknowledge the significant role of memory in learning, albeit for different purposes. Cognitivists assume that the memory system is actively involved in processing and storing information in an organised way, whereas behaviourists consider memory to be involved in the development of “habitual ways of responding” (Schunk, 2009).

Whilst there are commonalities between behaviourism and cognitivism, behaviourism is today challenged by the theory of constructivism (Ozmon & Craver). The constructivist theory of learning is cognitive in nature: learning is a process in which the learner actively connects information with previously assimilated knowledge and internally constructs or builds new ideas or concepts. In a learning environment that creates situations that facilitate active construction of students’ own knowledge, constructive cognitive processes are occurring.

Piaget asserted that knowledge is constructed through “cognitive schemes” in the learner as they interact with their physical and social world. These affirm or alter existing structures or concepts (Schunk, 2009). Consequently, adaptation to new experiences occurs and both prior knowledge and conceptual understanding are modified.

A constructivist approach to learning requires cognitive processing, especially that of assimilation. Meaningful learning involves the incorporation of new ideas into the existing ideas and knowledge structure of the learner. Derry (1996, cited in Schunk, 2009) refers to “cognitive constructivism” as the process of mental contradictions

(situations and experiences which challenge a person's current conceptual understanding) resulting from interactions with the environment. Learning from a constructivist view occurs at both the individual and social levels: "Constructivist accounts of learning and development highlight the contributions of individuals to what is learned. Social constructivist models further emphasize the importance of social interactions in the acquisition of skills and knowledge" (Schunk 2009, p. 236).

Knowledge is therefore produced according to the beliefs and experiences of an individual in contextualised situations. This knowledge is subjective and internalised. According to Vygotsky's sociocultural theory, "knowledge is also co-constructed between two or more people" (as cited in Schunk, 2009, p. 244). This social interaction is dependent on language as the community in which the learning is taking place has its own language. Leach and Scott (in Monk & Osborne 2000) observe that this means "Alternative conceptions are continually reinforced in day-to-day talk" (p. 45).

The construction of knowledge according to this theory is not a passive process. The situational language the learner is exposed to and uses must be made sense of and incorporated into existing ideas. The development of higher psychological structures, such as scientific concepts, happens as learners are involved in verbal and written language (Leach & Scott in Monk & Osborne, 2000). Similarly, Driver et al. (1994) argue that "From this perspective, knowledge and understandings, including scientific understandings, are constructed when individuals engage socially in talk and activity about shared problems or tasks" (p. 7).

From an empiricist view, scientific knowledge is the set of human constructs which explain and help understand natural phenomena. Implicit in this explanation is the construction of such knowledge. The next section will discuss how a constructivist approach to learning applies to the learning of science.

In my opinion, one very important role of practical work in the teaching of science is to provide the opportunity for students to interact with the physical and social environment. When students do so, I have always believed that they construct their own knowledge. Practical work provides opportunities for observation, utilisation of the senses, discussion and often repetition (of either practical experiences or re-visiting

theory that has been “learnt”). Through these opportunities, students are able to utilise cognitive skills to construct their knowledge. My viewpoint therefore aligns with the cognitivist and constructivist theories of learning.

In this study, the data analysis will attempt to establish whether students perceive learning as occurring from a constructivist perspective in practical work. A theory of learning that has emerged in the twenty-first century, called “connectivism” may influence emerging trends within practical work in science education. Connectivism has been described as learning theory for the digital age (Siemens, 2005) and while, bearing some similarity to social learning theories, it is significantly different to its predecessors. The connectivist view addresses learning that is stored and manipulated by technology, or learning that occurs within organisations (Siemens, 2005). There has been some criticism of the claim that connectivism is a new learning theory, the argument being that it is actually a pedagogical view, not a learning theory (Verhagen, 2006).

This “new theory” does raise for me, personally, the question of the value of certain types of practical work such as virtual laboratories and simulations which are gradually becoming more and more a part of “practical work”. Such a question is beyond the scope of this thesis, but it would be worth investigating alongside recent research findings and the findings of this study. Technology plays an important role in performing practical work in secondary and tertiary education. Much equipment has become “black box”, whereby the result/outcome is provided by the equipment with no understanding of the functioning or process required, performing the tasks that bench work once performed. Anecdotally though, and citing Applied Sciences at AUT as an example, hands-on practical work and bench work continue to be considered the most significant method for performing practical work.

2.3.2 Constructivism in learning science

From the constructivist perspective, teaching science is “not about filling students’ empty heads or about students acquiring new ideas, but about students developing or changing their existing ideas” (Bell, 1993, p. 23). But this may not be the way teaching happens in practice. Many students demand of lecturers sets of notes to memorise, and

their aim in practical work is solely to “get the correct result”. This may also be the intention of some science educators: the end result is that the student should be able to provide the correct answers or demonstrate correct skills or competencies regardless of how they arrived at them and whether or not they have the correct and appropriate depth of conceptual understanding.

Teaching methods in science, if they follow a constructivist theory of learning and acknowledge conceptual change as part of knowledge building, need to provide physical and social experiences that bring existing concepts into question and possibly into conflict with existing understandings, which lead to the development of modified concepts. Practical work in science is one such method that can potentially provide such an opportunity if utilised with the correct intention. If there is little or no evidence of the construction of knowledge resulting from the inclusion of practical work, it should then be asked as to whether practical work is being delivered in an appropriate manner to meet this aim, or is it being incorporated solely for the purpose of the acquisition of skills or competencies.

There is a vast number of examples cited in the literature of children’s alternative concepts, whereby a child’s explanation of a phenomena is a satisfactory explanation to them, but does not ‘fit’ acceptable scientific laws, (Bell, 1993) and common misconceptions of natural phenomena. An example I am aware of every year in the teaching of first year sciences at AUT relates to the concept of breathing. It is not unusual to discover that some students believe that it is the rush of air into the lungs that causes the chest to expand. Unfortunately it is also my experience that some students have not altered their understanding by the end of the course. They may be able to provide a correct answer which has been memorised, but if questioned further their understanding does not support their answer, indicating that their understanding has not been challenged during the course, which would encourage them to alter their existing ideas.

It is my belief that offering practical work relevant to concepts such as this provides more opportunity for learners to challenge their understanding than didactic teaching methods do. Student thinking needs to be challenged to potentially develop and improve conceptual understanding. As Watson (2000) observes, “Scientific concepts and

theories are often counter-intuitive and have to be constructed in the classroom by talking or reading about phenomena as well as by seeing them” (p. 60).

2.3.3 Constructivism as a rationale for practical work in learning science

Practical work is a pedagogy which allows for active investigation and hands-on experience and social interaction. This contributes to the construction of knowledge and classroom instruction from a constructivist perspective should include “ample hands-on investigative laboratory activities” (Saunders 1992, p. 140), in addition to group work and opportunities for active cognitive engagement.

Hodson (2005) supports the constructive theory of learning in science, arguing that practical work should not only be enjoyable but also bring about conceptual understanding. Conceptual understanding can require previous concepts to be annulled and new concepts constructed. Observation is an essential component of practical work as it can induce questioning and reflection which are essential in the development of conceptual understanding.

Fosnot (2005) argues that the purpose of a science class should be to gain a fuller understanding which requires articulation of the students’ own ideas along with those of others. If the belief that learning science is socially constructed is widely accepted, it could then be expected that a common understanding of the purpose of practical classes in science, held by teachers and students, is that they contribute and support this theory of learning.

There are various forms of practical work which take place in university laboratories, which will be discussed in the next section. Regardless of the type of practical work, however, fundamental to laboratories as “classrooms” is that “Classrooms are places where individuals are actively engaged with others in attempting to understand and interpret phenomena for themselves, and where social interaction in groups is seen to provide the physical experiences and to encourage reflection” (Driver et al., 1994, p. 6). Practical work can often result in unexpected/wrong/poor results for many reasons, such as equipment malfunction, poor instruction or poor manipulation of equipment. Such results can lead to mental contradictions which can potentially lead to the questioning of a student’s understanding. Discussion of unexpected results with peers and lecturers

provides an opportunity for construction of knowledge through accommodation to occur, as long as current understandings and these contradictions are addressed.

Regardless of the type of practical work, students are seeing, talking about and interacting physically with phenomena, and socially with their peers and lecturers, which according to a constructivist theory of learning is providing the opportunity for a student to critique their current conceptual understanding in relation to what they are seeing, doing and hearing. If they are actively involved in such activities the situation can promote questioning by students of their own understanding and this is an opportunity for conflict of ideas to arise and understanding to be tested. However, it may be questioned as to whether this construction of knowledge occurs purposefully unless the expectation or intention is communicated with the students as part of the activity. I am interested in responses by the participants in this study which may indicate any acknowledgement that through being actively involved in practical work, their existing knowledge or understanding has been altered.

2.4 The nature and purpose of practical work

“Practical work” is a term used by scientists, science educators and science students that encompasses a variety of activities intended to fulfil the aims they are trying to achieve. In education the format selected for practical work will presumably meet the intended outcomes, whether to support learning in science, to learn specific skills, or both.

Watson (2000) states that to meet the aim of encouraging accurate observation and description, phenomena must be observed, and in doing so the phenomena become more real by observation and description. Aims of science education also include the arousing and maintaining of interest and promoting logical thought processes and reasoning. These aims can potentially be achieved through a combination of different types of practical work.

Practical work or practical activities are therefore designed to accomplish a variety of aims in the teaching and learning of science. Common activities interpreted as practical work include laboratory activities, demonstrations, field trips and simulations. Laboratory activities may take a variety of formats. For example, they may be

investigative, recipe style, contrived or enquiry based; they may involve demonstration within the laboratory or be concerned with skill acquisition.

Regardless of the format of practical work, most is based upon the empirical approach (experience is the source of knowledge) and incorporates the recognised process of scientific investigation: the posing of a question, generation of an hypothesis and prediction, a method of investigation, recording of data, presentation and analysis of data, and the discussion and conclusion of findings. Practical work, as performed in laboratories or field work in science education, consists of all or parts of this process.

2.4.1 The perceived purpose of practical work in science

This section first presents arguments from the literature that support practical work and the reasons for this. Some educators doubt the value of practical work as an effective pedagogy, and the section concludes with their arguments.

The inclusion of practical work spread through education in the sciences in most countries in the mid- to late nineteenth century and has continued to the present day (Boud et al., 1986). Prior to laboratory and practical work being formally introduced to the teaching of science, practical work had been limited to demonstrations by lecturers and the cost of equipment and material was borne by the lecturer. The pressures which established the practical component of teaching and learning in science arose from the need for training in research, and student demand for practical work. The formal practical instruction which was required to meet the demands of jobs and to support apprenticeship training was not able to be provided by lectures, or lecture-demonstration (Boud et al., 1986) and so since World War II there have been ongoing and repeated attempts to change instruction in science education from lectures and textbook science to investigations and experiments (Rudolph, 2005). This change has sought to provide graduates with practical skills and the ability to perform complex experimental procedures.

The purpose of practical work has now expanded beyond the need to provide primarily practical skills and the opportunity to undertake complex experimental procedures. As an approach to learning, practical work is seen as beneficial in terms of contributing to cognitive, affective and skills based learning as well as providing a variety of learning

stimuli (Hodson, 2005). Teachers of school and university science courses expect practical work to achieve a wide range of aims, but there is less emphasis in tertiary science education on providing for a variety of learning styles. Having said this, one of the most important reasons for including practical work according to one of my colleagues at AUT, is to cater for different learning styles, such as visual and tactile learning (Dr. C. Higgins, personal communication, April 18, 2011). In my experience, in pre-degree and first year courses at universities there is still a need to cater for a variety of learning styles, hence the inclusion of practical work to provide such an opportunity.

If the rationale put forward for the inclusion of practical work is to meet the aims of science education as outlined in section 2.2, then the development of scientific skills is an expected outcome of learning science in pre-degree education. Most material on the topic of learning science extends scientific skills to include not only the practical skills acquired but also the attitudes associated with the process of scientific inquiry: the diverse ways in which scientists study the natural world, propose ideas, and explain and justify assertions based upon evidence derived from scientific work (Hofstein & Lunetta, 2003). In this way students are encouraged to become “scientifically capable”. As Hodson (1998) states, “Becoming scientifically capable involves considerably more than the acquisition of scientific skills, knowledge and understanding. It also involves the development of personal qualities and attitudes” (p. 3).

Practical skills are a key component in the process of scientific inquiry and achieving scientific capability, according to the NZC. Much published literature on the role of practical work in science education, for example that by researchers Bell (1993), Wellington (2000), Osborne (2003) and Hodson (2005), shares common themes with regard to the broader purposes of practical work in the teaching and learning of science, regardless of the type of practical work. Watson (2000) surveys three studies performed between 1964 and 1998 and summarises the four most popular aims of practical work in science according to teachers:

- to encourage accurate observation and description
- to make phenomena more real
- to arouse and maintain interest and to promote a logical and reasoning method of thought.

In addition, a study conducted by Swain et al. (1998, cited by Watson 2000), included as popular aims:

- to practice seeing problems and seeking ways to solve them
- to develop a critical attitude
- to develop an ability to cooperate
- for finding facts and arriving at new principles.

There have also been suggestions that laboratory courses can utilise students' higher-order thinking skills and increase retention and achievement (Cooper & Kerns, 2006); that the laboratory is important in promoting inquiry as a style of teaching and learning science (Hofstein & Lunetta, 2003); and that practical work can contribute to the individual and social construction of scientific knowledge and to becoming “enculturated” into the world of scientists (Hodson, 1998). Laboratory courses provide the opportunity for students to engage in activities similar to professionals who work in that discipline. Participation in practices that are culturally valued, such as those approved by the scientific community, is considered important and believed to promote deeper knowledge (Duschl, 2008).

While this is not an exhaustive list of the purposes behind the inclusion of practical work in the teaching and learning of science, it captures the dominant themes which recur in the literature and these will be discussed in relation to the themes that emerge from this study.

However, despite the perceived role of practical work in science education, departments in educational institutions that are under financial strain might question the necessity for “expensive” hands-on practical work (as discussed in Chapter 1).

Although “Many scientists and science educators are convinced that practical work *must* play an important role in learning science” (Watson, 2000, p. 57), Hofstein and Lunetta (2003) state that the prominence and inclusion of practical work has been questioned by educators for many years: “In the late 1970s and early 1980s, some educators began to seriously question both the effectiveness and the role of laboratory work, and the case for the laboratory was not as self-evident as it seemed” (p. 28). They further argue that

the assumption that laboratory experiences help students understand materials, phenomena, concepts, models, and relationships, almost independent of the nature of the laboratory experience, continues to be widespread in spite of sparse data collected from carefully designed and conducted studies. (Hofstein & Lunetta, 2003, p. 46)

Concern is also expressed by Osborne (2003) that scientific training as a form of education would produce only a specialist, not an educated person. This concern is also supported by Cooper and Kearns (2006) who observe that “Educators have grown increasingly concerned that the conventional laboratory format is not accomplishing any useful goal, except perhaps that of training technicians” (p. 1356).

The following section will discuss the perceived value of practical work, as cited in the literature, in relation to the perceived role and with respect to the concerns raised as discussed in this section.

2.4.2 Perceptions of the value of practical work

Views as to the purpose and efficacy of practical work have been gathered widely over decades from teachers, students and researchers. Authors cite their perceived aims of practical work as ranging from simple active learning (Wellington, 2000) to the more complex development of higher cognitive processes (Cooper & Kerns, 2006) and these are underpinned by a range of theories of learning as presented earlier in this chapter. In addition to the advantage of providing the opportunities presented in the previous section, it has been suggested that active involvement in the classroom can promote gender equity (Burkam, Lee & Smerdon, 1997), an issue in sciences classes that has been raised in the past. For these reasons, practical work should be valued as a teaching method contributing to the learning of science.

But there is a range of common concerns in the literature that could have one believe that practical work is not necessarily achieving the anticipated aims. It is argued that there is conflict between theory (the anticipated aims of practical work) and evidence (the educational outcomes) and that there is therefore a need to re-think the purposes of laboratory work to ensure that the way it is conducted reflects and achieves the intended aims (Shah, Riffat, & Reid, 2007).

For example, a recent study explored the effectiveness of practical work in 25 typical science lessons in an English secondary school and resulted in two findings: the practical work was effective in getting students to interact with physical objects in the required way, but it was not effective in getting students to use their scientific ideas to guide their actions or reflect on their data collected. The study identified that the design of the learning tasks did not encourage students to meet the higher cognitive challenges expected from the task (Abrahams & Millar, 2008).

Shah et al. (2007) found that although there is generally a positive attitude towards laboratory work on the part of students and that it is popular, students themselves conveyed that there was a lack of clarity about the nature and purpose of laboratory work. From a survey of previous findings, Shah et al. confirm that attitudes in the university learning situation are brought from school experiences, and that positive attitudes towards laboratory work are less evident in higher education due to the lack of clear purpose for students. The authors' recommendation is that the purposes of laboratory work need to be re-thought and conveyed to students, and that the way in which the laboratory work is conducted needs to reflect these purposes.

Another concern which has been raised – one exemplified by a study carried out by Pekmez, Johnson and Gott (2005) – addresses the importance of the role and ability of the teacher in facilitating the intended aims. To improve the value of practical work with respect to the intended purpose, there is “an urgent need to first develop a deeper understanding of the procedural knowledge base amongst a significant proportion of science teachers” (p. 21). This is in particular pertinent to tertiary science lecturers, who potentially have no formal teacher training.

Other research has established the positive influence of practical work on student achievement, attitudes and perceptions of practical sessions. Cooper & Kerns (2006) for example, observe that “effects of laboratories have been encouraging particularly with regard to increased achievement and retention rates” (p. 1356). Burrowes and Nazario (2008) found that inquiry based active laboratories improved student participation, raised academic achievement and enhanced attitudes towards Biology. These findings indicate that it is possible to create positive, beneficial learning experiences from

practical work. With such evidence of increased achievement it could be supposed that practical work is capable of contributing to the construction of knowledge.

Similarly, a study by Hirvonen and Viiri (2002) on Physics student teachers' attitudes to practical work done during their training found that participants believed practical work was advantageous to students in that it can foster both understanding of the content of, and the process involved in, learning physics. Work by Taraban, Box, Myers, Pollard and Bowen (2007) has shown that through using laboratories for instruction students gained significantly more content knowledge and knowledge of process skills in comparison to a traditional instruction method such as lectures.

There is much literature on how to do practical work in order to meet its prescribed aims. Wellington (2000) discusses different types of practical activity appropriate for different aims, such as observation and group work. Perkins-Gough (2006) reports on an investigation into integrated instructional units of science learning and found that effective laboratory experiences were "designed with clear learning outcomes in mind, thoughtfully sequenced into the flow of classroom instruction, designed to integrate learning of science content with learning about the processes of science, and to incorporate ongoing student reflection and discussion" (p. 94). Another investigation into the integration of laboratory and lecture activities in the science curriculum conducted by Burrowes and Nazario (2008) concluded that "the use of teaching methods based on constructivism, cooperative learning, inquiry and experimentation, served to enrich the class environment (and provided support to previous findings in this area)" (p. 18). These findings endorse the importance of science teachers understanding how students learn and facilitating this learning process.

The evidence cited in the previous paragraphs supporting the inclusion of practical work for reasons such as increased achievement, participation, knowledge retention and improved attitudes was dependent upon teachers having a clear understanding of the intended purpose and method of delivery of practical work. With clear pedagogical reasoning for incorporating practical work as a component of their teaching, it can be expected that teachers will experience and witness greater education value from the inclusion of practical work.

As stated in Chapter 1, teachers and lecturers assume the inclusion of practical work in science education, but it is also important to know student attitudes towards practical

work. It could be anticipated that the pedagogical reasoning for including practical work would be evident in students' views. The findings of the *Student Review of the Science Curriculum* (Cerini, Murray, & Reiss, 2003), a student-led review conducted in England in 2002 of the Science curriculum (a collaborative project between Planet Science, the Science Museum of London and the University of London), provide a student perspective on the inclusion of practical work in science education. Although students were mainly aged 16–19, it was found that respondent age rarely had any effect on student perspectives. When asked which was the most useful and effective method of teaching and learning science, doing a science experiment in class was ranked 3 out of 11 ways of learning (1 was highest; $n = 1,450$). Doing a science experiment in class was ranked 2 out of 11 as the most enjoyable part of school science. The findings of research by Osborne, Simon and Collins (2000) and Reiss (2000) support these results: students enjoy practical work and find it an effective way to learn.

The same student-led review asked the question “If the practical content of the course was increased, how would it most improve the learning experience?”. Here 47% of respondents ($n = 1,451$) selected “makes understanding theory easier” (the most selected response from the four options available). This finding indicates strong student belief that practical work supports learning.

The findings from the student-led review provide support for the inclusion of practical work in the teaching and learning of science at secondary school level in England, which could feasibly be extrapolated to learning science at university level in New Zealand. However, to support the continued inclusion of practical work in the teaching and learning of science in the New Zealand tertiary context, it must be shown that practical work is fulfilling the aims intended.

2.4.3 Amount of practical work in teaching science

A common introduction to educational research on the topic of practical work in science education could be typified by the statement: “It would be rare to find any science course in an institution of higher education without a substantial component of laboratory activity” (Boud, Dunn & Hegarty-Hazel, 1986, p. 3). The School of Applied Sciences at AUT is no exception to this rule. The school offers two undergraduate degree programmes, the Bachelor of Applied Science, comprising five majors, and the

Bachelor of Medical Laboratory Science. The science courses within these programmes generally consist of both theoretical and practical components.

As can be seen in Table 1 below, AUT, in which the case study reported in this research was situated, is also reasonably typical of tertiary providers of science education in New Zealand in the amount of practical work which accompanies the teaching and learning in the Sciences.

Table 1: Practical hours across a selection of courses within New Zealand universities

University	Course	Average laboratory hours per week for similar courses across universities in NZ
Otago	First year	1.25
	Second year courses	2.5
	Third year courses	2.75
Canterbury	First year	3
	Second year courses	4
	Third year courses	0
Waikato	First year	2.75
Auckland	First year	1.5
	Second year courses	1.5
	Third year courses	2.25
AUT(BSc)	First year	2
	Second year courses	2
	Third year courses	2
AUT	Second year	3
	Third year	4

Data on hours of practical work included in a selection of science courses similar to those offered by the School of Applied Sciences in other New Zealand universities is comparable to the average allocation of hours in AUT courses. That is, on average two hours per week for first, second and third year courses.

Within the School of Applied Sciences, first year courses include two hours of practical per week per semester. Second and third year courses in the Bachelor of Science also have two hours per week on average; field work in some disciplines contributes to the

hours and there is less on-site practical work per week. Second and third year courses in the Bachelor of Medical Laboratory Science include a more significant proportion of practical work; second year courses include three hours per week and third year courses include four hours per week.

The data in Table 1, which indicates that there is generally a “normal” allocation of hours to practical work across universities, also indicates universal support for the inclusion of practical work at New Zealand tertiary institutions. A similar allocation of hours to practical work is cited in a study by Radny and Duval (2005) from the University of Sydney in which an alternative approach to practical work in Physics was undertaken, but the hours were maintained, at 24 hours per semester (equivalent to the hours allocated to the first year physics course in Applied Sciences at AUT).

Personal experience from interaction with students entering tertiary level science subjects at AUT indicates variable experiences of practical work in their secondary science education. Students entering the Bachelor of Science, or pre-degree programmes such as the Diploma in Applied Science and Certificate in Applied Science, frequently display not only a lack of fundamental practical skills, such as reading scales on a variety of instruments, but also a lack of confidence in using equipment and performing practical investigations, poor observation and recording skills, and a lack of interest or ability in problem solving; all of which constitute a significant proportion of the anticipated outcomes of the science curriculum in schools. It is assumed on entry to tertiary level study that students have been exposed to, and potentially achieved success in, the stated outcomes of science in the NZC. This experienced lack of “scientific skills” could be due to a variety of factors; factors needing to be questioned further would be the quantity and nature of practical work included in the teaching and learning of science prior to entry to tertiary education. In some schools, for example, there could be more demonstration provided by the teacher than in others, as opposed to hands-on work by students.

The purpose of this study is to obtain an insight into the perceptions of tertiary level science students as to the value of practical work, which will undoubtedly be influenced by prior experiences. This study does not extend to consideration of those prior

experiences, but they may be intrinsically represented in student perceptions and this possibility will be acknowledged and considered in the analysis of emergent themes.

2.4.4 Resourcing practical work in tertiary education

The laboratory is seen as “one of the characteristic features of education in science at all levels” (Shah et al., 2007, p. 75). Many countries devote considerable resources to give students of science the opportunity of doing practical work in science lessons (Beatty & Woolnough, 1982; Watson & Prieto, 1994, cited in Watson 2000). As has been discussed above, there is on average two hours per week of practical or laboratory work for first and second year science courses across tertiary institutions in New Zealand, and three hours for third year science courses.

The cost of operating practical classes, especially if within a laboratory, is large in terms of staffing, equipment and consumables, as well as the provision of specialist spaces. Within AUT the ratio of staff to students in laboratories is 1:20, which is stipulated by health and safety regulations. In comparison, one lecturer is capable of delivering to a full lecture theatre, potentially holding hundreds of students.

Laboratory equipment and consumable resources are an additional cost which is not incurred in the delivery of lectures. Much laboratory equipment is costly to purchase and maintain, especially the equipment involved in the higher level laboratories which require specialist equipment. The large first year classes consume a large quantity of material within the practical component of their courses. Again this cost can be compared with that of delivery of lectures to large classes; the outlay for technical equipment is large, and there are ongoing maintenance costs and upgrades, but these costs are allocated across a large number of students and a large number of courses. There are no consumables to be taken into consideration.

Specialist spaces are considerably more costly to set up than lecturing spaces. These spaces have minimum requirements of power, gas and water reticulation and, in addition, a considerable amount of space for specialist equipment. The financial support provided for the running of laboratories and the inclusion of practical work in courses delivered by science departments indicates that the current perceived value by the institution of this component of the curriculum is high. However, if there are less costly

alternatives, continued support could come into question if students and lecturers do not share common views as to the value of practical work. Fraser, Giddings and McRobbie (1992) propose that the aims of laboratory work could be achieved more effectively and at lower cost in a non-laboratory setting using alternative methods of delivery. These will be discussed below.

In addition to teaching staff associated with practical work, there is the requirement for skilled staff responsible for setting up and maintaining equipment and the provision of the necessary consumables within the School of Applied Sciences at AUT; the ratio of lecturing staff to technicians is approximately 3:1. Hence technician staff is also a large and significant component of staffing associated with the delivery of practical work within the school.

Teaching staff will attest to the value of practical work, for a variety of reasons, regardless of cost. Boud (1986) reports senior staff “vigorously espousing the importance of laboratory work” (p. 3). Industry and registering bodies have the expectation of practical skills and knowledge, making compulsory the inclusion of this very costly pedagogy. Research, for example that carried out by Shah et al. (2007), informs us that students enjoy practical work, and value, for a variety of reasons, its inclusion in the delivery of science as a subject. Students, however, are not aware of the costs incurred, nor are they charged specifically for their participation in practical work, as compared to courses which do not include a practical component.

As there are alternative pedagogies offered or suggested as a means of providing some of the learning that practical work is purported to provide at a potentially reduced cost, the inclusion of traditional practical work needs to be confirmed as being valuable in supporting learning of science, for students, teachers and academic institutions. According to Boud (1986), as funds for higher education are in high demand, and some programmes of study are difficult to sustain, the position of laboratory work is being challenged by more efficient methods of delivery.

It is hoped that the findings of this study will confirm that the educational benefits and experiences gained from practical work more than justify the cost of providing practical work in science courses.

2.5 Current trends in approaches to practical work

Changes in operating systems in laboratories and the incorporation of modern technologies mean that many processes, as mentioned previously, have become automated, that is, “black box” technologies, in many fields of science. Hence there is a need to incorporate technology in practical work. Technology can be incorporated for more than one reason: it can prepare science graduates to function in a real laboratory setting or alternatively technology can be used to simulate or provide virtual experiences of “real” scientific experimentation.

Although, as Ma and Nickerson (2006) state, “Laboratory based courses play a critical role in scientific education” (p. 2), the authors go on to say “Automation is changing the nature of these laboratories, and there is long running debate about the value of hands-on versus simulated laboratories” (p. 2).

A selection of reasons, but by no means a complete list, cited for incorporating simulations in practical work can be derived from literature in the fields of pharmacology (Hughes, 2001) and engineering (Fiesel & Rosa, 2005). These include: reduction in costs, reduction in distraction from learning objectives due to laboratory manipulations, substitution of experimental studies where equipment is too large or dangerous, or situations in which the procedure may encounter moral objections.

Laboratories at AUT utilise very little simulation and virtual experiences; most practical activities are experimental procedures using first principles and practical skills and techniques fundamental to the scientist. The university invests in equipment that is essential to the functioning of experimental procedures. More expensive and complex equipment is associated more with research, but it is also introduced to and utilised by undergraduate students. Some courses in Applied Sciences have acknowledged “black box” technology that exists in the workplace and incorporate its principles into teaching and practical work.

There are good reasons for incorporating simulation or virtual experimentation in practical work, which may include familiarisation with equipment and technology which will be used in the role of the practicing technologist or scientist and experimentation which may not be feasibly possible for ethical reasons. There are

therefore situations and opportunities for lecturers to consider the utilisation of such practical methods in relation to the anticipated learning outcomes of practical work in courses in Applied Sciences, in conjunction with the practical hands-on activities.

2.6 Summary

This literature review has investigated the phenomenon of practical work in the teaching and learning of science from historical, epistemological, learning and pedagogical perspectives.

Historical perspectives and current theories of knowledge and learning are well researched and documented, nationally and internationally, as is research into science education. However, most science education research has been conducted predominantly in primary, middle school and secondary school education. There is a lack of research conducted into practical work in science education at tertiary level in New Zealand. Most recent studies into practical work in science education I reviewed were international studies.

The majority of literature available on science education, and in particular practical work as a pedagogical approach, pertains to pre-tertiary education. There is also a recognised lack of New Zealand literature on pedagogies used in science education, as expressed in a report to the Ministry of Education by Hipkins et al. (2002), which states that “there was a paucity of classroom research in which the effectiveness of different types of pedagogy were explicitly reported on” when a literature review of science education in New Zealand schools was conducted.

Nevertheless, findings from research, irrespective of students’ nationality or level of schooling, can be used as a foundation for an investigation set within tertiary science education within New Zealand. Science education is internationally recognised and delivered as a fundamental component of curricula and, as is evident in literature, practical work has potential as a pedagogy to contribute immensely to teaching and learning in science.

As stated in Chapter 1, the purpose of this study is to investigate perceptions held by students on the value of practical work. The findings inform not only my own teaching practice, but also that of my colleagues and the School of Applied Sciences in general.

The findings may also contribute to the pool of research on the role of practical work in tertiary-level science education.

CHAPTER 3: RESEARCH METHODS

- 3.1 Justification for using a case study
- 3.2 Research tools
- 3.3 Participants
- 3.4 Data collection
- 3.5 Quality criteria
- 3.6 Ethical considerations

3.1 Justification for using a case study

The aim of this study was to elucidate answers to the following questions:

1. How do Applied Science students perceive the value of practical work?
2. How does practical work contribute to the learning and understanding of science from a student's perspective?

A case study was selected as the most appropriate method to obtain in-depth knowledge and insight into student experiences. Hinds (2000) describes the case study as the exploration of questions in a specific environment. The utilisation of a case study provided the opportunity to gain perceptions of participants who were directly linked with the research questions. The research tools, which are discussed later in this chapter, elicited the authentic opinions of students who were involved in the courses evaluated as a means of establishing answers to the research questions.

This case study is an example of an “intrinsic” case study (Wellington, 2000), in which the purpose is not theory building as such, but to gain a better understanding of the chosen topic because it is of interest in itself. The topic of this study – the value of practical classes in science courses – is of particular relevance to the School of Applied Sciences as an organisation, its academics and students. Despite there being much historical and current literature available on the purpose and value of practical work in the teaching and learning of science, this research was performed to gain insight into the “case” of practical work in the teaching of sciences in the School of Applied Sciences at AUT, which can subsequently be used to inform practice and delivery of courses. As has been indicated earlier, there has been little research done into the value of practical work at tertiary level education, particularly in New Zealand.

Academics and students in any learning establishment may or may not be aware the expected academic outcomes of practical work in the teaching and learning of science and the reasoning behind them. This research is expected to arrive at a deeper understanding of students' appreciation of the purpose and outcomes of practical work in comparison to the cursory evidence which is collected as a matter of course annually. The data will be collected from participants using several research tools and integrated with personal and collegial anecdotal evidence.

One important characteristic of case study research is that the researcher does not start out with *a priori* theoretical notions (Gillham, 2000), as the theories that relate most to the findings will not be evident until the data has been collected from the selected context. I acknowledge that as an academic I do have pre-conceived theoretical notions as to the value of practical work in the teaching and learning of science, as do my colleagues. Open-mindedness must be maintained to be able to work inductively from the evidence in order to potentially develop grounded theory, theory which is evident in the evidence collected (Gillham, 2000), or at least to develop unbiased themes. From the data collected and interpreted in this study, theoretical notions may be confirmed or contradicted, which opens the way for reflection by us as academics on the delivery of practical work in science. Case studies provide an opportunity for widely held assumptions to be challenged (Gillham, 2000).

Problems associated with using the case study method include generalisability, validity and sampling (Wellington, 2000). The case study method needs to fit the purpose of the research, and in some research the purpose is to understand a specific case and apply the lessons learned more generally (Wolcott, 1995, cited in Wellington, 2000). In the present case the findings could potentially be generalisable to other universities. In some situations there could be a lack of generalisability, depending on the research questions being asked. But, as Wellington (2000) points out, it must be appreciated that the results of a case study are not and need not necessarily be generalisable. The findings of this study will inform the AUT School of Applied Sciences for the purposes of improved learning outcomes and best use of resources. The generalisability of the findings may be determined by a comparison with the limited amount of literature.

Selected courses in the School of Applied Sciences, Auckland University of Technology (AUT) were used in the case study. All courses offered by the School of Applied Sciences have a practical component: laboratory work in chemistry, physics and biology courses, and field work in the environmental and marine courses. A cross-section of courses and levels, ranging from first to third year, was selected to reflect the range of disciplines within the school. A summary of this selection of courses is presented in Table 2.

Table 2: Courses selected for inclusion in this study

<i>Course</i>	<i>Number of students</i>	<i>Level</i>
Foundation Biophysics	100	4
Foundation Human Anatomy and Physiology	100	4
General and Organic Chemistry	60	5
Food Microbiology	30	6
Molecular Genetics	50	7
Haematology III	10	7
Food Chemistry	20	7
Biological Chemistry	120	5
Organic Chemistry	20	6

The perceptions of students/participants gathered for this study were compared with the value of practical work as reported in the literature, in the context of and in relation to the support given by the School of Applied Sciences. As a result of this comparison, the school will be able to consider the contribution of practical work to courses offered from a more informed perspective, and it is an opportunity for lecturers to “hear” students’ voices across a range of subject areas and levels. An insight into the perceived value may result in the school investigating the resources devoted to practical work, and may encourage lecturers to evaluate the purpose and delivery of the practical work in their subject.

In terms of validity, as with all research, the methodology needs to satisfy both external and internal validity requirements. The external validity of a case study is dependent on its generalisability. Where there is not the possibility of, or need for, multiple case studies over a period of time or at different sites, Yin (2003) suggests a way to overcome the perceived problem of external validity associated with case studies is to

“generalize findings to ‘theory’ analogous to the way a scientist generalizes from experimental results to theory” (p. 38). This case study will follow such a suggestion; data will be analysed alongside theory.

Internal validity, which relates to influence the researcher has on the data, is aided by using more than one research tool, and a combination of qualitative and descriptive quantitative data. Examples of, and quotes from, responses are provided to support and justify my interpretation of data. The triangulation of data in the analysis, using responses to questionnaires, interviews and findings from the literature also assists in providing internal validity.

As Wellington (2000) points out, it must also be acknowledged that the reader will assess validity according to their own personal experience, knowledge and wisdom, and will also rely on and trust the integrity of the researcher in presenting the findings fairly and representatively.

3.2 Research tools

The research tools chosen permitted a range of data collection methods. Questionnaires and structured interviews were used, survey methods that capture both subjective and objective data. These tools were appropriate to the naturalistic approach of case studies, which gather data in a specific but natural setting and generally utilise qualitative methods of analysis (Wellington, 2000). The semi-structured interview can be the richest source of data if done well (Gillham, 2000), but in this research difficulty was experienced in obtaining a sufficient number of participants. Unfortunately there were only four responses, of which only three eventuated. This limitation will be discussed in Chapter 6.

A questionnaire was utilised as a tool to collect data from a large number of respondents. So as not to impose on a student’s class time, the questionnaire was handed to all potential recipients by my research assistant at the end of class time, and students were requested to return it to the research assistant at the same time during the same class the following week. In total 400 questionnaires were handed out.

The questionnaire (see Appendix B) consisted of a selection of fixed (or closed) questions to obtain purely quantitative data; Likert scale questions to obtain quantitative data, which can be considered descriptive (Mills, 2003); and open questions to obtain qualitative data and to potentially provide a source of “discrepant” data (Mills, 2003). The last type of question enables “unexpected” data to be obtained.

Interviews were used as a tool to gain in-depth information and development or clarification of the ideas (Hinds, 2000) emerging from the questionnaire. Interviewees, who came from the cohort of students, were first requested to complete the questionnaire. Students were asked to contact my research assistant by e-mail if they were interested in participating in an interview.

The interview was semi-structured, consisting of a selection of open, divergent questions providing an opportunity for the interviewee to express independent ideas on the topic. Interviews also provided the opportunity to elaborate on questions in ways that had not been anticipated by the researcher (Mills, 2003). Interviews were recorded using an iPhone to enable the research assistant to review and collate the data subsequent to the interview. The recording was erased by the research assistant after review of the data.

3.3 Participants

The participants in this research project included the researcher, a research assistant and the students involved in the selected courses involving practical sessions listed in Table 2 above. Data was collected at the end of the semester during which the course had been studied, and after results had been published. The reason for this was to reduce the perceived influence participation might have had upon students’ final results.

The participants invited to take part in the case study were students enrolled in the abovementioned courses in Applied Sciences at AUT. Participants were representative of the range of discipline areas, gender, age, ethnicity and levels of study across the school. As the researcher held a management position within the school, data was collected by a research assistant to avoid any potential conflict of interest.

3.4 Data collection

As noted above 400 questionnaires were distributed; 134 completed questionnaires were received. The questionnaire had been handed to all participants in the selected courses, requesting them to return the completed questionnaire to the research assistant at the same time in the same class the following week. There was also the possibility to return it a fortnight later, or submit it to a questionnaire response box held in the Applied Sciences reception area, from which the research assistant collected any returned. The questionnaires received represented a response rate of 33.5%.

An invitation to participate in an interview was extended at the time of distribution and collection of the questionnaire, and the invitation was extended via the School of Applied Sciences intranet on three occasions, to which four responses were received. From these four responses three interviews eventuated.

3.5 Quality criteria

Qualitative analyses need to be deemed credible and trustworthy; findings should resonate with those who are in, or are familiar with, the setting, and the processes and findings need to be believable (Mutch, 2005). A thorough literature review (Chapter 2) was completed which established recent findings from research, and appropriate ethical considerations ensured trustworthiness. Participant verification of interview data contributed to credibility.

Triangulation of data, whereby information is collected in a variety of ways, rather than relying solely on just one method, is strength of qualitative research (Mills, 2003). Data was collected using two different research tools, the findings of which were then compared and contrasted with the researcher's thoughts and the current literature.

The use of a questionnaire and a pre-prepared, semi-structured interview, provided a procedure which was reliable in that these tools could be further utilised if more data needed to be obtained, or if the procedure were to be repeated (Hinds, 2000).

The two selected research tools also produced results considered to be valid: the questions in both the questionnaire and interviews obtained student perceptions, which when analysed using content analysis provided data relevant to the questions asked.

3.6 Ethical considerations

As the research was being conducted by a practitioner in an area which incorporated their own practice with participants who were the researcher's students, the participants were in a potentially vulnerability position if the researcher had been directly involved in the collection of data: there was the potential for both compulsion to participate and the provision of inauthentic responses. The researcher was also in a position of "power over the participants" (Mutch, 2005, p. 78); there was potential for the students to believe that the process and outcomes of the research may have affected their results, either favourably or detrimentally. Data collection from the questionnaire and interview was therefore performed by a research assistant to avoid any potential conflict of interest. The research assistant was a postgraduate student from within the School of Applied Sciences who was an experienced lecturer, but was not currently involved in a teaching role.

The questionnaire was voluntary and the data collected confidential and anonymous. The information regarding the participant anonymity and confidentiality was transparent in the participant information sheet (Appendix A) and all participants involved in the interview were required to complete a consent form (Appendix D). Assurances were made to participants that records of interviews would not identify any individual: each was identified only by a code in data analysis and reporting.

Voluntary completion of the questionnaire was considered to signify consent. Participants involved in the interview process were provided with an opportunity to confirm the accuracy of the transcript prior to the data being forwarded to the researcher.

Ethics approval was granted by the Auckland University of Technology Ethics Committee (AUTEK).

CHAPTER 4: DATA ANALYSIS

- 4.1 Method of data analysis
- 4.2 Responses to closed questions
- 4.3 Responses to fixed questions
- 4.4 Responses to interviews
- 4.5 Summary

4.1 Method of data analysis

The data collected from both questionnaires (n = 134) and interviews (n = 3) were collated on an Excel spreadsheet. Responses to closed questions were summed and recorded to give a picture of the participants. Responses to open questions were coded and content analysis was used to interpret the data. Content analysis involves describing and developing themes, and correlating the findings from the questionnaire and interviews. Initially many categories were identified and created to code emergent themes; these were subsequently “subsumed into wider categories, to enable the reader to digest the information quickly” (Wilkinson, 1997, p. 79). Themes were identified according to the recurrent appearance of key words and phrases; responses frequently aligned with more than one category or theme and responses were frequently opposed in opinion.

The data collected from questionnaires and interviews was collated and coded according to the emergent themes. These themes were summarised and presented as “rich description” (Mutch, 2005, p. 180), using selected examples to either highlight the themes and categories, or support the theoretical underpinnings of practical work in science according to the literature.

To investigate any additional significance of the emergent themes, the data were further analysed in conjunction with the personal data of the respondent: gender, ethnicity, number of years of study at Auckland University of Technology (AUT), and highest level of study. Interview data were analysed in the context of themes identified from questionnaire data, and in addition, variation on themes as a result of a greater depth of response was identified. These themes were summarised and described using examples of responses as an illustration and representation of the extent of variation of response.

4.2 Participant profile

The responses to the closed questions of the questionnaire (Questions 1–4), established the participant profile. A total of 134 students in the School of Applied Sciences responded to the questionnaire of which 33% were male and 67% female. This is representative of the gender balance within courses in Applied Sciences at Auckland University of Technology, regardless of programme. An analysis of gender responses in conjunction with responses to questions is presented in Chapter 5.

The ethnicity of respondents was also representative of ethnicities in courses within the School of Applied Sciences.

Table 3: Ethnicity of respondents

Ethnicity	Number of respondents
New Zealander/ Kiwi (including any participant with additional ethnic identification to that of New Zealand/Kiwi)	29 (21.7%)
Asian	24 (17.9%)
Indian	19 (14.2%)
European (including any participant identifying a European county of descent)	17 (12.7%)
Pasifika	10 (7.5%)
Fijian Indian	7 (5.2%)
Maori	4 (2.9%)
Others (including three participants identifying themselves according to religion)	24 (17.9%)

Small numbers of students in pre-degree and undergraduate programmes are international students primarily from Asian and Middle Eastern countries. Most domestic students have attended secondary school in New Zealand. Ethnicities were further classified into broader groups, as presented in Table 3 above, to identify any links between ethnicity and responses to questions, which are discussed in Chapter 5.

The majority of participants, approximately 76%, were in their first year of study at AUT. The remainder were reasonably evenly distributed across the second and third years of study, with a smaller number in their fourth year. These figures correlate with the sizes of classes within the range of courses selected. First year courses are generic to all subsequent fields of study within the School of Applied Sciences, and are enrolled in by all first year students. The Certificate programme at Level 4 is a one year programme with a limited range of choice of courses; hence the class size is relatively large. The majority of these students leave AUT with the certificate and move on to other courses or seek employment; a small percentage staircase into the degree programme, which is the purpose of the programme.

First year courses also include a significant number of Diploma programme students. Students who do not have university entrance can complete one year of study and either graduate with a Diploma, or again staircase into the degree. Second year courses have smaller numbers. Students completing the first year common papers and progressing on to second year courses split into specialist courses according to the major enrolled in.

The highest level of study for the majority of participants who completed the questionnaire was Level 5, the first year of degree level study. There were consistently smaller numbers, across Levels 4 (pre-degree study), 6 and 7 (second and third year of study respectively). Data obtained on year of study and level of study was gathered to evaluate the relationship between perception of practical work and level of study, and any change in perception as a student advances through a tertiary science course. These findings are discussed in Chapter 5.

4.3 Responses to fixed questions

Questions 5–7 sought an initial response to the value of practical work. Question 5, “How do you rate the value of practical work to your study of science generally?”, required responses on a Likert scale, the results of which are presented in Table 4 below.

Table 4: Rating of value of practical work

Very high	Average	Very low	No response
65 (48.5%)	65 (48.5%)	3 (2.2%)	1 (0.8%)

There had been no clarification as to the meaning of the phrase “value of practical work” at the point at which this question appeared in the questionnaire and further open questions elucidated individuals’ reasons for their perceived value of practical work. Despite this, adding together the responses for very high and average, it can be seen that the vast majority, 97%, do rate practical work as being valuable. A minimal number of participants, 2.2%, rated the value of practical work as very low. One participant did not respond.

Question 6 was “Do you find practical work more valuable in some subjects than others?” Here 59% of participants responded affirmatively, indicating that they find practical work to be more valuable in some subjects than others, and 40% were of the opinion that the subject area does not alter the value of practical work. One participant provided no answer.

Further to an affirmative response, the participants were questioned as to which subject area(s) practical work is most valuable in and why. The majority of students that were of the opinion that practical work is more valuable in some subject areas than others identified one particular subject area. A minority listed a selection of science subjects in response to the question.

Table 5: Subject area(s) practical work is most valuable in

Course	Chemistry	Biology	Physics
Number of responses	48 (38%)	47 (37.5%)	31 (24.6%)

Though the figures alone are not of statistical significance, as not all students were studying or had studied courses in all subject areas, the data in Table 5 does show the subject areas that are representative of science subjects in the pre-degree and first year courses.

Chemistry courses, including specific chemistry courses identified by some (namely Biological Chemistry, Biochemistry and Analytical Chemistry) and Biology subjects (including Cellular Biology, Genetics, Microbiology courses and Ecology) were cited as the subject areas that practical work is most valuable by 38% and 37.5 % of respondents

respectively. Physics (which was used to include the areas of electronics and engineering) was also cited, but least frequently, by 23%. This is expected as there are fewer courses in Physics in comparison to Chemistry and Biology subject areas.

The following comments are representative of reasons provided by respondents for practical work being of value in certain subject areas:

“Puts the theory into practice”

“You get to see first-hand something you may not have understood in the lecture”

“Gives you a better understanding”

“More hands-on work helps you to learn more”

Other common responses are typified by “After completing the degree or diploma, in actual workplaces, the students will be requiring [*sic*] to handle chemicals or instruments etc.” and “as you can only learn techniques by working hands on”. These indicate that the perceived value is the practical skills provided that are necessary in some subject areas.

The responses to Question 7 are presented in Table 6. The purpose of this question was to investigate the opinions of students to some of the common reasons given for the inclusion of practical work.

Table 6: Participant responses to common reasons for practical work

Response	Always	Sometimes	Never	No response
You behave like a scientist	44 (32.8%)	77 (57.5%)	8 (5.9%)	5 (3.8%)
You learn scientific skills	96 (71.7%)	35 (26.1%)	0 (0%)	3 (2.2%)
It is enjoyable	71 (53%)	58 (43.3%)	3 (2.2%)	2 (1.5%)
You are actively involved in learning	103 (76.8%)	29 (21.6%)	1 (0.08%)	1 (0.08%)
It helps you to understand scientific concepts	90 (67.2%)	42 (31.3%)	0 (0%)	2 (1.5%)
You work as part of a team	61 (45.5%)	69 (51.5%)	3 (2.2%)	1 (0.08%)

Responses to the statement “You behave like a scientist” indicate that the majority have the opinion that practical work is valuable as it does at least sometimes require students to emulate the behaviour of scientists; 57.5% were of the opinion that you sometimes do and 32.8% felt that you always do. The minority either did not respond (3.8%) or were of the opinion that they never behave like a scientist (5.9%).

It can be seen from the responses to subsequent questions that although some participants stated that they “never” behave like scientists in Question 7, they attribute value to practical work for other reasons such as the reinforcement of theory. Such participants made statements like “It applies to theory parts, by doing it in practical and it helps me to learn more and it stays in my mind more.”

There was very strong support for the statement “You learn scientific skills”; 71.7% were of the opinion that you always learn scientific skills; 26.1% believed you sometimes do; and no participants responded “never” (2.2% did not respond to this question). Although three participants did not respond, two responded to previous questions, with one rating the value of practical work as “high” and the other “average”.

Similarly, the majority of participants were of the opinion that practical work is valuable because it is enjoyable. The three participants who were of the opinion that practical work is never enjoyable did respond to further questions, indicating that they do value practical work for other reasons, despite having stated that they did not enjoy it.

There was only one participant who responded negatively to the statement “You are actively involved in learning”. The majority (76.8%) affirmed that practical work is valuable because practical work always involves active learning, and 21.6% were of the opinion that sometimes you are actively involved in learning. Hence 98.4% of participants acknowledged that active involvement in learning science occurs during practical work.

Responses to practical work being valuable because “It helps you to understand scientific concepts” were similar: the majority (67%) responding “always”; 31% responding “sometimes” and no participants responded “never”. There were two participants who did not respond. Of those that responded with “sometimes”, several

elaborated in later responses with comments such as “It is much easier to understand it if you see it that it works instead of just learning by heart.” This comment suggests that learning of a concept was supported for this student if there was an associated practical. Another participant elaborated with “technical experience for work”, displaying no support for the idea of practical work contributing to understanding.

Finally, responses to the statement “You work as part of a team” were less supportive of the response “always”, with only 45.5% viewing practical work as always requiring teamwork. But the majority responded that a least sometimes they worked as part of a team (97% in total); 2% of participants responded with “never” and one provided no response. These three responses raise the question as to the use of the term “teamwork” as opposed to term “group work”. Many practical sessions are run in groups, but this is often for convenience and the potential benefits of teamwork arising from such practices are perhaps overlooked or disregarded. Participation as part of a team is a commonly identified aim of practical work in science (as in Chapter 2); this is analysed further in Chapter 5 in conjunction with the year/level of study and study area. In the School of Applied Sciences, group/teamwork is more common in the first year of study in the core science subject areas. Practical work at the higher levels of study and in specialist areas becomes individualised.

Questions 8–10 were open questions which sought qualitative responses to the questions “In what way(s) does practical help you to learn”, “Are there any other reasons/advantages for practical work being a valuable part of studying science subjects?” and “Think of the practical session that has had the greatest impact on your learning in science at Auckland University of Technology. What made this practical so effective/good?”

It is possible that the statements in Question 7 pre-empted some of the responses to Questions 8 to 10, but those statements were paraphrased by respondents in the later questions and in most cases expanded upon and qualified.

Question 8, “In what way(s) does practical work help you to learn”, produced a variety of responses which were initially coded according to 24 sub-themes identified by key

words or phrases. These were further refined into the six major themes presented in Table 7.

Table 7: Major themes and sub-themes on how practical work helps students to learn

Major theme	Sub-themes
Helps and supports understanding/learning (sub-themes appearing in 79 responses)	<ul style="list-style-type: none"> • confidence • saves reading • helps to learn more • teamwork • stays in the mind more • understanding of new concepts • better understanding • adds value • reinforces lectures • applies to real life
Interesting (sub-themes appearing in 10 responses)	<ul style="list-style-type: none"> • develops interest • fulfilling and enjoyable • new things • adds value • fine focus on science
Relates to a future career (sub-themes appearing in 5 responses)	<ul style="list-style-type: none"> • what work will be like • skills related to career/practical skills
Hands on and visual learning (sub-themes appearing in 70 responses)	<ul style="list-style-type: none"> • see things happening • hands on approach • senses involved
Applies theory to practice and practice to theory (sub-themes appearing in 29 responses)	<ul style="list-style-type: none"> • applies to theory • theory into practice/how theory applies to practical techniques • practical examples
Develops skills (sub-themes appearing in 3 responses)	<ul style="list-style-type: none"> • learning new technologies • develop/learn new skills • scientific method

Note that the number of responses exceeded the number of participants due to many responses being able to be coded to more than one subtheme, and therefore theme. The number of responses corresponding to each theme does indicate the relative strength of the theme. This also applies to Tables 8 and 9 later in this chapter.

Each of the sub-themes emerged through coding responses which contained similar words or phrases. For example, the sub-theme “understanding of new concepts” was coded for using words and phrases which appeared in many responses, expressed in a variety of ways, but with fundamentally the same meaning. Examples of responses coded within this sub-theme were:

- “We learn the concepts and how they are applied to real life situations”,
- “Practical’s [*sic*] makes it easier to understand new concepts, specifically with practical examples”
- “As in some concepts, it cannot be fully expressed in theory . . .”
- “It makes it easier to understand the concept of the theory of science relating to the practical”
- “In having a concept and start thinking logically”

All sub-themes which could be associated with the process of learning were grouped within the one major theme, that of helping or supporting learning and understanding.

Many responses indicated that as practical work was interesting, and that it helped in the learning of science. Sub-themes contributing to this theme included:

- develops interest
- fulfilling and enjoyable
- new things
- adds value
- fine focus on science

There were a significant number of responses which included the key words “work” or “career”, such as “technical experience for work”. Using these key words, sub-themes contributing to the theme “Relates to a future career” were:

- what work will be like
- skills related to career/practical skills

Many responses included mention of the use of the senses involved in learning. For example the sub-theme “sees things happening” was developed from responses such as:

- “It shows instead of describing, seeing is believing”
- “Because you can see things happening as opposed to just reading about it”
- “But it’s good to see what I should know”
- “You can see for yourself how ‘things’ work, see in person how things work”

There were also many references made to a “hands-on” approach or opportunity to learn which were incorporated within the same theme, acknowledging the utilisation of the senses to learn.

The phrases “it applies to theory” and “theory into practice” regularly appeared within the responses, and these were coded as “it applies to theory”, “theory into practice/how theory applies to practical techniques” or “practical examples”. All linked theory and practical together as an important reason for the inclusion of practical work in the learning of science.

The final major theme emerged from sub-themes relating to the development of skills arising from the inclusion of practical work. The skills mentioned related to hands-on practical techniques, the use of technology, and the learning and utilisation of the “scientific method”. Many phrases and responses aligned with more than one sub-theme and were therefore coded to more than one theme. For example “Practicals help me to learn science by actually showing the work” reflects the two sub-themes “helps to learn more” and “see things happening”. The following particularly long response was coded into no less than four sub-themes:

“In practicals, the experiments are done step by step and at each step observations are made. These observations give a better understanding of the theory component. Understanding concepts is very important. Practical does also make a subject fun and enjoyable. Many people don’t like theory work and just as many don’t like practical’s but having both gives a break to everyone and develop interest in either side.”

There were responses which were very insightful, such as the quote below, which will be discussed in Chapter 5 in conjunction with the current literature on the value of practical work:

“It gives us the basic skills required for working in a lab. It enables us to gain experience and some confidence or important skills required in the science community. It prepares us for our future careers, providing helpful techniques, skills or knowledge we can use in the future. Practical are good practice before entering the workforce. In practical’s we are actually putting what we learnt in theory into practise rather than just learning from reading. Many concepts and techniques cannot be understood just by reading/theory work.”

Some responses were unique and difficult to interpret in terms of the identified sub-themes. For example, “saves reading” was interpreted to mean that practical work provides an alternative way to learn and understand. “As a kinaesthetic learner and as a

dyslexic, hand on work takes relief from time consuming and hardworking reading” was coded into the same sub-theme as above. Some subjective discretion was required in a minimal number of responses.

The sub-themes “see things happening”, “hands on approach” and “senses involved” aligned to produce the theme “Hands-on and visual”. These sub-themes could also have been incorporated into the theme “Helps and supports understanding/learning”, but as will be discussed in Chapter 5, the emergent themes both have their individual merit and contribute to wider overarching themes. Further discussion will in some cases draw upon sub-themes from other themes where appropriate; for example sub-themes within “Interest” will be discussed within the theme “Helps and supports learning/understanding”. Each of the emergent themes and their contributing sub-themes will be discussed in detail in Chapter 5.

Question 9 asked the question “Are there any other reasons/advantages for practical work being a valuable part of studying science subjects?” The responses were coded into 19 sub-themes initially, which were then refined into five major themes, as presented in Table 8 below. Again, key words and phrases were identified and coded as sub-themes. The sub-themes were then grouped into major themes, of which there were five.

There were many responses given to Questions 8 and 9 that were very similar. But there was additional reasoning provided by many in response to Question 9. For example, one respondent wrote “The obvious answer is that it reinstalls what I have learnt in the lecture” for Question 8, and “For me it is a good basis for deciding what I want to do in the future in terms of my degree” for Question 9. The response to Question 9 in this example was able to be coded for a sub-theme that emerged in Question 8.

Hence there were four common themes which emerged in response questions 8 and 9 indicate that the ways in which practical work contributes to the learning of science is perceived as the reason *why* practical work is valuable in the study of science.

Comments such as “relates to the theory in lectures – make it easier to understand”, “useful for applying theory” and “we learn more by actually doing the practical yourself

and you get a better understanding of things” were coded into sub-themes which were united by the common overarching theme of helping and supporting understanding and learning.

Table 8: Reasons for practical work being a valuable part of studying science subjects

Major Theme	Sub-themes
Helps and supports understanding/learning (sub-themes appearing in 24 responses)	<ul style="list-style-type: none"> • easier to understand theory • backs up theory • better understanding • learn more • puts information in perspective • helps start study in science • applies to real life • confidence • problem solving
Interesting (sub-themes appearing in 7 responses)	<ul style="list-style-type: none"> • less boring • interest/amazing/fascinating • big part of science
Relates to a future career (sub-themes appearing in 20 responses)	<ul style="list-style-type: none"> • prepares you for a job • practical skills • deciding what to do in future
Hands on and visual learning (sub-themes appearing in 10 responses)	<ul style="list-style-type: none"> • hands on is more fun • learning by doing/observing
Opportunity for group work (sub-themes appearing in 8 responses)	<ul style="list-style-type: none"> • learn from each other/group/scientist • get to know people better

Sub-themes such as “puts information in perspective”; “helps start study in science”; “applies to real life”; “confidence”; and “problem solving” were also included in this theme as each is implicit in the support of learning and understanding. This theme was the most predominant one to emerge as an additional reason for practical work being considered a valuable part of learning science.

“Interest” was another theme which emerged. The response “less boring” appeared more than once, and this was categorised into the theme “generates interest” by

implication. “The amazing things we get to see and do that other people who don’t study science don’t see and won’t understand how amazingly things work” again was interpreted as implying interest.

A large number of responses cited an “other” reason for practical work being valuable as the role it plays in relation to a future career. The sub-themes which generated this theme included key phrases such as:

- prepares you for a job
- practical skills
- deciding what to do in future

Comments which supported this theme included, for example:

“Easier to get a job”

“For me it a good basis for deciding what I want to do in the future in terms of my degree”

“When we are job searching as graduates we can attribute the many hours spent doing practical work as valuable practical experience”.

Similar to the responses to Question 8, many responses to Question 9 confirmed that the opportunity to interact via the senses during practical work was an additional reason supporting the value of practical work. “Learning by doing” and “you can see what is being talked about in lectures and do it yourself, putting it into your brain again, making it more memorable” illustrate the perceived benefit of the hands on experience, and “hands on experience always fun [*sic*]” was a frequent response, demonstrating that enjoyment of the experience contributes to the value of practical work.

One theme that emerged from Question 9 which had also been ranked highly in Question 7 was the recognised contribution of the ability to participate in a group or team when undertaking practical work. There were two sub-themes apparent: group or teamwork contributing to learning, and group work providing the opportunity for social engagement with other students. Responses such as “In practical we can learn from each other sometimes one knows or understands something and they can explain it to their group” and “as a group activity it improves relationships with other students . . .” illustrate these sub-themes.

The responses to Question 10, “Think of the practical session that has had the greatest impact on your learning in science at AUT. What made this practical so

effective/good?”, were coded into 20 sub-themes, which were further refined into four major themes. These themes are presented in Table 9.

Table 9: Themes on what makes a practical have great impact

Major Theme	Sub-themes
Helps and supports learning/understanding (sub-themes appearing in 38 responses)	<ul style="list-style-type: none"> • helps learn more about the subject • more understanding of theory • confirms theory • theory / practical support each other • educational • good tutoring • well structured • ask questions • applies to our lives • retention
Interesting (sub-themes appearing in 12 responses)	<ul style="list-style-type: none"> • never boring • interesting • fun / enjoyment
Hands on and visual learning (sub-themes appearing in 15 responses)	<ul style="list-style-type: none"> • opportunity to do it oneself • see what was happening
Advantage of being in a laboratory setting (sub-themes appearing in 20 responses)	<ul style="list-style-type: none"> • operating instruments is important • can repeat until right • feeling like a scientist • a lot of resources available • participation

As with Questions 8 and 9, the predominant recurring theme that emerged was that of supporting learning. This theme was developed from sub-themes similar to those which emerged from Questions 8 and 9, supported by comments such as:

“We were able to do practical on our own and by this we were able to understand what we were doing”

“I like doing practical work to find out the result. It made me much easier to understand [*sic*]”

“Over several weeks the lab was quite repetitive which reinforced theory and observing the expected or not expected results was constantly reinforced over several weeks – this meant theory was being revisited every week and ended up with a good understanding”

There was also a selection of sub-themes which specifically related to learning in a laboratory setting. These sub-themes related to opportunities which arise in practical sessions as opposed to lectures, such as access to and availability of tutors and

resources, and the opportunity to ask questions due to the smaller group size. Comments were also made with respect to the structure and organisation of the practical sessions aiding learning.

Similarly, “Interest” was a theme which also emerged from this question. Comments such as “Always working never bored” and “The practical was fun and interesting” were coded into sub-themes by identifying words or phrases such as “not bored/boring” and “interesting”.

“Hands-on and visual” was another recurrent theme. There were many responses which indicated that the effectiveness of a practical session related to the opportunity to operate kinaesthetically and utilise the senses whilst learning. “Titrations. I would have been lost without having the opportunity to do it myself” and “visualising really helped the concepts learnt which enable to grasp the theories with deeper understanding” were representative responses generating the relevant sub-themes.

The fourth theme which emerged related specifically to the learning setting being in a laboratory. The coding of sub-themes related to access of resources such as instruments, “Operating instruments is very crucial”, “Operating like a scientist” and also participation in the activity: “Inclusive participation – not just demonstrations”.

Each of these themes which emerged from the qualitative Questions 8–10 will be discussed in conjunction with findings obtained from the literature in Chapter 5.

4.4 Responses to interviews

Three participants volunteered to be interviewed, two were female and one male (S2); one female was in the first year of the degree (S1) and one in the third (S3), and the male was in the third year of study (S2). All three identified themselves as Kiwi/New Zealand European. Participants S1 and S2 were in the Bachelor of Applied Science programme, but were majoring in different areas, and S3 was in the Bachelor of Medical Laboratory Science. Both programmes share common courses in the first year, but specialise (including the differing majors within the one programme) from the second year of study on.

The first qualitative interview question required the participant to reflect on how they had learnt science prior to coming to AUT. S2 had no recollection, stating that it was over 20 years since they had attended school and “could not remember anything from school”. S1 and S2 participants’ recollections of learning science were expressed in terms of the practical work they did. For example, “We did red cabbage litmus . . .” and “doing dissections and things like that . . .”. I assume that, appreciating the purpose of this study, these participants immediately focused on the practical work they could recall rather than any other methods of teaching and learning that took place in science. Alternatively, their recollections could be truly representative of how they learnt science; that is, their learning was “attached” to practical work.

The next question asked for an opinion as to whether practical work had contributed to their learning of science. Again the participant who had not attended school (S2) for many years was unable to provide a response to this question as he had no recollection. S1 responded stating that practical work was more relevant in some areas of science than others, and hence contributed to learning in those areas where it was relevant:

“I actually found that biology the practical was relevant, but I found it hard to find the connection with chemistry it was a bit hard to sort of, you learn specific things like specific experiments in chemistry but it doesn’t really relate to the general theory.”

S3 did not differentiate between areas, but stated that practical work helped with learning “very much”.

All three participants were firmly of the belief that students assume that practical work will be a component of study in science. S2 affirmed this assumption by qualifying the purpose of the practical component to be “able to take it into the real world to use”. Both S2 and S3 were of the opinion that science is a practical subject; S3 expanded by stating that a science graduate will be working in a practical situation which requires practical skills.

When asked to explain their understanding of the term “practical work”, S1 and S2 both responded by confirming that practical work requires the student “to do” something and that this activity relates to and backs up the theory. S2 also stated that practical work enables one to visually see how principles work. S3 defined practical work as the

experiments or field trips that relate to the theory being taught, which correlates with the ideas of S1 and S2.

All three participants confirmed that they believed that practical work should and does differ depending on the level of study. Lower levels of study consist of “basic” practical work and at higher levels the practical work becomes more specialised and complex.

Participants were then asked as to their understanding of the word “value” when asked “What is the value of laboratory based practical sessions?” The words “beneficial”, “enjoy” “improve” and “support” were used in relation to knowledge, understanding, and application of skills. When asked to rate the value of practical work, which the research assistant clarified 1 as being of least value and 5 most, S1 and S2 both rated the value as 5, and S3 as 4–5.

These responses were more extreme in their ranking in comparison to the responses to the questionnaire. In the latter, nearly 50% of respondents were of the opinion that practical work is of very high value and nearly 50% of the opinion that practical work is of “average” value. The differences in responses between the questionnaire and interview can be attributed to the fact that the small number of participants interviewed was possibly representative of those that perceived the value of practical as being very high; these participants were likely interested in supporting this study and thus volunteered to be interviewed.

S1 and S2 both explained their rating on the basis of the contribution of practical work to learning: by doing and seeing, more is retained. S3 qualified their response by confirming that most of the practical work performed would be used in the workplace and, even if not, it helped understand how and why such practical work, analytical tests in particular, works.

In response to the question asking if practical work is more valuable in some science subjects than others, S1 differentiated between subjects. She considered some subjects to be more experimentally based (such as Chemistry) and some more theoretical (such as Physics), with practical work being more valuable in those subjects which are

experiment based. This was elaborated on to explain that the skills acquired in the “experimental” subjects would be put into practice in industry as a graduate.

S2 was strongly of the opinion that practical work is equally valuable across all science subjects as it provides the opportunity to experience and gain “hands-on practical knowledge”, which, in his opinion, was a very important consideration for an employer when employing staff in a scientific area.

S3 also believed practical work to be equally important across all science subjects, owing to the contribution practical work makes to learning. Interestingly, this participant was the student who will be graduating with a degree, leading to potential employment in a very practical laboratory based role. This student viewed the value of practical work in terms of the contribution to learning, rather than the skills acquired, which is not the response one might have expected from a student in such a programme. These responses concur with the responses obtained from the same question asked in the questionnaire, with the same reasons being cited.

The next two interview questions elicited responses which resembled a number of responses to Question 9 in the questionnaire. Participants were first asked for their thoughts on why practical work is incorporated in the teaching of science. All three responded that practical work reinforces the theory learnt: by being able to apply the theory to the real world, by being able to learn in a different way, and providing a better understanding. S3 also stated that the degree she was completing will result in working in a lab, so the inclusion of practical work was providing the opportunity to learn how to work in a lab.

When asked the question “In what ways do you think practical work helps someone learn science?”, participants provided similar responses. All stated that practical sessions enable the application of scientific theory and principles to be “seen”, in comparison to reading about these theories and what is expected in reality, which aids understanding.

The participants were asked how the design or purpose of practical work impacts upon its perceived value. S1 indicated that they consider it very important to have the session

demonstrated or well explained initially to avoid following a set of instructions with possibly no understanding. All three indicated that practical work was most valuable when they performed the practical session themselves in comparison to a demonstration being performed. S3 emphasized the value of performing the work as an individual. Comments were also made about lab work sometimes not producing the expected results, but these were qualified in terms of some component of the practical session being helpful “anyway”.

The interview included a question on the impact of assessment of practical work on its perceived value. All three agreed practical work needs to be assessed, but for a variety of reasons. S1 stated that skills need to be assessed to affirm that what is being taken out into industry is being performed correctly. She also stated that she would not place much importance on practical work if it was not assessed. Similarly, S2 and S3 were of the belief that many students would not attend practical sessions if the work was not assessed. Both confirmed that they would have attended regardless of whether it was or not, however; S2 would also have attended as he enjoyed the practical work and stated it was more important to him than the theory. This question would have to be asked of a greater number of students to form a valid impression: no validity can be placed upon the assumption of two participants that students would not attend practical sessions if they were not assessed. The three responses obtained nevertheless do support the importance, or value, of practical work being assessed.

When a hypothetical situation in which there was no practical work incorporated in the teaching of science subjects was put to the participants, S1 doubted this could ever eventuate as “sciences have to have a practical component”. S2 confirmed that processes involved in the application of the theory would not be learnt in such circumstances, and S3 felt they would have less understanding. S2 elaborated on other perceived advantages of practical work which would be lost if it were not a component of teaching science. These included the opportunity for group work and the opportunity to talk and discuss ideas with other students during practical sessions.

Finally, participant S2 offered an additional comment as to the value of practical work prior to the end of the interview. The comment pertained to the state of some of the equipment available for use in the university laboratories: “Some of the equipment is dilapidated or out of date. The equipment needs to be kept up to date”. He did

acknowledge that, once in the workplace, one is going to be learning “all over again” with more up to date equipment, and that the importance of practical work is to gain the basic knowledge relating to the application of the equipment. This issue was alluded to by participant S3 also: “Many practical applications are automated in industry, but the learning of the theory behind the tests the machinery performs is important”. This participant had also acknowledged that not all experiments or tests “work” as expected, but there is value derived from some the fundamental purpose of the exercise.

The responses to the interviews will be discussed in conjunction with the responses to the questionnaires and literature findings in the following chapter.

4.5 Summary

The major themes which emerged from the coded data for each of the qualitative questions in the questionnaire converged into four overarching themes. The responses to the interviews aligned with these overarching themes from the questionnaires; no new themes emerged, but some themes were emphasised.

The predominant themes that emerged from the data were:

- helps and supports learning/understanding
- interest
- hands-on and visual learning
- application to real life
- application of theory to practice and practice to theory
- development of skills and related to a future career
- advantage of being in a laboratory setting
- opportunity for group work

These were then categorised into four overarching themes by combining common themes. The contribution of the themes to each overarching theme will be further explored in chapter five. The themes

- helps and supports learning/understanding
- interest
- hands-on and visual learning

were combined into the one overarching theme:

- support of learning and understanding.

The themes

- application to real life
- application of theory to practice and practice to theory
- advantage of being in a laboratory setting

were combined into the one overarching theme:

- real life approach

The two final overarching themes were

- skills and career development
- opportunity for individual/group work

Despite being categorised into four overarching themes, it will be apparent in chapter five that there is overlap of themes within the overarching themes; some themes contribute to more than one major idea. These overarching themes will be discussed in the next chapter with the aims of constructing a comprehensive view of the student perspective and relating this viewpoint to current and historical literature on the learning of science, in particular the value and contribution of practical work in science courses.

CHAPTER 5: DISCUSSION

- 5.1 Introduction
- 5.2 Discussion of the findings
- 5.3 Additional findings relating to the case study
- 5.4 Summary of findings

5.1 Introduction

Chapter 4 presented the sub-themes which were developed from the coding of responses to the questionnaire and supported by responses to interviews. These sub-themes were then grouped into major themes. These major themes have been further categorised into four overarching themes that will now be considered alongside findings from literature.

The four overarching themes are:

- support of learning and understanding
- real life approach
- skills and career development
- opportunity for individual/group work

The predominant overarching theme that emerged was the support of learning and understanding that practical work provides. This theme was developed from the relevant major themes: practical work both generating interest in science and catering for different learning styles, and the application of theory to practice and practice to theory.

While most research into the role of practical work in science education is situated in primary and secondary education, the fundamental epistemology and pedagogical principles of practical work apply equally to undergraduate education. As discussed in Chapter 2, although science education at tertiary level is for more specific purposes or outcomes, the profile of the graduate of Applied Sciences includes similar attributes to those described in the aims of science education during the compulsory years of schooling. As identified in the literature review, practical work is acknowledged as an important pedagogy in the development of these attributes. Teachers of undergraduate students regard practical work as integral to science disciplines, arguing in support of the rich learning opportunities provided (Feteris, 2007), but from my experiences most support is in the form of anecdotal evidence and subjective judgements as to its value.

An important finding from the literature review was that most studies into practical or laboratory work at undergraduate level have focused on specific components and aspects of university laboratory work, such as in undergraduate Physics, Biology or Chemistry, instead of the contribution of practical work to learning in science in general.

The overarching themes listed above will now be discussed in turn. The chapter concludes with findings that are particular to this case study.

5.2 Discussion of the findings

5.2.1 Support of learning and understanding

This overarching theme, which was recurrent throughout the responses to qualitative and quantitative questions from participants, confirms that there is a commonly held view by students that practical work supports student learning in the gaining of knowledge and understanding of science; students in this case study endorsed the view that, pedagogically, practical work is beneficial as a teaching method in science courses. Many reasons and explanations were given. These will be cited and discussed below.

The majority of participants (97%) rated the value of practical work in science as either average or very high; only 2.2% rated practical work as of low value. Similarly, the majority of participants (67.3%) indicated that they value practical work because it *always* helps with the gaining of knowledge in science, and 31.3% indicated that it *sometimes* helps.

These findings are similar to an English Science curriculum review performed in 2002 (Cerini et al., 2003) which collated the views on the Science curriculum and science teaching of respondents ranging from under 14 to over 45 years of age, with the majority in the 16–19 age bracket. In that review, 47% of respondents stated that practical work makes understanding theory easier. Recurring sub-themes which emerged from Questions 8–10 of this study's questionnaire included, for example, practical work reinforcing the content of lectures; helping learning; clarifying; improving understanding; and supporting theory. These sub-themes confirm that

students acknowledge the value of practical work in supporting their learning in science.

The respondents' perceptions are supported by the findings of a quantitative study by Taraban et al. (2007), in which the results of tests indicated that the utilisation of laboratory work as a teaching method significantly supported students in gaining content knowledge. Similarly, the *Student Review of the Science Curriculum* (Cerini et al., 2003) which was carried out in England; research by Osborne et al. (2000); and that of Reiss (2000) all found that students believe that practical work is the most useful and effective method of learning science. One particularly pertinent questionnaire response was "some concepts cannot be expressed in theory . . . therefore demonstration of practical experiments will assist students to have a better understanding along with the theory", and another participant stated, "there is a lot of knowledge gained which can't be acquired in class".

Exactly how practical work assists students in their learning of science, or how practical work reinforces knowledge in science, was not explicit from responses in terms of theories of learning, but most participants did make reference to the opportunity for "repeated exposure to the theory" and expressed the opinion that scientific knowledge and scientific concepts presented in lectures were supported, reinforced and confirmed by the practical work they carried out. Responses such as "practical application of theoretical learning reinforces theory learnt in lectures"; "over several weeks the lab was quite repetitive which reinforces theory"; and "observing the expected or not expected [*sic*] results was constantly reinforced over several weeks – this meant theory was being revisited every week and ended up with a good understanding" illustrate the perceived importance of repeated opportunities and repeated exposure as being supportive of learning. Similarly, a simple response such as "it shows how the theory works in with the practical techniques" indicates the role of practical work in conjunction with the learning of theory, from a student perspective.

Students are generally of the opinion, according to the findings from this study and anecdotal evidence, that there is a "body" of scientific knowledge to be learnt in science courses. Responses indicate that this knowledge is "learnt" in lectures in which the common mode of delivery historically has been didactic and indeed still is today, and

experiences gained by performing practical work provide support and an alternative way of learning this knowledge. These perceptions on the gaining of scientific knowledge through the engagement in hands-on practical work in addition to lectures correlate with two recognised positions in the literature on the nature of knowledge: that of rationalism (Schunk, 2008), whereby knowledge is derived from reason and this knowledge is stable and reliable (Bunting, 2006), and that of empiricism, whereby experience is the source of knowledge (Schunk, 2008), which has been developed by observation, construction and communication of ideas (Driver et al., 1994). Lectures support, in particular, the rationalist position and practical work the empiricist position. It is through practical work that there are opportunities to observe theory in practice and potentially contribute to the construction of conceptual knowledge by individuals. Complementary to practical work is the opportunity for communication between lecturers and students, and communication between students, to occur to a greater extent than in lecture delivery of content.

Although one of the common aims of practical work in science according to Watson (2000) and Hodson (1998) is the finding of facts and arriving at new principles, there were a limited number of responses suggesting that practical work involves problem solving, critical thinking or a sense of inquiry. The lack of such could indicate a perception of science as being rational and non-problematic knowledge (Driver et al., 1994). Alternatively, the way in which practical work is delivered to the respondents, for example in recipe style, may be the reason such aims were not identified by participants.

The perception that practical work is simply reinforcing the facts and already established scientific principles is of concern if one expects the purposes of practical work to be those expressed in the literature; practical work is intended to include the development of a sense of inquiry and the use of problem solving as a means of establishing theory and developing further knowledge (Ministry of Education, 2007). This perception held by students may certainly be the impression they have developed as to the purpose of practical work due to the style of delivery in the School of Applied Sciences, and the lack of awareness by students, and perhaps lecturers, as to the principles underpinning practical work as a pedagogical approach to teaching science. This concern will be discussed further in Chapter 6.

The identified themes can be extrapolated to confirm that students do believe that practical work contributes significantly to the process of learning by providing the opportunity to have experiential opportunities, despite there being little overt evidence provided by students to indicate an awareness of how they learn and how they build their knowledge. This lack of evidence could be the result of the study questions not providing the opportunity for such responses or reflection, and this would therefore be a limitation of the study. However, there is research evidence, such as the study of Hirvonen and Viiri (2002), that practical work does help the understanding of the content of (specifically) physics and the process involved in learning physics. Other evidence presented by Taraban et al. (2007) found that students achieved greater learning gains after completing labs which involved active learning. Similarly, research into the role of practical work by Cooper & Kerns (2006) provides evidence of increased achievement, and that of Duschl (2008) evidence of deeper knowledge.

Although the purpose of practical work in the science curriculum as cited by Watson (2000) and Hofstein and Lunetta (2004) makes no specific reference to the improvement of scientific conceptual knowledge as such, it would seem unlikely that practical work would be included as such a significant component in the science curriculum if educators and students were of the opinion that practical work did not help or enhance the gaining and understanding of scientific knowledge, concepts, processes and skills. However, practical work can be taken for granted and the assumption of the aims of practical work being met needs to be examined.

Using the student responses in this study, there is very strong evidence from a student perspective to support the view that practical work is valuable for a range of reasons in addition to the learning of practical skills. Many respondents commented on the learning of practical skills, but many responses indicated other benefits. Student perceptions indicate that practical work certainly helps and supports learning in science, which refutes the concern present in literature that the conventional laboratory format of teaching in science is not accomplishing any useful goal, except perhaps that of training technicians, (Cooper & Kearns, 2006). A significant number of responses confirmed the development of a deeper understanding of science owing to the participation in practical work, for example, "Visualising really helped the concepts learnt which enable to grasp the theories with deeper understanding". Particular

examples from this case study, such as a reference made to chemistry laboratory sessions, or laboratory classes in the Bachelor of Medical Laboratory Science programme, convincingly confirm the value of practical sessions in supporting learning of theoretical knowledge in that subject area.

The scientists and technologists Auckland University of Technology (AUT) is training possess not only the practical skills of the technician, but the underpinning theoretical knowledge. Skills are taught and learnt in conjunction with theory, not in isolation, which is the defining differentiation between the training of technicians as opposed to the development of scientists and technologists; this fits with AUT's vision of itself as an applied university which interrelates theory and practice.

Responses to interview questions also confirm that students perceive their learning across science subjects is "attached" to practical work, the implication here being that the inclusion of practical work is a requirement as it is an integral component of their learning. Comments such as "important across all science subjects owing to the contribution practical work makes to learning"; "practical work reinforces the theory learnt"; and "providing a better understanding" all acknowledge the perception held regarding the valued contribution of practical work to the knowledge gained in science.

Sub-themes such as "reinforces lectures", "backs up theory" "more understanding of theory" "confirmed theory" and "theory/practical support each other" all indicate that students perceive there to be both repeated exposure and an alternative form of representation of the theoretical content through practical work, reinforcing knowledge and concepts that are being learnt in lectures.

Practical sessions do provide repeated exposure and reinforcement of not only skills, but also theoretical concepts during physical events which can be observed by the student. Although the opportunity for repeated exposure may be limited, the pedagogy of practical work as a style of delivery appears to be considered very valuable by students as it reinforces and perhaps clarifies existing knowledge. Repeated exposure occurs within subjects and across subject areas, which contributes to the reinforcement of concepts; there is also the potential to approach a concept or principle from a different perspective which may be more meaningful for some students. One example is

the subject of the gas laws, which is a topic often presented in both Chemistry and Physics, and may also be included in Biology topics. By applying a topic to a range of learning settings a student has more than one opportunity or context to encounter what is being learnt, thus providing the opportunity to reinforce knowledge from several perspectives.

Some participants commented that practical work resolved confusion which arose from lectures. I interpret this as meaning some students did not gain full understanding from the lectures alone. Improved understanding as a result of practical work can be explained in terms of cognitive construction of knowledge, whereby adaptation to experiences brings about modification of both prior knowledge and conceptual understanding. As discussed in Chapter 2, Piaget asserted that knowledge is constructed in and by the learner as they interact with their physical world, constructing or altering existing structures or concepts (Schunk, 2009). In this situation, practical work is the physical world, promoting the construction of conceptual understanding which has not occurred in the lecture situation.

The constructivist theory of learning also asserts that it is the challenging of ideas, and the bringing into question of current understanding that promotes deeper conceptual understanding. In this case study, the “confusion” which has arisen in lectures can be interpreted as the challenging of ideas.

There were several respondents who commented on the fact that on occasion practical work “goes wrong”. If knowledge were being constructed during practical work this type of situation could potentially provide an opportunity for the challenging of existing ideas. But this was a criticism of practical work, which is also evident from anecdotal evidence: some students make comments and demonstrate practices which indicate that their expectation is of certain results, and are willing to ignore results obtained, or change their results to suit anticipated outcomes. I have also observed that there is also a lack of critique of practical work by students when it provides results other than expected; responses provided no indication that unexpected results could bring theory into question. Reasons given were associated with experimental design or malfunctioning equipment only.

This is of concern with respect to one of the aims of practical work according to Swain et al. (1998, cited by Watson 2000), which is to develop a critical attitude. If the delivery of a science course at a tertiary institution is to train technologists and scientists, it is of grave concern that students believe implicitly in scientific theory without question and are expecting the practical to unconditionally confirm this theory. This goes against the purposes of practical work in science as being to develop a critical attitude and a sense of inquiry, and to develop scientists capable of functioning in the scientific process. This again may be due to a misunderstanding or lack of understanding of the role of practical work by students; a lack of communication as the role of practical work by lecturers; or inappropriate delivery of practical work by lecturers/teachers.

These above concerns are summarised by Hofstein and Lunetta (2003) when commenting on factors that inhibit learning in a laboratory setting:

Many of the activities outlined for students in laboratory guides continue to offer 'cook-book' lists of tasks for students to follow ritualistically. They do not engage students in thinking about the larger purposes of their investigation and of the sequence of tasks they need to achieve those ends. (p. 47)

This type of situation, if managed well by the instructor (whether physically present or through an instruction manual), can be utilised to fulfil the aims of practical work: it can either bring about a change of understanding or deeper understanding for students, or provide opportunities for students to critique outcomes, as a practising scientist would. This will be discussed further in Chapter 6, which presents the implications of these findings with respect to teaching practice.

Many participants indicated that their perceived value of practical work in learning science was as an aid to remembering, or committing to memory, scientific knowledge. The theme "Helps and supports understanding /learning" was generated from sub-themes such as "stays in the mind" and "retention". Despite the concern that arises from responses which indicate that students may perceive scientific knowledge as that which is purely committed to memory, the cognitive theory of learning acknowledges the role of the memory in learning (Schunk, 2008) and the responses confirmed that students value practical work as it helps students "remember" things scientific. As Scaife states, cited in Wellington (2000), "Memory is essential: without it there can be no learning" (p. 73). The contribution practical work makes to retention of scientific information is a

consequence of the practical experience providing repeated exposure to, or “backing-up” and reinforcing, what has been learnt in lectures.

Being actively involved in one’s own learning – the principle behind a constructivist model of learning – was often cited as the reason for making theory more memorable. Active learning makes learning more memorable in conjunction with and in addition to the opportunity for repeated exposure to ideas, as discussed earlier in this chapter. The significant role that memory plays in promoting learning was evident in responses such as “you get to see first-hand what you have learnt in the lectures and the information sticks” and “visual and first hand learning to me is a lot easier to remember”. Practical work involves both visual and tactile learning, which aids retention and caters for different learning styles, which will be discussed below. The opportunity to see theory in action was also mentioned as creating a visual memory. Interviewees remembered particular practical sessions, usually with an associated visual image, from very early educational experiences. One could relate the perceived contribution that practical work makes to students’ memory to the observed increased achievement rates cited in studies by Cooper and Kerns (2006) and Burrowes and Nazario (2008).

Interestingly, responses to the closed questionnaire question asking whether participants believed practical work to be more valuable in some subjects than others indicated that practical work was of almost equal value across the subjects Chemistry, Biology and Physics, with slightly more value attached to Chemistry. However, responses to open questions included comments referring specifically to Chemistry. For example, there was reference made to the use of apparatus and chemicals, and the provision of a “visual reference” as making learning in Chemistry “easier”. This would seem to indicate that practical work is more beneficial in some subject areas than others.

5.2.1.1 Generating interest

Anecdotally, students find practical work interesting and practical work promotes their interest and learning in science. I have observed a sense of excitement and enthusiasm when students enter a laboratory to commence practical work. The data collected included responses indicating that practical work was interesting, never boring, and exciting and enjoyable. The majority (53%) of participants in this case study were of the opinion that practical work is always enjoyable and 43.3 % found it enjoyable

sometimes. Abrahams and Millar (2008), Osborne (2003) and Reiss (2000) report that students enjoy practical work, and the *Student Review of the Science Curriculum* (Cerini et al., 2003) found that doing a science experiment in class is the second most enjoyable way to learn science. I included fulfilment, fun and enjoyment in the theme “interest” as I believe these responses would not appear if the experience of practical work were not deemed to be interesting. One participant stated that due to the practical being fun, they learnt more. There were only three students who reported that they “never” found practical work enjoyable; despite not finding it enjoyable, however, one of these respondents saw value in the technical skills acquired, and another in the fact that “by doing it is easier to learn”.

Responses in this study support one of the common aims of practical work in science according to Watson (2000), which is to “arouse and maintain interest”. The response that practical work makes science “amazing/fascinating” and the sympathy one participant expressed for those who do not have the opportunity to experience the amazement of science represent views that practical work does promote interest. Reasons for interest being generated by practical work align with other themes emerging in this study, which include being in a laboratory setting, the opportunity to learn new information, using complex equipment and new technologies, and the application of practical work to real life.

5.2.1.2 Learning styles

Many participants made reference to practical work aiding their learning due to the style of learning that it involves. Themes which related to learning style included involvement of the senses, in particular “seeing things happen”, “hands-on” and “doing”. Responses typical of these themes include “Things are much better learnt when all the senses are involved; seen felt and smelt” and “Visualising really helped the concepts learnt which enable me to grasp the theories with deeper understanding.” This supports comments made by a colleague relating to the inclusion of practical work: one of the most important reasons for including practical work is to cater for different learning styles, such as visual and tactile (Dr. C. Higgins, personal communication, April 18, 2011).

These themes were further supported by some participants identifying their own personal learning style as being either visual or tactile. There were also many references made to “having experience” and some references made to practical work providing stimuli which helped with learning. Hodson (2005) asserts that as an approach to learning practical work is beneficial in that it provides a variety of stimuli.

Not only were there references to learning being enhanced by visual and tactile opportunities, many respondents referred to the opportunity to participate actively in their learning. This is interpreted here as learning occurring through physical involvement in comparison to more passive methodologies, such as the more traditional lecture style of delivery of information. No less than 76.8 % of participants responded “always” to the question “you are actively involved in learning”, with 21.6 % responding “sometimes”. This finding correlates with theory on facilitation of the construction of knowledge, that students be actively involved in their investigation of phenomena (Driver et al., 1994) and learning from actions rather than passive observations (Piaget and Inhelder, 1969, cited in Bell, 1993). Wellington (2000) also cites one aim of practical work to be a method which promotes active learning. All three interviewees held the view that practical work reinforces the theory learnt by providing the opportunity to learn in a different way and thus providing a better understanding.

Comments from participants such as “hands-on” and “by doing” are indicators of active learning taking place, and various reasons were provided why these make practical work valuable from the student perspective. Overlooking the two responses which referred to practical work making learning easier as it does not require “reading of books” (for example, “Hands on work takes relief [*sic*] from time consuming and hardworking [*sic*] reading”), common reasons included that “by doing” information is easier to learn, information is more memorable, and the learning experience is “first-hand”. The reasons given indicate that the inclusion of practical work is an effective way of learning. The large number of responses collected which included reference to the opportunity for active learning strongly supports this. These findings also concur with studies that have evaluated the role of practical work in the teaching and learning of science throughout the compulsory sector of education, such as the findings of the *Student Review of the Science Curriculum* (Cerini et al., 2003), which found that doing

a science experiment in class was considered to be the most useful and effective way of learning.

Several participants made the comment that scientific techniques can only be learnt “hands-on”. Techniques can be “taught” in lectures, but it is often not until a student is required to do practical work that a lack of understanding is revealed. And there are some techniques which would be inappropriate and cumbersome to be taught in lectures. An example which comes to mind is that of connecting multimeters in electrical circuits. The concept of multimeters being connected in parallel and series can often be readily quoted or written correctly by students, but many are unable to correctly demonstrate this in practice by many until there has been repeated opportunity for practice. Without accurate practical skills there would be little or no scope for further investigation or inquiry in science.

The opportunity to have hands-on experience also aligns with experiential learning which underpins the empiricist view of knowledge, whereby experience is the source of knowledge (Schunk, 2008) and generates understanding (Bell, 1993). Responses often made reference to what had already been learnt in lectures, but many indicated that practical experience not only reinforced what has been learnt in lectures, but also provided an opportunity to confirm the knowledge “first-hand”. This theme indicates that this first-hand experience may provide an opportunity for conceptual change to occur, thereby constructing knowledge through experience (Bell, 1993). Students also indicated that there were opportunities to communicate with others which, from an empiricist view, is an effective means of gaining knowledge (Driver et al., 1994).

The opportunity to gain knowledge by observation was evident in many responses. For example, “If I see what is being taught . . . I have a greater understanding of that topic” is representative of a number of responses relating the “seeing” or observation involved in practical work to the gaining of knowledge and understanding of concepts. Whilst providing a learning opportunity which supports visual learners, there is also an important pedagogical reason for the provision of activities which involve observation, which is to encourage accurate observation and description (Watson, 2000).

Students themselves are perhaps unlikely to appreciate the role of observation in the development of their scientific capability, but the findings from this study confirm that they perceive the opportunity to observe as contributing significantly to their learning in science. Similarly, as was discussed in Chapter 2, many phenomena are counter-intuitive (Watson, 2000), for example the phenomenon of the process of breathing in humans. The “seeing” of these phenomena contributes to the construction of conceptual understanding.

The perceptions of participants in this study demonstrate that, in general, students value practical work for the opportunity it provides to cater for different learning styles, including the ability to be actively involved in the learning experience. These findings confirm that students do value practical work as contributing to the process of learning science and they align with findings in the literature in support of the role of practical work for the same reasons.

5.2.2 Real life approach

Another overarching theme which emerged was the application of practical work to real life. Responses made reference to practical work applying to real life, and practical work providing the opportunity to relate the theory learnt to real life situations. One of the commonly held opinions as to the purpose of practical work in science is that it makes phenomena more real (Hodson, 2000), and the New Zealand Ministry of Education (2007) anticipates that by studying science, students will be able to relate their knowledge and skills to their own lives and cultures.

This theme is significant in itself; anecdotally, students comment during practical sessions that having the opportunity to be involved in practical work which relates directly to real life helps them apply the theory they are learning. This theme supports the predominant overarching theme of supporting learning and understanding. By connecting theory to associated real life applications, practical work helps learning by making the content more memorable and comprehensible. All three interviewees also held the view that practical work reinforces the theory learnt by providing the opportunity to apply the theoretical concepts being learnt to the real world.

An associated emergent theme relating to practical work applying to real life is the value placed on the laboratory setting. As students enter a lab, don their lab coat and adhere to rules similar to that of a “real” working laboratory, the experience is more real and therefore more meaningful. They are not “just learning the theory”. This theme correlates with the theme “behaving like a scientist” and both play a role in providing a real life approach to learning science. The response from one student reflects this theme well: “Feeling like a scientist carrying out tests and being able to come to conclusions from your practical work that you’ve carried out”; a similar response was “you are treated as a ‘scientist’, not a student”.

The importance of the role of the physical environment in the learning process has been explained in terms of the process of “enculturation”. The behaviourist and cognitive theories of learning both recognise the importance of the environment in learning and the construction of knowledge (as discussed in Chapter 2). From a behaviourist perspective, observable changes in environmental events enhance and aid learning. With respect to science, these environmental events will therefore be required to take place in an authentic environment, i.e. the laboratory or in the field.

From a constructivist perspective, one means by which concepts develop as a result of altering and modifying conceptual understanding is as a result of exposure to “phenomena”. Complex scientific phenomena which are becoming part of a developing scientist’s conceptual understanding may not be readily encountered in their immediate world, hence to make it real, and therefore applicable to their own lives, the setting is important. Laboratory work and purposeful field trips enable students to encounter phenomena which they otherwise would not come in contact with. In Hipkins et al. (2002), Bell notes that often students’ everyday experiences actually lead to misunderstanding, whereas in a controlled scientific environment, phenomena can be demonstrated, encountered and utilised to induce correct understanding. Consider the aforementioned example of human breathing: the only observable change occurring to the observer is the rise and fall of the chest, with no easily observable coordinated movement of air; a controlled scientific investigation could correct any misunderstandings.

Participant responses to “you behave like a scientist” were: *always* (32.8%), *sometimes* (57.5%), and *never* (5.9%). These responses, along with the importance of the physical environment, indicate that being enculturated into the world of the scientist is important from a student’s perspective. This is endorsed by Hodson (1998) and Duschl (2008) who assert that both construction of scientific knowledge and deeper understanding are promoted by participation in activities similar to professionals who work in that discipline. Practical work also contributes to the development of desirable attributes associated with “being a scientist”, thinking the way a scientist thinks, and becoming enculturated into the world of scientists (Hodson, 1998). One response that represented this theme was “Real life validity, related to my desired career path and interesting working environment e.g. using expensive machinery.”

Students at higher levels of study become more and more engaged in their learning and demonstrate a more serious attitude towards practical work, engaging in it as if it were real. Comments such as: “It gives us the basic skills for working in a lab. It enables us to gain experience and some confidence or important skills required in the science community. It prepares us for our future careers . . .” reflect this appreciation of the role of practical work.

The design of practical work enables students to work in smaller groups, to work more closely both with each other and the instructors, and this is evident in responses such as “As a group activity it improves relationships with other students and enables another opportunity to speak/ ask questions of each other and the lecturer”. Despite the practical work existing in a teaching and learning environment, the observable differences in behaviour, performance and attitudes give the impression that students have become “enculturated” during their course of study into the world of the scientist.

The importance of the role of practical work in providing experiences that make the learning of science more real is evident from the findings in this study, supporting the provision of the costly resources required by the physical laboratory environment and field work.

5.2.3 Skills and career development

The Applied Sciences graduate profile (presented in Chapter 2), includes being competent in skills to take into the workplace. Question 7 of the questionnaire asked whether the inclusion of practical work in courses for the purpose of learning skills contributes to the value of practical work. Responses indicated that 71.7% of participants value practical work in science because practical skills were *always* learnt, while 26.1% replied that they were *sometimes* learnt.

A trend was apparent in the responses: students' perception of the value of practical work was relative to both the level of study and the subject area which the student was studying. The practical work associated with first year courses introduces fundamental skills and demonstrates fundamental scientific phenomena and principles, in addition to providing an environment that supports the learning of scientific knowledge as discussed in Chapter 2. Responses from students in their first year of study or in pre-degree courses related most often to the support practical work provided in their learning of science, as was expected.

As the level of study increases, the complexity of skills, equipment and instrumentation increases, as does the associated complex knowledge which prepares the student for the workplace, as indicated by responses in the previous section. Included in this is the development of attributes enabling the student to function as a scientist, as described in the AUT graduate profile, among which is the ability to problem solve and further knowledge.

Many participant responses referred to the development of practical skills as being of great importance in preparation for a future career. Opportunities are available for students to become familiar with, and competent in, handling instruments and new technologies. Responses also indicated that exposure to the practical aspect of science assists students with career choices, and again, the gaining of practical skills was valued by students as it is implicit in the scientific method and role of the scientist. These findings relate not only to the inclusion of investigations and experiments in science education, which was historically to provide graduates with practical skills (Rudolph, 2005), but also to the wider attributes of the scientist as expressed in the New Zealand Curriculum (Ministry of Education, 2007).

The opportunity to have hands-on experiences and be able to repeat and perfect skills recalls B. F. Skinner's theory of reinforcement (Schunk, 2009). Anecdotal examples commonly observed by lecturers in the School of Applied Sciences involve the correct use of microscopes and pipettes. While this can be covered in didactic teaching sessions, it is repeated practice which enables a student to become competent in such skills. In lower level practical classes where group work is more common across courses due to class sizes, it is evident from assessment results that those who have not participated fully and therefore have not benefited from repeated opportunities have often missed out on not only the skills but also the associated knowledge.

These findings confirm that the learning and acquiring of scientific skills not only equips students with necessary skills to operate scientifically but also supports students in their learning and understanding of theory, preparing themselves for a future career. These findings also reject the concern presented in the literature that the conventional laboratory format of teaching in science is not accomplishing any useful goal, except perhaps that of training technicians (Cooper & Kearns, 2006).

5.2.4 Individual/group work

Study responses, in particular the interview responses, perceived one distinct advantage of practical work as that of providing the opportunity for group work and therefore the opportunity to talk and discuss ideas with other students during practical sessions. Interaction during group work includes the talk and activity associated with social engagement over shared problems or tasks (Driver et al., 1994) and the opportunity for students to articulate their own ideas alongside others (Twomey Fosnot, 2005). Although some practical sessions in our school require students to work independently to master particular skills, they do have access to the lecturer, a laboratory assistant or other students on the same task with whom they can interact and communicate.

The cognitive theory of learning acknowledges the role of the social environment in the learning process (Schunk, 2008), and the empiricist view of knowledge holds that knowledge is developed by communication of ideas (Driver et al., 1994). Both highlight the importance of group work, interaction, and communication in learning. Student responses as to the value of practical work emphasized the importance of such opportunities with respect to the learning that takes place as a result. For example, "In

practical we can learn from each other – sometimes someone knows or understands and they can explain it to their group.”

The theme of group work also aligns with one of the widely held aims of practical work cited by Watson (2000), that of developing the ability to cooperate. The term “team work”, or “group work” as provided in responses, is interpreted here as involving cooperation. Anecdotally, very rarely does a situation arise whereby there is lack of cooperation evident within a group, but there may be those who do not participate fully, and those who are passive observers, who then gain little from the exercise. Those students who do not participate fully subsequently often perform poorly in assessment.

Having said this, one participant expressed a negative opinion of group work in the questionnaire, commenting that “Working in groups sometimes is hard because you want to do your own experiment to make sure it is done properly and some people just rush the lab.” This indicates that group work can pose difficulties. Others were of the opinion that group work impedes their learning as some students are not committed to learning from the practical work. This can be witnessed in some practical sessions, with some students relying on others in the group to complete the tasks and having no involvement themselves except to record the group’s results. This issue will be further discussed in Chapter 6.

If group work is used to facilitate the social construction of knowledge, I believe this needs to be made explicit to students. Lecturers do need to be aware of potential difficulties associated with group work as a teaching method, and manage group work to avoid such negative experiences for students. And if the aim is to develop the ability to cooperate, this must be explicit in the objectives of the practical session. In addition, students studying at higher levels indicated an appreciation of working as part of a team, emulating the role of the scientist who is perceived as functioning as part of a team.

Group work as a method can be utilised in problem solving activities. However, practical work, as offered in Applied Sciences, is not based on problem solving activities, and this issue is also taken up in Chapter 6. There may be potential to

enhance the use of group work at AUT, which is considered by students to be of value in the learning of science.

5.3 Additional findings relating to the case study

Data collected for this study were also analysed for the purpose of elucidating any links between gender, ethnicity and level of study at AUT and students' perceptions of the value of practical work in science.

There appeared to be no significant difference between gender and the rating of the value of practical work. Of the 44 male participants, a slight majority of 55% rated the value of practical work very high, as compared to 43% rating it average, whereas of the 90 female participants, a slight minority of 46%, rated the value as very high as compared to 51% rating it average.

In pre-degree and first year courses of study at university, my observations suggest that more female students than male students are reticent to manipulate equipment. When participating in group work, I have also observed female students deferring to male students within the same group.

Although Burkam, Lee and Smerdon (1997) state that active involvement in the classroom such as in practical work promotes gender equity, it appears that there are different levels of involvement in relation to gender in pre-degree and first year courses. Wolf and Fraser (2007) argue this phenomenon is due to females' attitudes towards science becoming more negative than males' throughout secondary school education. This difference in degree of participation in practical work does appear to change in the later years of study, with differences in participation according to gender being less evident. These negative attitudes and behaviour are perhaps perpetrated in the lower level courses taken at university, but continued involvement in a science programme alters these negative attitudes.

This observation regarding gender may also be explained by social factors. As stated by Rennie (2003), "It [gender] is just one (very complex) variable among the many social categories (including race, religion, ethnicity and class) that contributes to the construction of gender and science" (p. 110).

From personal observations and anecdotal evidence of colleagues, cultural differences appear to have some influence on attitudes towards practical work. Participants identifying themselves as African, New Zealand (including those who identified as Kiwi, Pakeha, New Zealand/European) and Indian (including those who identified as Fijian Indian and Sri Lankan) generally rated the value of practical work as very high. Those identifying as Afghani, Asian (which also included those participants who specifically identified themselves as Chinese, Korean and Taiwanese), Pasifika and Maori generally rated the value of practical work as average.

According to Osborne et al. (2000), cultural attitudes towards the study of science have rarely been investigated, and therefore nor have attitudes toward the value of practical work in science. Woodrow (1996, as cited by Osborne et al., 2000), argues that different cultural groups hold different perspectives on the value of science with respect to both potential careers and the nature of science. This is not clearly evident in the findings of this study, despite the above generalisations; within each culture there is a range of individual ratings. Individual differences could relate to factors other than culture, such as gender or individual learning style.

Although this study did not identify any significant difference in the perceived value of practical work by participants of different cultures, my personal observations indicate that at the entry level courses to university, Pasifika students, in general, appear to lack confidence in working with experimental apparatus (there was, however, one response by a Pasifika student in the data collected to the contrary). Reasons for this could be cultural; alternatively this observation could be due to a variety of other reasons such as a lack of previous opportunities for practical work and experience. This is an area for potential research in the future; the impact previous experiences and opportunities have on student participation in and perceptions of practical work in the learning of science needs to be investigated further.

There is the perception amongst my colleagues and students that there exists an attitude held by some cultures that the correct answer is more important than experimental results from practical work. This is apparent in situations where students will record observations or results which are representative of what is expected according to theory,

not the outcome of the practical investigation. This demonstrates a lack of understanding of both the role of practical work and the scientific method.

These observations and responses are more within lower level classes, especially pre-degree and first year degree classes. Further investigation would be required to establish if this is indeed a cultural attitude, and to determine the impact this has on the intended purpose and the delivery of practical work in science education.

Participants were asked how many years they had been studying at AUT, and the highest level of study they were undertaking. Participants who were in their first year of study were studying at either Level 4 (pre-degree) or Level 5 (first year undergraduate). Those in their second year were generally studying at Level 6 and those in their third or fourth year Level 7.

There was a distinct transition in the perception of participants in terms of the value of practical work across the years and levels of study. The trend indicates that as years and level of study increase, so does the rating of the value of practical work. This observed trend in the rating is as one would expect according to comments provided by students in the higher levels of study, and those who had been studying for a number of years. Comments made by these students acknowledged the opportunities practical work was providing them for preparation and entry into the work force and for augmenting their learning. In addition, students at higher levels of study are often working alongside the lecturer, and in courses which have fewer students. These factors possibly provide the opportunity for an environment to be more focused on specific learning outcomes, including specific practical skills.

Students at lower levels are generally not as focused on specific career goals and are often participating in a course with large numbers. Hence participation in practical work is potentially not as meaningful for this cohort; participants at lower levels indicated the most benefit to be derived from practical work was the support for their learning.

Although each of these additional findings raises areas of further research into the role of practical work in science, gender, ethnicity and level of study of a student do not

appear to substantially impact upon students' perceived value of practical work in Applied Sciences at AUT.

5.4 Summary of findings

This chapter has discussed the findings of this case study in relation to the emergent themes from participant responses to the questionnaire and interview, and to findings from the literature.

In summary, participants in this case study, students of the School of Applied Sciences at AUT, widely perceive practical work to be very valuable due to the contribution it makes to their learning and understanding of science. The findings both align with and diverge from the perceived value of practical work as obtained from the literature.

Student perceptions from these findings and those reported in the literature revealed strong similarities. The intended educational value of practical work, according to the literature, academics and educationalists, identifies reasons which were not identified by students. The disparity between the perceptions of academics and educationalists on the one hand and students on the other should encourage lecturers in Applied Sciences at AUT to reflect on the purpose and delivery of practical work within courses. This will be discussed further in the following chapter.

CHAPTER 6: CONCLUSIONS

- 6.1 Summary of research findings
- 6.2 Strengths and limitations of study
- 6.3 Implications
- 6.4 Recommendations
- 6.5 Further research

6.1 Summary of research findings

The themes which emerged in this study indicate strong support by students for the inclusion of practical work in the teaching and learning of science, which appears to be primarily due to the multiple ways in which practical work supports learning and understanding. Strong support for practical work was also due to the “real life approach” of practical work, the opportunities provided for group work, and the relatedness to skill and career development.

Despite the lack of student responses indicating significant reflection on the less overt aims of practical work, such as the development of higher cognitive skills, logical and reasoning method of thought, or the higher-order thinking skills as expressed by Watson (2000), I would not have expected such reflection unless the students were aware of the cognitive processes involved in learning. The achievement or otherwise of such intended outcomes would need to be evaluated by a practical instructor who is knowledgeable and aware of these aims. Similarly, although students frequently commented on the opportunity to observe phenomena, whether practical work does indeed encourage accurate observation and description could best be evaluated by lecturers through either formative or summative assessment.

A very small number of responses to Question 9 of the questionnaire, which sought reasons for practical work being of value in the learning of science, included the opportunity or expectation to problem solve in practical sessions. The fact that some did identify this reason would suggest that practical work is meeting or has the potential to meet one of the aims of practical work in literature identified by Swain et al. (1998, cited by Watson 2000), that of providing the opportunity to identify and solve problems.

From my personal experience, and from observations of practical work performed in Applied Sciences, “problem solving” as a teaching method is not well utilised, if at all. Students gain knowledge and acquire practical skills which enable problems to be solved, but the problems being solved in most practical classes are those with pre-determined methods, answers or solutions. This is very much the positivist approach.

As is evident in the data, practical classes are providing the knowledge and skills which will prepare students to be able to inquire and problem solve; they are reinforcing and applying theory, actively involving students in their learning and developing observational and technical skills, all of which are essential to future problem solving and inquiry. But there appears to be little opportunity for the “finding of facts and arriving at new principles” (Swain et al. 1998, cited in Watson, 2000) and there appears to be little use of inquiry as a style of teaching and learning science (Hofstein & Lunetta, 2003). This opens up an opportunity for reflection and discussion with colleagues as to whether practical work could be modified within the School of Applied Sciences at Auckland University of Technology (AUT) to incorporate problem solving and inquiry based learning.

In the context of this case study, although training in practical skills (the “skill and career development” theme) is important, students also acknowledged the value of practical work in contributing to their knowledge and understanding of scientific concepts and principles. Responses certainly indicated there was more to the learning of scientific skills than acquiring the skills alone. This refutes the concern that “the conventional laboratory format is not accomplishing any useful goal, except perhaps that of training technicians” (Cooper & Kearns, 2006, p. 1356). In addition, the opportunity for group work was identified not only for the role it plays in learning but also in functioning as part of a team, as may be expected of a scientist.

To summarise, the findings from this investigation provided evidence that students perceive practical work as being highly valuable, irrespective of level of study, subject area, gender and ethnicity. Some findings provide evidence that the inclusion of practical work in courses is supporting the education of the graduate from the School of Applied Sciences to achieve the anticipated characteristics of the graduate profile. The

greatest perceived value was the contribution practical work makes to the learning and understanding of science for the individual.

6.2 Strengths and limitations of study

Firstly, the strengths of this study are as follows:

- The case study method was appropriate to elicit views held by students within the learning environment provided by the School of Applied Sciences at AUT. These views have not been collected previously as a comprehensive set of data for the purpose of evaluating the value of practical work in the delivery of sciences within the school. The data have revealed student perceptions which open the way for reflection on practice and further research within the school.
- The dissemination of the findings of this study will provide the opportunity for my colleagues to gain a broad perception of the value of practical work to students within the environment in which they are teaching.
- Most literature on the topic of practical work in science education in New Zealand (and worldwide) is predominantly either situated in primary or secondary school level or is focused in one area of science education. The findings of this study contribute a view from a different perspective, that of the tertiary student on the pedagogy of practical work across a range of science subjects.
- Students within the School of Applied Sciences who elected to participate in this study had the opportunity to have their voice heard. As the participants were representative of a cross-section of students within Applied Sciences, the inclusion of practical work in courses has been validated as a valuable learning experience for students. The researcher also benefited from gaining students' views of the delivery of the practical component of science courses. The findings indicated the need for improvement in the delivery of practical work if it is to meet expected aims.
- The research tools utilised, questionnaire and interview, provided the opportunity for insightful and in-depth responses to be made, in comparison to the feedback obtained from the annual student survey. The annual survey is used primarily to identify problems, rather than to generate reflection on pedagogical practice. The breadth and depth of the study within the school has provided greater opportunity for reflection by students on the inclusion of practical work.

The chosen research method – a case study involving the collection of qualitative data – was a significant strength of this study. Students' views within the researcher's institution were ascertained, which was the stated purpose of the study.

While the study's findings are of benefit to the researcher and the School of Applied Sciences, the study's limitations also need to be noted. The first is the possible lack of generalisability of the findings. Students in other tertiary institutions may not have the same perceptions of practical work, depending upon their experiences within that institution, and the background or learning orientations of those individual students. Similarly, participants within the school were sought from a cross-section of courses representative of a reasonably typical science programme. Experiences and perceptions could be expected to vary if participants were sought from a wider range of courses.

Another limitation of this study is the relatively small cohort of participants, in particular the low number of participants in the interview, which was designed to obtain more in-depth responses. Despite selecting courses with larger enrolment numbers within the school, it was problematic obtaining participants across a range of courses and a range of levels of study, as was avoiding requesting participants to complete the questionnaire on more than one occasion.

Some responses to the questionnaire revealed a weakness in the questions asked, in that they provoked little reflection on the epistemological or pedagogical underpinning of practical work by students. It was not obvious to me until after the literature review has been completed that this was going to be an issue. The qualitative questions were very open questions, providing no suggestions of anticipated or desired thematic responses. Hence the responses were honest and unaffected.

Questions pertinent to the expected aims of practical work in science education could also have been asked. This approach may have provided valuable insights as to whether any of the broader aims of practical work contributing to AUT's graduate profile are being met.

The researcher has also reported lecturer views throughout this thesis. These views have been based on limited collegial discussions on to the specific topic of the role of

practical work in science courses, and on observation and anecdotal evidence. In retrospect, it would have been beneficial to have surveyed staff simultaneously to obtain their perspectives.

There was also a limitation with respect to the researcher's perspective on practical work in a tertiary education institution; the researcher has limited recent exposure to the delivery of practical work in other New Zealand tertiary institutions. Although a comparative study was not intended or performed, this lack of exposure limits the researcher's perspective on practical work. Similarly, opinions of staff who have had recent experiences in other tertiary institutions were not sought. The sole response providing any comparison was provided by one participant, who was critical of the value of practical work as it is offered in Applied Sciences. This criticism will be discussed in the next section of the chapter.

Whilst these limitations need to be taken into consideration, I am confident that the strengths of this study outweigh its limitations with respect to the benefits these findings bring to the School of Applied Sciences, my colleagues and myself. All will be more informed as to the student perspective and hence able to utilise this perspective in reflection as to the contribution of practical work to teaching and learning in science from pedagogical and resourcing perspectives.

6.3 Implications and recommendations

Considering the findings of this study, there are possible implications for lecturers in AUT's School of Applied Sciences, including myself. These implications lead to recommendations which aim to enhance the contribution practical work makes to student learning, student participation and to the development of students as practising technicians, technologists or scientists.

These recommendations relate to:

- improvement in the perception of practical work by students by conveying to students the wider educational value of practical work
- establishment of common expected aims of practical work for lecturers within the School of Applied Sciences

- improvement in delivery of practical work to meet anticipated aims of lecturers
- measurement of the effectiveness of practical work in meeting the expected aims

Although there were only a minimal number of responses which indicated a level of dissatisfaction with aspects of the delivery of practical work, there are areas of concern which could be addressed to improve student perceptions.

Several responses to questions referred to faulty equipment. Some students, although perceiving practical work to be representative of what happens in “real life”, have expectations that equipment will always be fault-free. Occasionally the comment was made, in particular by students in pre-degree or first year degree courses, that the “experiment didn’t work”. Again, on occasions, the perception of the student was that the experiment failed as the results were not as expected. If lecturers undertook to educate students as to the process, purpose and value of practical work at an early stage in tertiary education, student perceptions of practical work in the cases of faulty equipment and experiments that “don’t work” could be altered to align more closely with the scientific process.

One particularly negative response which had a great impact upon me was criticism of the poor attitude and preparedness of fellow students in practical classes. Comparison was made with their personal experience of university laboratory work in Europe, where students were expected to be more responsible for their own learning in practical classes. The participant elaborated by comparing expectations. In the European university students were expected to arrive well prepared, perform the practical with little assistance from staff, and tidy up after the practical. The implication made was that students in Applied Sciences arrive poorly prepared, that there was little responsibility placed on students to either appreciate or perform all components of the practical, and that they should be responsible when cleaning and tidying equipment at the conclusion of the practical. If one of the aims of practical work is to train students to capably perform in a laboratory setting, one would assume each of these aspects to be a vital component of the training.

As discussed in Chapter 5, the pedagogical benefits of practical work as a teaching and learning method in the broader context of education were not identified or

acknowledged by participants. If the broader educational purposes were made explicit to students, opportunities for learning and development beyond simply the technical skills and the application of or reinforcement of theory could be conducive to greater benefits to be gained from practical work. The findings of this study and the concerns of Shah et al. (2007) are similar. That is, in higher education, the purposes of practical work need to be determined and expressed to students. This recommendation would require staff within the school to develop a common set of aims to provide to students on commencement of their tertiary science education.

The School of Applied Sciences has evolved from being part of a technical institute to part of a university “for a changing world”. This has shifted the profile of the graduate from that of the more skills-reliant role of technician to the more knowledge-reliant roles of technologist and scientist. As the school is preparing students to not only be equipped to enter the workforce upon graduation, but also to be life-long learners and critics of society, it would be appropriate for staff to work together and develop a set of broad educational aims which can be promoted and utilised in the delivery of practical work. These aims should be developed in conjunction with the aims of the school science curriculum in New Zealand, from which the majority of our students emerge, and the common aims of practical work identified in literature.

In conjunction with the recommendation above is the potential for lecturers to adapt and adjust the method and purpose of delivery of practical work within courses to accommodate the wider educative aims of practical work as discussed in Chapter 2. The culture within Applied Sciences focuses on the achievement of specified outcomes of practical work, most commonly taking the format of a pre-designed practical exercise implicitly incorporating some of the broader expectations of practical work such as accurate observation and recording. Less explicit, or even lacking, are the expectations of critical thinking, the ability to problem solve, and the development a sense of ongoing inquiry. To undertake a change in style and purpose of delivery of practical work within the school would require staff to firstly establish and agree on the desired aims of practical work, and secondly to undertake professional development to learn, adapt and incorporate potentially new (to staff) methodologies into practical work. The final recommendation emerging from this study concerns evaluating the effectiveness of practical work. Assessment currently utilised in practical work in

Applied Sciences rarely evaluates abilities beyond content and skills. If the aims of practical work were to be broadened and expressed to students, evaluation of these aims, and the accompanying teaching methodologies, should be performed to confirm whether they are being achieved successfully. My understanding is that lecturers assume that both the broader aims of practical work and the more potentially difficult outcomes to assess, such as the ability to problem solve, to think critically and logically, and to cooperate as part of a team, are “intrinsically” met. In addition to evaluating practical work to measure effectiveness in meeting intended aims, assessment of practical work can also encourage students to perform well and gain improved results (Cooper & Kearns, 2006). As expressed by one participant, assessment of practical work is required to make it valuable.

These recommendations present an opportunity to further investigate the findings from this study with my colleagues within the School of Applied Sciences. I can see benefit in this. We are a school of scientists and science educators, many of whom have not participated in any formal teacher training. Many staff are heavily involved in scientific research and many are involved in the teaching of large numbers of students. There are few opportunities – and indeed no expectation – to critically reflect on the educational value or benefit of the practical content of our courses.

By conducting this case study, I personally have gained an understanding of the student perspective of practical work within the School of Applied Sciences. The literature review has led me to the conclusion that the role of practical work in science education can be aligned with the constructivist view of learning. But the findings indicate to me that whilst students value practical work, there was little evidence of delivery catering for a constructivist approach. The teaching and delivery of science in this particular tertiary institution appears to adhere to the traditional view of science and the traditional methods of delivery; that is, the positivist view of science and didactic and skills based delivery of practical work.

In light of the evidence from the literature as to the role of practical work in science education, the approach to teaching needs to change to better enable students to learn, retain and apply scientific ideas. I am of the opinion that both on the personal and

school levels, opportunity exists to develop and enhance the benefit and value of the inclusion of practical work for broader educational benefits.

Currently practical work is achieving identified purposes such as reinforcing knowledge and mastering skills, but a move away from the positivist view and the didactic approach could create opportunities for students to be more involved in constructing their own knowledge from experiences, and developing cognitive skills which are not necessarily evident in the current setting. As the aims and purposes of practical work have evolved over the last century, as discussed in Chapter 2, delivery similarly needs to be modified to provide opportunities to meet these aims.

6.4 Further research

The findings of this study are encouraging for the School of Applied Sciences, justifying the associated resourcing required to support practical work in science courses, however the narrow range of expected outcomes and aims of practical work, identified and acknowledged by students, does present an opportunity for improvement in the purpose and delivery of practical work.

Prior to changes being made, further research involving staff reflections on their own practice, and views of staff as to the aims and anticipated outcomes of practical work, would be required. References have been made throughout this thesis to anecdotal evidence collected from a limited number of staff within the school. This evidence provides neither a consensus nor a broad picture of lecturer expectations of the use, aims or effectiveness of practical work within courses in tertiary education.

The collecting of opinions of lecturers will provide opportunities, as a school, to question the pedagogical purposes and the epistemology underpinning practical work with respect to the wider aims of practical work identified in literature. Following debate, clear objectives could be developed as to the purpose of practical work within courses delivered by the school. There are currently no such stated objectives within documentation attached to either programmes or individual courses.

Alongside this research, styles of delivery of practical work utilised by lecturers could be investigated for the purpose of determining whether they do meet the perceived aims

of practical work by lecturers, courses and programmes. The findings could identify which styles are more supportive of the constructivist approach, if the School of Applied Sciences is supportive of such an approach, and help meet the wider aims of practical work within the school.

Following further research, the integration of findings, and the making of any changes to the aims and delivery of practical work within the school, it would be advantageous to again seek the perceptions of the students. The purpose of this would be to evaluate whether student perceptions of the value of practical work had undergone a paradigm shift, a shift from the positivist and skill based perception.

As noted in many studies over the last 20 years, there is concern as to the whether practical work is effective in meeting the intended aims (Cooper & Kearns, 2006; Hofstein & Lunetta, 2003; Abrahams & Millar, 2008; Fraser et al., 1992). The findings of this research, if supportive of practical work meeting the intended aims of practical work within the school, could potentially be published to allay these concerns.

A more broad area of research that would be of value is a study of the aims of, and methods of delivery, of practical work in tertiary education in New Zealand. There is much literature on the role of practical work in primary and secondary school education, but little situated in tertiary programmes of science education. The New Zealand science curriculum is a document which responds to research into how students learn science, what constitutes science, and the place of science and technology in a rapidly changing world. Students entering tertiary institutions have had the benefit of this curriculum; it is important to know if tertiary providers of science programmes perpetuate the aims of science education, or if the aims of science education at tertiary level are meeting different needs.

Findings from the suggested areas of further research could be of interest and importance to tertiary providers in New Zealand, as the issue of a lack of awareness of the purpose of practical work in tertiary level education has been identified from this research. Research on current aims and practice in practical work, and responding to changes in expectations, may be of benefit to the wider scientific community in that it contributes to the profile of the resulting graduate.

In summary, the findings of this study verify the value of practical work in the learning of science from the student perspective. This is heartening for lecturers and the management team of a school delivering science papers. But the lack of responses providing affirmation as to meeting the wider aims of practical work in science courses, and no confirmation of any teaching approach other than the didactic one, reveals there is room for improvement in the delivery of these courses within the School of Applied Sciences.

While Costa et al. (1999) argue that “the gap between science education research and the practice of science education remains very wide” (p. 36), the authors nevertheless acknowledge that science education research has been prolific for more than 30 years, and there are many recommended strategies to bring science education research and the practice of science education closer together. This study originated from my desire to do just this. It is anticipated that the findings of this research will promote both collegial debate and professional development to further enhance the pedagogy of practical work in science courses at tertiary level so that there is closer alignment between instructional practices and current views of learning, as well as scientists’ views of science.

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APPENDICES

APPENDIX A

Participant Information Sheet



Date Information Sheet Produced: 23 August 2010

Project Title

Tertiary students' perceived value of practical work as contributing to the learning of science.

An Invitation

I am Wendy Emson, lecturer and Associate Head of School in Applied Sciences, AUT, and am carrying out research which will contribute to my Masters in Education qualification. You are invited to participate in this research and participation is completely voluntary. You may withdraw at any time without any adverse consequences.

What is the purpose of this research?

The purpose of this research is to find out what students value about practical work in science courses in Applied Sciences at AUT. The findings will be published as a thesis towards the Masters in Education and presented to staff in the School.

How was I identified and why am I being invited to participate in this research?

You have been identified as a potential participant as you are enrolled in an Applied Science course which has a practical component. Courses from within the School which have practical work have been selected and they are representative of the different areas and levels in science.

What will happen in this research?

You will be invited to participate in an anonymous questionnaire, to which you will provide written answers to questions which will take approximately 10 minutes.

In addition you will be invited to participate in an interview as well at a pre-arranged time. Only a small number of students will be needed to take part in these interviews and a selection of volunteers will be made so as to ensure data is gathered from a range of courses; both genders; and from a representation of cultures. The interview will be conducted by a research assistant

and will involve verbally answering questions to which your answers will be recorded, and will take no more than 30 minutes.

The findings of this research may be used in publications and presentations in an academic context, but all participants will remain anonymous.

What are the discomforts and risks?

You may think that there may be advantages or disadvantages in taking part in this research, due to my role as Associate Head of School, but I will never know who has submitted a questionnaire or participated in the interview. You will be interacting only with a research assistant who will be collecting and collating the data and who will maintain the anonymity of participants throughout.

As the questions are about your opinions on practical work it is unlikely that you would experience discomfort, embarrassment or risk.

How will these discomforts and risks be alleviated?

It is unlikely that you would find the questionnaire threatening in any way, as it is completely voluntary, anonymous, and the questions are about your perspectives of practical work in science.

Your participation in the one to one interview is again completely voluntary. The interview will be held in private in a room in the School of Applied Sciences which is located away from the researcher's office.

The questions, which are designed to gather more in-depth responses on your perspectives of practical work in science courses, will be non-threatening and you will not be expected to answer any you do not wish to.

The collated data will not be analysed by the researcher until the conclusion of semester and after student final results have been published.

What are the benefits?

The benefits to you are that you will be able to read about how other students feel about practical work, and the benefit to the School is that we can use your opinions to inform decisions made about practical work and teaching and learning in Applied Sciences.

How will my privacy be protected?

1. If you participate in this research you will be returning a numbered anonymous questionnaire in an envelope to a large box which will prevent you being identified in any way.

2. Should you be taking part in the interview, the consent forms for the interviews will be seen only by the research assistant and by the Supervisor of this project. The one to one interview will be held in private in a room in the School of Applied Sciences. The research assistant will assign you a pseudonym to maintain your anonymity to the researcher and give you the opportunity to approve the data you have provided. The research assistant will then provide the researcher with the approved anonymous data only.

What opportunity do I have to consider this invitation?

As the questionnaires will not be collected in for a week you have the opportunity to consider the invitation to complete the questionnaire and you are not obliged to volunteer to be interviewed.

How do I agree to participate in this research?

Your completion of the questionnaire will indicate your consent to participate.

If you wish to participate in the interview, please contact the research assistant after completion of the questionnaire, using the contact details provided by them. You will then be forwarded a consent form to complete and you can return it to the research assistant if you are selected for the interview.

Will I receive feedback on the results of this research?

There will be no feedback on the results of this research to you as a participant unless you are interested to know in which case you can contact the research assistant. The results are for my benefit as part of my Masters qualification, and to inform the lecturing staff in our School by way of a seminar presentation.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified to the Supervisor, Michele Whitten, mwhitten@aut.ac.nz 09 921 9999 ext 7038

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEK, Madeline Banda, madeline.banda@aut.ac.nz , 921 9999 ext 8044.

Whom do I contact for further information about this research?

Research Assistant Contact Details:

Lynda Guildford, lyngui02@aut.ac.nz

Project Supervisor Contact Details:

Michele Whitten, mwhitten@aut.ac.nz 09 921 9999 ext 7038

Approved by the Auckland University of Technology Ethics Committee on 15/09/2010

AUTEK Reference number: 10/162

APPENDIX B



Questionnaire on the value of laboratory based practical sessions

Thank-you for taking the time to complete this questionnaire.

Your completion of the questionnaire implies your consent as a participant.

This questionnaire is anonymous and voluntary, and will take approximately 10 minutes to complete.

The research assistant will attend the class a week later to collect the completed questionnaires.

When completed, please place in the box provided by the research assistant.

Question one

What is your gender?

Female

Male

Question two

What is your culture/ what culture do you identify with?

Question three

How many years have you been studying in Applied Sciences at AUT?

Question four

What is the highest level are you studying at this year? (*Circle the appropriate number*)

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Question five

How do you rate the value of practical work to your study of science generally?

very high

average

very low

Question six

Do you find practical work more valuable in some subjects than others?

No

Yes



If "yes", which subject area(s) is practical work most valuable in?

Why is practical work most valuable in these areas?

Question seven

Practical work in science is valuable because:

you behave like a scientist	always	sometimes	never
you learn scientific skills	always	sometimes	never
it is enjoyable	always	sometimes	never
you are actively involved in learning	always	sometimes	never
it helps you to understand scientific concepts	always	sometimes	never
you work as part of a team	always	sometimes	never

Question eight

In what way(s) does practical help you to **learn** science?

(if you need more space please use the reverse side of the last page)

Question nine

Are there any other reasons/advantages for practical work being a valuable part of studying science subjects?

Question ten

Think of the practical session that has had the greatest impact on your learning in science at AUT.

What made this practical so effective/good?

Thank-you very much for responding to this questionnaire.
If you are interested in the findings on completion of this project, please contact the research assistant.

Research assistant's contact details:
Lynda Guildford: lyngui02@aut.ac.nz

APPENDIX C

Interview questions on the value of laboratory based practical sessions

The interviewee is required to have read and understood the participant information sheet and completed the consent form prior to the interview commencing.

The research assistant will perform all interviews and record written responses to the following questions on the sheet below. The interview will be digitally recorded to avoid omission or incorrect recording of responses. The recording will be identified by the same code as the written transcript.

The interview will be recorded as a code to ensure confidentiality and there will be no identification of the interviewee. Once the recording has been transcribed the interviewee will be invited to approve the transcript. The data will then be made available to the researcher.

Question one

What gender is the participant?

Female

Male

Question two

What is your culture/ what culture do you identify with?

Question three

Prior to coming to AUT what are your recollections of how you' learnt science, and how did practical work contribute to that learning?

Do you think it is automatically assumed by most students that studying a science subject has a practical component?

Question four

What is your understanding of the term 'practical work'?

Question five

How many years have you been studying in Applied Sciences at AUT and which area of science are you studying?

What is the highest level are you studying at this year?

Do you think that the practical work in science is different for students at different levels and if so in what way?

Question six

If I ask “what is the value of laboratory based practical sessions?” what do you understand by the meaning of the word ‘value’?

Question seven

How do you rate the value of practical work in your study of science generally and on what do you base your rating?

Question eight

Do you find practical work more valuable in some subjects than others?

In which areas is it more valuable and what makes it more valuable in one area than another?

Question nine

What are some of the reasons you think practical work is incorporated into the teaching of science?

Question ten

In what ways do you think practical work helps someone to **learn** science?

Question eleven

What features of the design or purpose of a practical session make it most valuable to you? Can you give some examples?

Question twelve

Do you think that the way in which practical work is assessed alters the perceived value?

Question thirteen

Would you imagine your learning in science would be affected if there were no practical work and in what way?

Thank-you very much for participating in this interview. I will contact you when the interview has been transcribed for you to approve and if you are interested in the findings on completion of this project, please contact me.

Research assistant’s contact details: lyngui02@aut.ac.nz

APPENDIX D

Consent Form



Project title: The perceived value of laboratory based practical sessions by students as contributing to the learning of science.

Project Supervisor: **Michele Whitten**

Researcher: Wendy Emson

- I have read and understood the information provided about this research project in the Information Sheet dated 13 June 2010.
- I have had an opportunity to ask questions and to have them answered.
- I understand that notes will be taken during the interview and that it will also be audio-taped and transcribed, and this will be performed by an independent third person, the research assistant, to ensure privacy and confidentiality.
- I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- If I withdraw, I understand that all relevant information including tapes and transcripts, or parts thereof, will be destroyed.
- I agree to take part in this research.
- I understand that I might be invited back to clarify any aspects arising from interpretation of responses from the interview.
- I wish to receive a copy of the report from the research (please tick one): Yes No

Participant’s signature:.....

Participant’s name:.....

Participant’s Contact Details (if appropriate):
.....
.....

Research assistant’s details
.....
.....

Date:

Approved by the Auckland University of Technology Ethics Committee on

AUTEC Reference number

Note: The Participant should retain a copy of this form.

Note: The Participant should retain a copy of this form.