THE INFLUENCE OF FIRST-YEAR CHEMISTRY STUDENTS' LEARNING EXPERIENCES ON THEIR EDUCATIONAL CHOICES

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It was not a matter of how well one could think ... but of how well one could handle a pipette and perform [a] *titration in the laboratory.*

John Nash (Nobel Laureate in Economics)

PUBLICATIONS ARISING FROM THIS THESIS

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ABSTRACT

The research presented in this thesis examined the influence students' learning experiences in their first year chemistry classes had on their enrolment choices. Students enrolled in first-year chemistry were surveyed three times throughout their academic year using a purpose designed questionnaire – at the start of the year (n=126), the end of the first semester (n=109) and the end of the second semester (n=84). Additionally, a cohort of 19 students were interviewed at the same stages throughout the year. The research involved investigating students' learning experiences, attitude-towards-chemistry and chemistry self-efficacy. Additionally, students attitude-towards-enrolling in chemistry, perceived control over enrolling in chemistry and normative beliefs (perception of associates' beliefs) about enrolling in chemistry were examined. Finally, all of these aspects were related to students' enrolment intentions

The structure of the research was guided by the *Modified Theory of Planned Behaviour* (MTPB), which relates behaviour directly to intention to carry out the behaviour (Ajzen, 1989). The MTPB suggests that students' enrolment in second-year chemistry is directly related to their intention to enrol in second-year chemistry. Furthermore, the MTPB suggests that students' enrolment intentions are influenced by their attitude-towards-enrolling in second year chemistry, their perceived control over enrolling in second-year chemistry and subjective norm about enrolling in second-year chemistry. The MTPB also suggests that attitude-towards-enrolling in second-year chemistry is influenced by students' attitude-towards-chemistry, chemistry self-efficacy and first-year chemistry learning experiences.

The MTPB was used to inform the methodology of the inquiry. The research involved following students throughout their first-year of chemistry study. Students were interviewed at key stages using a semi-structured interview protocol developed to include questions on all key areas of the MTPB.

Furthermore, students were surveyed at three stages using the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ).

The CAEQ was developed to examine chemistry learning experiences, attitude-towards-chemistry and chemistry self-efficacy - using the MTPB as a guiding framework. The instrument was designed in a manner that maximised construct validity and piloted with a cohort of science and technology students (n=129) at the end of their first-year. Based on statistical analysis the instrument was modified and subsequently administered on two occasions at two tertiary institutions (n = 669). Statistical data along with additional data gathered from interviews suggests that the CAEQ possess good construct validity and will prove a useful tool for tertiary level educators who wish to gain an understanding of factors that influence student choice of chemistry enrolment.

The findings from this research suggest that learning experiences have some impact on students' enrolment intentions. Students who drop out of chemistry at some stage of their first-year cited experiences in their classes as a reason for this. There is also a cohort of students' who drop out of university entirely during their first semester of study. Chemistry self-efficacy also impacted upon students' enrolment choices with students who had perceived they had achieved in their first-year of chemistry study likely to intend to continue to on and study chemistry at second-year level.

Other factors that influenced students' enrolment intentions included a desire to have a broad spectrum of courses in their degree, and an interest in the subject from secondary schooling. A number of students enrolled in first-year chemistry as a compulsory part of another degree programme, consequently their decisions to study second-year chemistry were dependent on whether a course was compulsory or not.

Students perceived their associates to have a wide range of beliefs about chemistry including stereotypical images such as mad scientists and laboratory-based images. Additionally, students thought their peers would think chemists did not consider society when designing research, whereas their parents and mentors – typically employed in a science related field – would hold more positive conceptions.

It appears that reduced number of enrolments at the second–year level are contributed to by students' dropping chemistry at some stage throughout their first-year. Additionally there were no corresponding cohort of students that choose to pick-up a chemistry course courses. The salient beliefs that directly influenced students' enrolment intentions were negative learning experiences in laboratory classes and students' chemistry self-efficacy beliefs. Additionally, students who enrolled in first-year chemistry as a compulsory paper often made their decision about enrolling in second-year chemistry based whether they had any compulsory second-year chemistry courses. Normative beliefs appeared to have little direct impact on students' enrolment intentions, however, they had some indirect effect with students who had associates in a science related field more likely to enrol in second-year chemistry than those that did not.

The findings from this research suggest that academic staff need to modify their teaching practice, especially in laboratory classes. Students need to be taught study skills and skills for coping at university in order to reduce the drop-out rate from university entirely. Additionally the relationship between self-efficacy and enrolment intentions suggests that tasks designed to improve students' self-efficacy should be incorporated into the curriculum. Another potential method of improving student retention is to introduce a mentoring scheme so that students have positive social reinforcement encouraging them to study chemistry.

GLOSSARY

Associates	Referents in behaviour e.g. Peers, parents, mentors.
Attitude	A mental and neutral state of readiness, organised through experience, exerting a directive and dynamic influence upon the individuals' response to all objects and situations with which it is related.
Attitude-towards-chemistry	A mental and neutral state of readiness about chemistry, organised through experience.
Attitude-towards-chemistry in society	A mental and neutral state of readiness about chemistry and its role in society, organised through experience.
Attitude-towards-chemists	A mental and neutral state of readiness about chemists, organised through experience.
Attitude-towards-enrolling in second-year chemistry	A mental and neutral state of readiness, organised through experience, exerting a directive and dynamic influence upon the individuals' intentions to enrol in second-year chemistry.
Career interest in chemistry	A mental and neutral state of readiness about carrying out chemistry activities as part of a career, organised through experience.
Chemistry	The learned patterns for thinking, feeling and acting that are transmitted via the acquisition of chemistry theory, skills and values.
Chemistry self-efficacy	People's judgements of their capabilities to organise and execute studying chemistry at university.
Control belief	Antecedent belief of perceived behavioural control.
Learning experiences	Any experience in a tertiary chemistry environment that results in a belief formation about chemistry - where that belief is attitudinal, knowledge, or skill based.
Lecture learning experience	Any experience in a lecture class that results in a belief formation about chemistry - where that belief is attitudinal, knowledge, or skill based.
Leisure interest in chemistry	A mental and neutral state of readiness about carrying out chemistry activities in leisure time organised through experience.
Normative belief	Antecedent belief of subjective norm.
Perceived control over enrolling in second-year chemistry	The perceived ease or difficulty of performing enrolling in second-year chemistry.
Practical learning experience	Any experience in a laboratory class that results in a belief formation about chemistry - where that belief is attitudinal, knowledge, or skill based.

Required skills of chemists	A mental and neutral state of readiness about the skills required of chemists, organised through experience.
Self-efficacy	People's judgements of their capabilities to organise and execute courses of action required to attain designated types of performance.
Subjective norm	An individual's perception of their associates' attitude-towards-them studying chemistry at second-year level.
Tutorial learning experience	Any experience in a tutorial class that results in a belief formation about chemistry - where that belief is attitudinal, knowledge, or skill based.

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CHAPTER 1
INTRODUCTION

This chapter provides an introduction to the thesis. The research reported in this thesis concerns an inquiry into the influence of first-year chemistry students' learning experiences on their educational choices. This chapter argues the need for this research within in the context of the inquiry. It begins with the background to the inquiry and a discussion of the nature of the research process. This is followed by the purpose of the inquiry and the definitions of the terms used throughout the thesis. The chapter concludes with a detailed description of the context of the research, and an outline of the organisation of the thesis.

1.1 Background to the Inquiry

In the six years preceding this inquiry the chemistry department involved in this study has observed a steady decrease in the number of students choosing to enrol as chemistry majors. The number of chemistry majors in their second year of undergraduate study has reduced from 68 in 1995 to 37 in 2000, the lowest since 1987.[1] As a significant component of tertiary education funding is directly related to enrolment, low enrolments impact significantly on departmental finances, particularly at the advanced levels. Despite experiencing a decrease in the number of students declaring themselves as chemistry majors in their second year of undergraduate study, first-year enrolments have remained relatively stable. Anecdotal evidence from staff and graduate students who teach in first-year laboratories, suggests that first-year learning experiences in chemistry courses are off-putting. In particular, it has been suggested that the first-year chemistry students find it difficult, abstract, and of little interest or relevance. Research has revealed that this belief is widespread and is found among students from a variety of backgrounds and age levels (Coll, 1999; Johnstone, 2000; Laws, 1996). The work reported in this thesis thus sought to

[1] Based on enrolment figures for second-year physical chemistry, a compulsory course for chemistry majors.

understand in detail what influence, if any, first-year tertiary chemistry learning experiences exerts on students' enrolment choices.

1.2 Purpose of the Inquiry

The purpose of this inquiry was to investigate enrolment choices of first-year chemistry students, and the influence first-year learning experiences on enrolment choices. This broad aim was refined to the following specific research questions:

1. **What are student first-year chemistry learning experiences, attitude-towards-chemistry and chemistry self-efficacy, how does student background influence these and what influence, if any does student first-year chemistry learning experiences have on attitude-towards-chemistry and chemistry self-efficacy?**
    - i. What are student first-year chemistry learning experiences?
    - ii. What influence, if any, does student gender, ethnicity, socio-economic background and enrolment reasons have on their learning experiences?
    - iii. What is student attitude-towards-chemistry?
    - iv. What influence, if any, does student gender, ethnicity, socio-economic background and enrolment reason have on attitude-towards-chemistry?
    - v. What is student chemistry self-efficacy?
    - vi. What influence, if any, does student gender, ethnicity, socio-economic background and enrolment reason have on chemistry self-efficacy?
    - vii. What influence, if any, does student attitude-towards-chemistry have on learning experiences?
    - viii. What influence, if any does student chemistry self-efficacy have on learning experiences?

2. **What are student attitude-towards-enrolling in chemistry and what influence, if any, does student first-year learning experiences, attitude-towards-chemistry and chemistry self-efficacy have on student attitude-towards-enrolling in second-year chemistry?**
   - i. What is student attitude-toward-enrolling in second-year chemistry?
   - ii. What influence, if any, does student first-year learning experiences have on attitude-towards-enrolling in second-year chemistry?
   - iii. What influence, if any, does student attitude-towards-chemistry have on attitude-towards-enrolling in second-year chemistry?
   - iv. What influence, if any, does student chemistry self-efficacy have on attitude-towards-enrolling in second-year chemistry?

3. **Do students hold control beliefs about enrolling in second-year chemistry, if so what are they, and what influence, if any, do student first-year learning experiences, attitude-toward-chemistry and chemistry self-efficacy have on student perceived control over enrolling in second-year chemistry?**
   - i. Do students hold control beliefs about enrolling in second-year chemistry?
   - ii. If students hold control beliefs about enrolling in second-year chemistry, what is student perceived control over enrolling in second-year chemistry?
   - iii. What influence, if any, does student first-year learning experiences have on perceived control over enrolling in second-year chemistry?
   - v. What influence, if any, does student attitude-towards-chemistry have on perceived control over enrolling in second-year chemistry?
   - iv. What influence, if any, does student chemistry self-efficacy have on perceived control over enrolling in second-year chemistry?

4. **What are student perceptions of associates attitude-towards-chemistry and normative beliefs and what influence, if any, does student**

perception of associates attitudes-towards-chemistry have on subjective norm?

i. What are student perceptions of associates attitude-towards-chemistry?

ii. What is student subjective norm?

iii. What influence, if any, does student perception of associates attitude-towards-chemistry have on subjective norm?

5. **What influence, if any, does student attitude-towards-enrolling in second-year chemistry, perceived control over enrolling in second-year chemistry, and subjective norm, have on intentions to enrol in second-year chemistry?**

i. What are student intentions to enrol in second-year chemistry?

ii. What influence, if any, does student attitude-towards-enrolling in second-year chemistry have on intentions to enrol in second-year chemistry?

iii. What influence, if any, does student perceived control over enrolling in second-year chemistry have on intentions to enrol in second-year chemistry?

iv. What influence, if any, does student subjective norm, have on intentions to enrol in second-year chemistry?

1.3 Nature of the Inquiry

This inquiry investigated students' second-year chemistry education choices and the impact of first-year chemistry learning experiences had on these choices. This was investigated via an inquiry in which a cohort of first-year chemistry students were followed throughout their first-year, from the start of their first-year chemistry classes to the end of the year when they made their decisions whether to enrol in second-year chemistry courses. The inquiry used a multiple-methods approach, employing both survey and interview techniques. A survey instrument, the *Chemistry Attitude and Experiences Questionnaire* (CAEQ), was developed during the inquiry, and used to quantify changes in student-attitude-towards-chemistry, student self-efficacy and student first-year chemistry learning experiences. The CAEQ was administered to the entire first-year chemistry class at the beginning of the year, the end of the first semester course, and the end of the second semester course. The quantitative data gathered from these surveys were triangulated with qualitative data gathered from interviews of a cohort of students at different stages throughout the year.

1.4 Definition of Terms

A number of terms have been used throughout the thesis and are defined here. First, attitude is defined using Allports (1935) definition: "a mental and neutral state of readiness, organised through experience, exerting a directive and dynamic influence upon the individuals' response to all objects and situations with which it is related" (as cited in Horowitz & Bordens, 1995, p. 228). Second, self-efficacy is defined using Banduras (1986) definition: "people's judgements of their capabilities to organize and execute courses of action required to attain designated types of performance (p. 391). Chemistry was defined as "the learned patterns for thinking, feeling and acting that are transmitted via the acquisition of chemistry theory, skills and values." Learning experiences were defined as "any experience in a tertiary chemistry environment that resulted in a belief formation about chemistry as defined above (where that belief is attitudinal, knowledge, or skill based). Further details about the definition of all these terms are presented in Chapter 3 (Section 3.3, p. 47).

1.5 Significance of the Inquiry

There are three major stakeholders for whom this inquiry is of significance: tertiary chemistry educators, first-year tertiary chemistry students, and science education researchers. The findings of this inquiry may help tertiary chemistry educators to identify factors that influence attrition in enrolments from the first to second year. The findings also may provide data that may be used to help improve first-year chemistry learning experiences. Finally, the inquiry has provided science education researchers with a survey instrument, the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ), that may be used to research first-year tertiary chemistry students' attitude-towards-chemistry, chemistry self-efficacy, and learning experiences, in other contexts.

1.6 Context of the Inquiry

The inquiry was carried out within the New Zealand tertiary education system; consequently, it is appropriate to briefly outline some of the changes that the tertiary education sector in New Zealand has experienced in recent years.

1.6.1 New Zealand Tertiary Education System

The New Zealand tertiary education system is diverse in nature, containing institutions both publicly and privately owned (Ministry of Education [MoE], 2000). However, the majority of students enrolled in tertiary education in New Zealand attend one of the 38 Government-funded public *Tertiary Education Institutions* (TEIs). Of these, nine have been attributed the status of university, with the remainder classified as polytechnics or institutes of technology. Historically, only universities were able to confer undergraduate and postgraduate degrees, with polytechnics and institutes of technology restricted to the awarding of diplomas and certificates. However, the introduction of the Education Act (1989), enabled polytechnics and institutes of technology to confer degrees (MoE, 2000). The Education Act (1989) also changed the manner in which TEIs were funded, shifting to a system based almost solely on the number of enrolled *Equivalent Full Time Students* (EFTS). The New Zealand tertiary education system has consequently become highly competitive in nature. As each institution's funding is based on enrolments, the TEIs have diversified their course offerings in order to increase their 'market share' of enrolments. This has resulted in replication of courses particularly between universities, with, for example, in the upper North Island (with a catchment population of ca. one and a half million) four different universities offering first-year chemistry courses.

The EFTS-based funding model also has influenced the administration of TEIs with the finances for each school of study, and to some extent their component departments, influenced by enrolments. Hence, departments with falling enrolments are confronted with the possibility of budget cuts which could ultimately result in staff redundancies or a reduction in research facilities. Science departments are particularly vulnerable, as they require higher levels of expenditure in terms of capital equipment and running costs compared with other departments. There is some recognition of this fact in the provision of differential EFTS-based funding for the sciences and engineering, but at the time of writing the additional funding for science was not adequate to cover the resources needed to fund science.

1.6.2 Student Funding for Tertiary Study

For students, enrolment choices between institutions are influenced by a variety of factors including economic factors (Joseph & Joseph, 1998). In the past 10 years the New Zealand Government reduced its subsidy of tuition costs by over 20% (MoE, 2001). Consequently, TEIs have increased tuition fees substantially, with, for example, in 2001, the tuition fees for a first-year science student at the university involved in this inquiry approximately $NZ3800 compared with around $NZ250 in 1992. At the same time Government funding for student allowances has been cut by similar amounts. The net result has been a significant increase in the cost of tertiary education for students. The Government introduced a student loan scheme that allowed students to borrow money for tuition, course related costs, and in some cases, living expenses. This resulted in student debt at the end of 2001 in the region of $NZ4.1 billion (MoE, 2001). A new loan structure was introduced in 1998 to address the issue of spiralling student debt. However, a recent review of the tertiary education system suggests that many of these initiatives will be discontinued and student debt will likely continue to rise (Tertiary Education Advisory Commission [TEAC], 2000, 2001a,b,c).

1.6.3 The Institution Involved in the Inquiry

The institution involved in this inquiry is located in an urban community in a wealthy dairy farming area. It has approximately 12,000 EFTS, enrolled in undergraduate and postgraduate degrees across five schools and one faculty (Arts & Social Sciences) . The School of Science and Technology, with around 1000 EFTS, is one of the smaller in the University. The School offers Bachelor of Science (BSc) degrees in all the major science disciplines (chemistry, physics, biology and the Earth sciences), technology (currently being phased out), computing and mathematical sciences, and, for the first time in 2001, some engineering. The School has a strong focus on applied science, with parallel Bachelor of Science and Technology (BSc(Tech)) degrees in science and technology, technology, and Bachelor of Technology (BTech) and Bachelor of Engineering (BE) degrees in engineering, all of which have a work-based learning component. The School structure consists of five departments each offering degree majors in their discipline as well as a number of specified programmes such as animal behaviour and marine science.

The chemistry department offers courses for chemistry majors based along classical divisions of the subject (i.e., organic, inorganic, analytical, and physical), as well as other applied or general interest courses such as spectroscopy, environmental chemistry, and forensic and toxicological chemistry. Three first-year chemistry papers are offered, two are required for the major, the other being a chemical hazards course designed for students with an interest in industrial chemistry. The two compulsory courses form the focus for this inquiry.

1.7 Organisation of the Thesis

This thesis contains nine chapters, beginning with Chapter 1, the introduction. A review of relevant studies in the science education literature is presented in Chapter 2 and focuses on research in the areas of attitude-towards-science, science self-efficacy, learning experiences and the influence of learning experiences on enrolment choices. Other topics reviewed from the literature include studies into other potential influences on enrolment choices; namely, normative and control beliefs. The theoretical framework, including the fundamental assumptions of the inquiry, is presented in Chapter 3. This is followed by Chapter 4, which contains a description of the methodology, with a particular focus on the issue of the trustworthiness of the inquiry. Chapter 5 is concerned with the development of the CAEQ survey instrument, drawing on the theoretical framework provided in Chapter 3, and the methodology in Chapter 4. Chapter 6 presents the findings from the research in this inquiry about the influence of learning experiences on student attitude-towards-chemistry and chemistry self-efficacy. Chapter 7 continues with the research findings and presents the findings pertaining to the influence of learning experiences, attitude-towards-chemistry and chemistry self-efficacy on the students' attitude-towards-enrolling in second-year chemistry. Students' control beliefs about enrolling in second-year chemistry and the influence of their associates' perceptions about enrolling in second-year chemistry also are presented in Chapter 7. Chapter 8 presents the research findings on the salient influences of students' learning experiences on their attitude-towards-enrolling in second-year chemistry and the importance they place on control and normative beliefs. In Chapter 9 the findings from Chapters 6-8 are discussed in terms of the relevant literature and the conclusions and implications of the inquiry are detailed.

1.8 Chapter Review

The background to this inquiry at the departmental level suggests a need for research into students' chemistry enrolment choices. That is, the chemistry department involved in the inquiry has a particular problem in the decreasing number of student enrolments. This inquiry seeks to understand the reason for this trend, with particular emphasis on the factors that the department may have some influence upon, namely, student learning experiences, attitude-towards-chemistry and chemistry self-efficacy. It is important to note that the educational context that the department and students operate within influences this problem, with the department required to keep enrolment levels high in order to be financially sustainable. There are a lot of options for tertiary students within New Zealand, with institutes of technology now offering degrees, and a large variety of courses available to students within a university. What is clear from this introduction is the need for research into chemistry students' enrolment choices at this institution.

1.9 Chapter Summary

This chapter has provided an argument why this research needs to be carried out at this institution, and the potential usefulness to other key stakeholders. It began with a discussion on the background of the thesis, followed by details of the purpose and nature of the inquiry. Some of the terms used in the thesis were defined, and the significance of the inquiry outlined. The wider context of the inquiry was then presented, followed by a discussion on the organisation of the thesis. The next chapter, Chapter 2, discusses the literature relevant to the inquiry, and argues the importance of this inquiry on an international level.

CHAPTER 2
LITERATURE REVIEW

The previous chapter provided an overview on the importance of the research questions within the context of the department involved in the study. Building on from this, this chapter provides a review of relevant literature for the thesis arguing the importance of this research in an international context. This argument will be structured with a focus on the research questions presented in Chapter 1 (p. 2). It is worthwhile to note at this point that much of the literature investigated is focussed on science education, rather than specifically chemistry education. The chapter begins with a discussion of research into the influence of learning experiences on attitude-towards-science and science self-efficacy. Included in this is a review of research into tertiary learning experiences, student attitude-towards-science and science self-efficacy. This is followed by a description of studies of attitude-towards-enrolling in science courses, and the influence of attitude-towards-science and science self-efficacy on students' attitude-towards-enrolling in science courses. A discussion on students' perceived control over enrolling in science courses is presented next, followed by a review of literature on associates' attitude-towards-science, normative beliefs about taking science (beliefs students hold about their associates' perceptions about them studying science), and the influence of associates attitude-towards-science on normative beliefs. Next is a description of the influence of learning experiences on attitude-towards-enrolling in science, perceived control over enrolling in science and subjective norm. The chapter concludes with a review of the literature on the influence of attitude-towards-enrolling in science, perceived control over enrolling in science and subjective norm, on students' enrolment choices.

2.1 Student Learning Experiences and their Influence on Attitude-Towards-Science and Science Self-Efficacy

2.1.1 Learning Experiences

The content, structure and teaching style for first-year or introductory tertiary chemistry courses are similar across the world (Fensham 1992; Zoller, 1990). In introductory courses students are typically introduced to the fundamentals of chemistry including basic organic and physical chemistry, atomic theory, and solution chemistry such as the mole concept, equilibria, solubility, acid-base and so forth. The usual means of delivery of these concepts are lectures, laboratory classes, and tutorials, although the emphasis placed of these modes of delivery varies from institution to institution.

For large classes, which are common at the first-year level, particularly for course containing an element of 'service teaching', lectures are the principal source of delivery of coursework. They are typically about one hour duration, and provide little opportunity for students to ask questions (Fensham 1992). Common teaching methods include the provision of extensive written material presented on black- or whiteboards, overhead projectors, along with extensive verbal instruction. These methods mean students must concentrate on copying written material (even if written notes are provided, this is usually after the lecture, or at the end of the lecture course) rather than 'processing' or attempting to understand content (Laws, 1996). *Non-English Speaking Background* (NESB) students in particular find such a teaching style problematic and as a consequence rely heavily on prescribed textbooks (Mulligan & Kirkpatrick, 2000).

At the secondary and tertiary levels, science students' perceptions of their lessons are linked to their perceptions of teaching staff (e.g. Aldridge, Fraser, Murray et al., 2002). Research suggests that students who are positive about their teaching are usually positive about their classes (Ebenezer & Zoller, 1993; Waldrip & Fisher, 2001; Young, Fraser & Woolnough, 1997). However, research suggests that students' and instructors' views about what makes a 'good' science teacher are different (Robertson & Bond, 2001, Yäger & Penick, 1986). For example, instructors at the tertiary level value research ability, and see competence in research as an important factor in the ability to teach science effectively (Robertson & Bond, 2001). Surprisingly, there is little research on students' perceptions of a good lecturer at tertiary level, although there is a plethora of research on lecturer effectiveness (see, e.g., Donald, 1993). At, secondary school, however, students rate content knowledge of their teachers highly in aspects of good teaching (Wareing, 1990) - content knowledge relates to research competence for tertiary level educators. However, research into students at postgraduate level suggests that students do not rate research competence when choosing a PhD supervisor as they presume academics are expert in their fields (Neale, 2000).

The literature suggests that even at the primary or elementary school level students prefer methods other than the traditional 'chalk and talk' approach for the teaching of science. For example, students prefer the 'social' aspects of science such as discussion of content, 'creative' science, and an entertainment component within the context of the lecture topic (George & Kaplan, 1988; Piburn, 1993; Sullins, Hernandez, Fuller & Tashiro, 1995). A number of reasons for have been posited to explain why student preferences in teaching style have not be taken on board; for example, teachers and academics are constrained by course prescriptions, government prescribed curricula, or departmental policy and, especially in developing countries, financial constraints (Giddlings, 1993; Sullins, Hernandez, Fuller & Tashiro, 1995; Swain, Monk & Johnson, 1999).

Laboratory classes are more popular with students because such lessons involve students in more exciting physical activities such as making observations and using new apparatus or scientific equipment (Bennett, Rollnick, Green & White, 2001; Piburn, 1993). However, while laboratory classes may be more enjoyable for students, they are not necessarily more effective sources of learning. For instance, teaching experiments are often designed with unrealistic or highly predictable outcomes, that neither challenge students nor engage students cognitively (Meester & Maskill, 1995). Furthermore, students are introduced to many new practical techniques without sufficient time in the laboratory to effectively master these new skills (Meester & Maskill, 1995). This is particularly true in large first-year tertiary laboratory classes which may rely on bench demonstrations and typically have a higher student to staff ratio (Fensham, 1992). Students' perceptions of their laboratory classes are related to their perceptions of the teachers and graduate assistants. Students value the opportunity to ask questions of teaching staff (Bennett, Rollnick, Green & White, 2001), but tend to have negative perceptions of their laboratory classes if they find staff unapproachable or perceive them as lacking in confidence due to, for example, lack of experience (Fensham, 1992; Van Keulen et al., 1995). Students also find it difficult to link ideas presented in lecture and laboratory environments (Laws, 1996; Van Keulen et al., 1995).

There is much less research on students' perceptions of their tutorial classes. What research there is, suggests that the smaller class sizes provide an opportunity for tutors to answer questions (Laws, 1996; White et al., 1995). Mature and NESB students in particular value tutorials due to the small class sizes and what they perceive to be generally more enthusiastic and approachable tutors (Bennett, Rollnick, Green & White, 2001; Mulligan & Kirkpatrick, 2000).

For first-year students beginning their tertiary studies, all three learning environments (i.e., lectures, tutorials and laboratory classes) are somewhat alien as they represent significantly different experiences to those encountered at secondary school. At the secondary level, the focus is commonly on content knowledge for end-of-year external examinations (White et al., 1995). Beginning tertiary education is a particularly difficult experience for mature students who have typically been absent from formal education for long periods of time (Fensham, 1992). Likewise, NESB students find beginning tertiary studies difficult, since they also have to cope with learning new content in a second language (Mulligan & Kirkpatrick, 2000). Consequently, there is often a high attrition rate at the first-year level, particularly in the sciences (Wilson, Ackerman & Malave, 2000). However, the recent introduction of academic orientation or bridging programmes at the tertiary wide level has been effective in reducing the attrition rate, by, for example, offering university orientation courses that include an introduction to the physical environment and academic study, as well as, changing enrolment information structures to ensure students are better informed about the courses they are enrolling in (Pitkethly & Prosser, 2000).

It appears from the literature that students' general perceptions of first-year science, and in particular, their chemistry classes, are not particularly positive. In addition, there is a large body of literature on alternative conceptions of first-year chemistry students, in most content areas (Boo, 1998; Hesse & Anderson, 1992), but particularly in the topic of equilibria (Huddle & Pillay, 1996; Quílez-Pardo & Solaz-Portolés, 1995), that suggests current teaching practices are not as effective as might be hoped (Bonner & Holiday, 2001). This has resulted in recent debate on the appropriateness on the traditional first-year chemistry course content and teaching style (see, e.g., Kettle, 2001). Principal stakeholders in science education including academics (Shumba & Glass, 1994; Razali & Yäger, 1994), prospective employers (Reid, 2000) and science funding bodies (Kyle, 1997) have suggested that traditional chemistry courses over-emphasise content at the expense of higher cognitive skills such as problem-solving, communication, and the nature of the research process (Coles, 1998). There is also debate in the literature regarding the importance of teaching chemistry concepts as opposed to teaching the use of problem-solving algorithms and related techniques (Chang & Bell, 2002; Jackman, Moellenberg & Brabson, 1990). Interestingly, assessment of chemistry courses is typically based on algorithmic type problems rather than conceptual understanding. It seems this occurs because examiners assume that students will be unable to solve algorithmic problems without the related conceptual understanding (Hobden, 2001). In other words, if students can solve algorithmic type problems, they must understand the underlying concepts. However, research suggests that while students with greater conceptual understanding are better at solving algorithmic problems – suggesting a casual link (Mason, Shell & Crawley, 1997; Voska & Heikkinen, 2000), they fail to link the use of algorithms with the underlying chemistry/science concepts (Bunce, Gabel & Samuel, 1991). It is interesting to note that students that focus on the learning of concepts are more successful in their further chemistry studies – studies that build on concepts presented in introductory courses (Mason, Shell & Crawley, 1997). Additionally, there is some evidence to suggest that the examination driven nature of courses can influence students' perceptions of the course. For example, previous research has suggested that teachers believe some students do not embrace new learning environments and techniques due to concerns about examinations (Aldridge, Fraser, Murray et al., 2002).

There is a large body of research concerned with the development of new methods for the teaching of chemistry at all schooling levels – in fact typically methods found effective at secondary level are also effective in the tertiary environment. The research reported in the literature has sought to improve student achievement, understanding of chemistry concepts, ways to improve student attitude-towards-chemistry, and interest in chemistry. Suggestions include making chemistry concepts more meaningful and relevant to students by teaching with analogy (O'Brien & Treagust, 2001; Treagust, Chittleborough & Mamiala, 2001). For example, O'Brien and Treagust (2001) found that at secondary school level the use of analogies is an effective method for teaching chemistry, if students were also required to critique the analogy. Additionally, the use of mixed media teaching tools has been found to be effective at both secondary and tertiary levels (Aldridge, Fraser, Fisher & Wood, 2002; Shrigley, Alfke, Szabo & Welliver, 1975). For example, Dechsri, Jones & Heikkinen (1997) examined the role of visual aids such as figures and diagrams within chemistry laboratory manuals, and found that students performed better cognitively and had an improved attitude-towards-chemistry when material was presented visually. Similarly, the use of flow diagrams and concept maps in tertiary chemistry laboratory classes has been shown to be effective in allowing students to better link the chemistry concepts under investigation in the laboratory setting (Markow & Lonning, 1998, Davidowitz & Rollnick, 2001). At the secondary school level, students showed a preference for working in teams rather than individually in a chemistry classroom environment (Lowe & Fisher, 2000), and methods that make use of collaborative groups have been found to be useful in improving the teaching of chemistry at tertiary level (Birk, Bauer & Leedy, 2001). Additionally, teaching chemistry concepts situated within relevant contexts has been found to be effective at both secondary and tertiary levels (Ebenezer & Zoller, 1993; Manzanal, Barreiro & Jiménez, 1999). Some authors suggest that chemistry is best taught by taking into account the actual contexts that students are likely to encounter in future or planned careers (Choi & Song, 1996). Other findings at tertiary level suggest that chemistry learning is enhanced by better preparation before engaging in laboratory work in laboratory classes (Rollnick, Zwane, Staskun & Lotz , 2001), and active engagement in lecture classes through the lecturer asking questions of the class (Byers, 2001). Overall the literature on both secondary and tertiary chemistry education proposes a shift away from traditional means of content delivery in both secondary and tertiary levels, with or without the entertainment aspect of the 'whiz bang' approach, towards courses that use topical, relevant, examples from everyday life experiences (Bodner, 2001). For example, activities such as creating geometric figures to illustrate chemical structure and weighing gases found in the air to determine molecular weight have been reported to be successful (Bodner, 2001; Kettle, 2001).

Some authors argue that the nature of the research process and the nature of science are already incorporated in traditional chemistry courses (Allchin, 1999; Ryder, Leach & Driver, 1999). For example, Allchin (1999) argues that as science is a value-laden activity as a cultural 'institution', then the teaching of science also teaches science values. However, studies at the secondary school level suggest that more focus on teaching students about the nature of science improves the manner in which they approach the learning of science (Krasilchik, 1990; Thomas & McRobbie, 2001). A habitual concern with new teaching methods, such as those proposed here, is that such approaches are more time consuming compared with traditional teaching approaches, resulting in less content being covered in class. This is a particular issue in compulsory schooling, but is also at the tertiary level given the rapid advancement of science providing increasing pressure on course content. However, it has been reported that overall student achievement can be improved by decreasing course content (Sunburg, Dinin & Li, 1994), or by modifying the demographics of the students enrolled in the institution (de Alva, 2000).

It has been suggested that tertiary teachers should modify their classroom practices to produce a more learner-centred environment. Such a notion has arisen, in part, from the constructivist view of learning that has been so influential in curriculum development for compulsory schooling worldwide (Russell, 1993; Shaw & Etchberger, 1993). Research on the validity of this claim and students' perceptions of a more learner-focussed approach to science teaching has been carried out in both secondary and tertiary level classrooms (e.g., Von Sencker & Lissitz, 1999). However, it has been suggested that for learner-centred science instruction to be effective, students require a high level of scientific vocabulary and content knowledge, commonly achieved by teacher-centred methods (Von Sencker & Lissitz, 1999). Some students respond well to learner-centred teaching finding it more mentally and emotionally engaging particularly in laboratories (Waldrip & Fisher, 2001; Young, Fraser & Woolnough, 1997), but others dislike such an approach and prefer a teacher-dominated style of teaching (Coll, Taylor & Fisher, 2002; Lucas & Roth, 1996). It has been suggested one reason students prefer teacher-centred instruction is their desire to establish exactly what teachers think it is important for them to know, particularly when assessment is largely dependent on summative external examinations (Mulligan & Kirkpatrick, 2000).

2.1.2 Attitude-Towards-Science

In the past, student attitude-towards-science has been extensively studied and reviewed (Gardner, 1975; Koballa, 1990; Schibeci, 1984). More recently attitude-towards-science appears to re-emerging as a field of study, as societal changes mean previous findings may no longer be relevant (Bennett, Rollnick, Green & White, 2001). Much of this interest in attitude-towards-science has found that scientists' believe that the general public fail to appreciate the role and contribution science has made to society (Levinson et al., 2000). Additionally, a specific concern about student attitude-towards-science is the influence negative attitudes may have on student enrolment in science and student achievement in science (Greenfield, 1996; Schibeci & Riley, 1986). For example, Greenfield (1996) found that there was a relationship between science achievement and attitude-towards-science in primary and secondary school levels. That is, students with lower grades in science also had a less positive attitude-towards-science.

Student attitude-towards-science has mostly been investigated using purpose-designed questionnaires or instruments (e.g., Lowe & Fisher, 2000). Two of the most widely used instruments employed to measure attitude-towards-science are the *Scientific Attitudes Inventory II* (SAI II) (Moore & Foy, 1997) and the *Test of Science Related Attitudes* (TOSRA) (Fraser, 1978), with, for example, Munby, (1983), citing over 30 studies using the original version of the Scientific Attitudes Inventory (SAI). However, both the TOSRA and SAI II instruments have been subjected to extensive criticism in the literature (e.g., Munby, 1982; 1983; 1997) (for further details see Chapter 5, Section 5.1, p. 106). As a consequence more recently alternative methodologies, including the development of new instruments (Bennett, Rollnick, Green & White, 2001; Germann, 1988) and the use of interview techniques, have become evident (Piburn, 1993).

Some authors suggest that the scientific community believe students think of scientists in terms of the 'mad scientist' stereotype (e.g., Billingsley, 2000). Research undertaken in the past 20 years suggests that although the mad scientist stereotype does exist in the minds of some students (Jones, Howe & Rua, 2000; Schibeci, 1986), others, particularly female students, think scientists are less anti-social than the stereotype presumes (Lips, 1992). Whilst some students identify scientists as people that help society, particularly in relation to environmental issues and medicine (Dawson & O'Connor, 1991; Koballa, 1990), science is perceived by others to be destructive to civilisation and to contribute to the creation of societal problems (Jones et al., 2000). There also is some confusion regarding the nature of science and the nature of scientific research (Allchin, 1990; Krasilchik, 1990; Lederman, 1992). For example, students do not view science as a social activity - knowledge validation and choices of research are seen to be preordained and immutable, rather than socially-negotiated via peer-review, or as beliefs held by a community of practitioners (Ryder, Leach & Driver, 1999).

Recent research on the influence of context on attitude-towards-science has focussed on gender, ethnicity, and the effect of age and intelligence (Koballa, 1990). It seems there is little difference in the strength and polarity of male and female attitude-towards-science (Rennie & Dunne, 1994; Piburn, 1993; Thompson & Soyibo, 2002), suggesting the wide-spread gender differences Gardner (1975) reported previously in his review of attitude-towards-science are now less prevalent. Interestingly, salient beliefs contributing to males and females attitude-towards-science have been shown to be considerably different, with males perceiving science as interacting with society whereas females considering science to be laboratory based (Jones, Howe & Rua, 2000). More recent research suggests that ethnicity has greater impact on attitude-towards-science than gender, with, for example, students of Asian ethnicity possessing a more positive attitude-towards-science than others such as Europeans (Aldridge, Huang, & Fraser, 1999) and students of Pacific Island descent (Greenfield, 1996). However, within broad ethnicity groupings, for example, native Pacific Islanders, there is seemingly little difference in student attitude-towards-science (Rennie & Dunne, 1994). It has been suggested that this is a function of socio-economic rather than ethnic factors, although the issue has not been investigated extensively (Schibeci, 1984). Other factors reported to influence student attitude-towards-science include age and exposure to science (Myers & Fouts, 1992). For example, a cross-age study of attitude-towards-science found that as students get older and have increasingly more choice in participating in science activities, their attitude-towards-science becomes less positive (Butler, 1999). This culminates at the tertiary level where it was found that science majors have a significantly more positive attitude-towards-science than non-majors (Gogolin & Swartz, 1992).

2.1.3 The Influence of Student Learning Experiences on Attitude-Towards-Science

Interestingly, there is a paucity of research on the influence of learning experiences on student attitude-towards-science at tertiary level. However, students' learning experiences and experiences with teachers influence their attitude-towards-science at all levels of compulsory schooling (Speering & Rennie, 1996; Talton & Simpson, 1987). Quantitative research which has collected data on students perceptions on their learning environment and attitude-towards-science have shown that middle (Years 6 – 8) and secondary school student perceptions of their preferred classroom environment is strongly correlated with their attitude-towards-science (Talton & Simpson, 1987; Simpson & Oliver, 1985). Specifically, there is a strong correlation between attitude-towards-science and student 'satisfaction' with the work required in class, 'positive learning opportunities' and the 'level of organisation' of the teacher (Haladyna, Olsen & Shaughnessy, 1982; Myers & Fouts, 1992). Learning environments in secondary school classes that ostensibly contribute to negative attitude-towards-science, by way of contrast, include that achieved in co-educational schools (O'Brien & Porter, 1994). Additionally, research suggests that students attending compulsory science classes perceived their learning environment more positively and possess a more positive attitude-towards science, despite having little interest in science at the beginning of the course (Myers & Fouts, 1992). These findings suggest that there may be a link between student's experiences in science classes and their attitude-towards-science.

Teacher-student interaction, as part of student learning experiences, also influences student attitude-towards-science (Schibeci & Riley, 1986). Not surprisingly, students at Year 7 - 8 level prefer their teachers to be friendly and knowledgeable (Speering & Rennie, 1996). In particular, students with negative attitude-towards-science are influenced by negative perceptions of their teachers (Gogolin & Swartz, 1992). Specifically, non-science major students at the tertiary level who have had negative experiences with teachers are likely to have a lesser understanding about the nature of science and be more anxious and confused about studying science. Teacher attributes that result in negative attitudes in the transition between middle and secondary school include teaching style and strategies with students not enjoying less active teaching approaches in which note-taking dominates (Gibson & Chase, 2002; Speering & Rennie, 1996). Similarly, students at secondary school level have suggested they prefer contextual learning, indicating they prefer science learning when the teacher relates the subject matter of science to their everyday experiences (Ebenezer & Zoller, 1993). As tertiary teaching is heavily dominated by a note-taking style of teaching it is likely that a dislike for this style of teaching will also be found at tertiary level (Laws, 1996). Similarly, students in secondary school with negative attitude-towards-science believe that their teachers lacked science content knowledge (Wareing, 1990). Also at tertiary level student attitude-towards-science is enhanced if the level of the course is appropriate to the students' level of interest, for example, non-science majors in a science course designed specifically for students not advancing in science (Gogolin & Swartz, 1992; Sunburg, Dinin & Li, 1994).

The influence of in-class and out-of-class teaching interventions on attitude-towards-science has been investigated in a number of studies (Haladyna & Shaughnessy, 1982; Jarvis & Pell, 2002b; Lowe & Fisher, 2000). Project work in particular has been found to increase students' understanding of how scientists conduct research (Ryder & Leach, 1999). For example, higher level undergraduate students were more aware of the length of time it took to carry out research and the systematic approach of data collection after working on science projects. For other students the highly contextualised project work increased awareness of the importance of socialisation and group work in science. Recent research in secondary school classrooms that have previously not taught through experimental practice suggests that incorporating experimental practice, can improve student attitude-towards-science (Thompson & Soyibo, 2002). Out-of-class interventions in science also have resulted in changes to student attitude-towards-science, as at primary school level, a visit to a Challenger space station centre simulation resulted in more positive attitude-towards-science. This finding was particularly prevalent amongst female students, who exhibited an increased awareness about the social aspect of science (Jarvis & Pell, 2001, 2002a).

The relationship between attitude-towards-science and learning experience is, however, not unidirectional, as students with a positive attitude-towards-science are typically more engaged in science learning activities, which likely results in them having more positive learning experiences (Butler, 1999; Germann, 1988). Hence, research findings suggesting causal links between teaching interventions and student attitude towards-science need to be treated with caution. Indeed, perhaps the best predictor of student attitude-towards-science in intervention studies is attitude-towards-science at the start of the study - suggesting that student attitude-towards-science in fact is not easily changed (Schibeci, 1989). As such, this is consistent with research in students' alternative conceptions, which has shown students' views are often tenaciously held (Pfundt & Duit, 1994, 1997).

2.1.4 Science Self-Efficacy

Science is often perceived as difficult compared with other subjects such as in the humanities. This may be due, in part, to the belief that students must obtain the 'correct' answer - during summative assessment at least (Dawson & O'Connor, 1991). Yet, studies of student science self-efficacy (perception of their ability to undertake science tasks) are sparse in comparison with studies on mathematics self-efficacy (Gainor & Lent, 1998; Lent, Lopez & Bieschke, 1991; Lent, Lopez, Brown & Gore, 1996) and pre-service science teachers' science self-efficacy (de Laat & Watters, 1995; Ramey-Gassert, Shroyer & Staver, 1996). However, there has been some recent research practice in this area (see, e.g., Yang, Andre & Whigham, 2001). In fact there is a growing body of quantitative instruments designed to measure different facets of science self-efficacy (Andrew, 1998; Baldwin, Ebert-May & Burns, 1999). It is important to note however, that as self-efficacy is task specific an instrument that measures science self-efficacy of, for example, nursing students, is not appropriate to measure the science self-efficacy of first-year chemistry students (Andrew, 1998). In contrast with other attitudinal studies, self-efficacy also has been researched using qualitative methods as well as quantitative means (Ramey-Gassert, Shroyer & Staver, 1996). There are a number factors that influence self-efficacy, including contextual variables such as school learning environments (Lorsbach & Jinks, 1999; Tymms, 1997). For example, Tymms (1997) study of science in primary schools found that science self-efficacy (which he termed self-concept) is related to individual school variables. Both Tymms (1997) and Lorsbach & Jinks (1999) suggest findings such as these may be related to the learning environments of the students. Science self-efficacy is also influenced by student attitude-towards-science (Jones & Young, 1995; Talton & Simpson, 1986; Smist & Owen, 1994). For example, a statistically significant correlation was observed between students' perception of the normality of scientists and their chemistry self-efficacy amongst secondary school students in the US (Smist & Owen, 1994). Studies suggest that science self-efficacy is related to science achievement, with students who have greater science self-efficacy achieving higher grades in science and having greater motivation to achieve in science (Lent, Larkin & Brown, 1984; Rowe, 1988; Williams, 1994). Interestingly, self-efficacy appears not to be influenced by other psychological variables such as self-esteem, with for example, Lent, Larkin and Brown's (1986) study of undergraduate science students finding no correlation between science self-efficacy and general self-esteem.

Research suggests that mathematics self-efficacy influences science self-efficacy (Betz & Hackett, 1983; Lent, Larkin & Brown, 1984). This research has focussed on a number of factors relating to mathematics self-efficacy such as the relationship between mathematics self-efficacy and academic choice (see Section 2.2.4, p. 30). Although, studies of secondary school coeducational and single sex institutions found no statistically significant differences between male and female student science self-efficacy (Rowe, 1988), generally males have higher mathematics self-efficacy than females (Betz & Hackett, 1983; Lent, Lopez & Bieschke, 1991). A study of tertiary psychology students' mathematics and science self-efficacy suggests that mathematics self-efficacy differences between genders is not related to self-efficacy per se, rather it is a function of different levels of interest in the subjects themselves (Lent, Lopez & Bieschke, 1991).

There also appears to be a relationship between gender and science self-efficacy, with males reported to possess greater science self-efficacy than females (Anderman & Young, 1994; Andre, Whigham, Hendrickson & Chambers, 1999). However, this may be specific to the science discipline with, for example, females more confident about performing tasks in the natural and life sciences, and males more confident about their ability in the physical sciences (Andre, et al., 1999; Koballa, 1990; Yang, Andre & Whigham, 2001). As science self-efficacy is not necessarily a function of gender (Lips, 1992), it is unclear whether these male/female differences in subjects are a gender issue, or, like mathematics self-efficacy, a function of other underlying variables. To illustrate, science self-efficacy is related to students' area of science expertise and prior experiences in science, with physics, chemistry majors having higher self-efficacy towards the physical sciences compared with engineering and biology students (Bodner et al., 2001; Koballa, 1990).

2.1.5 *Influence of Student Learning Experiences on Science Self-Efficacy*

Combinations of vicarious experiences, such as video tapes of successful graduates talking about mathematics and sciences, and performance-based implementations, such as a simple mathematics test, have been reported to be effective in improving students' mathematics self-efficacy (Luzzo, Hasper Albert, Bibby & Martinelli, 1999). However, research on the effectiveness of interventions designed to improve science self-efficacy is less convincing. Some interventions appear to influence self-efficacy beliefs in the short-term, but others seemingly have little effect (Betz & Schifano, 2000; Dawes, Horan & Hackett, 2000). For example, a construction-based intervention designed to improve the science self-efficacy of female undergraduate students had the desired effect (Betz & Schifano, 2000), however, in a study of secondary school students an experimental intervention designed to improve student self-efficacy had little effect (Dawes et al., 2000). Furthermore, there is little, if any, evidence to suggest that interventions that influence science self-efficacy have any long-term effect. Interventions reported to be effective, include tests designed specifically to be easy to pass - intended to build students' confidence about their ability and thus increase their self-efficacy for a given topic or task (Chang & Bell, 2002). This, it seems, is more effective than vicarious experiences, such as exposure to 'successful' students that found mathematics difficult at the graduate level. This latter strategy seeks to enhance student self-efficacy by enabling them to compare themselves with others - of comparable or lesser ability than themselves - who have proven to be successful (Luzzo et al., 1999). In fact, vicarious experiences can reduce students' science self-efficacy, especially when students are exposed to high achieving peers (Anderman & Young, 1994).

2.2 Antecedents of Student Attitude-Towards-Enrolling in Science Courses

2.2.1 Attitude-Towards-Enrolling in a Science Course

As students have more experiences with studying science, their attitude-towards-science becomes less positive (Dekker, Highway & de Laeter, 2001; Yäger & Penick, 1986). Students develop a negative attitude-towards-enrolling in science courses early in their educational careers, with, for example, primary school students in the US as young as new entrants (kindergarten) showing a preference for mathematics and reading over science (Andre, Whigham, Hendrickson & Chambers, 1999). Similarly in the UK students who are interested in science in early primary school show a decline in interest in school science as they progress to higher levels of primary education (Jarvis & Pell, 2002a). Furthermore, by middle school (Years 6-8), fifty percent of US students do not plan on taking science beyond what is required of them as compulsory courses (Simpson & Oliver, 1985). As US students progress to secondary school and are given the option of the extent to which they wish to study science, student attitude-towards-studying science becomes more negative (Crawley & Black, 1992).

Of those students who do choose to take science at the secondary school level and beyond, there are marked gender differences in the type of science studied, with males preferring the physical sciences (physics and/or chemistry) and females preferring general science or the life sciences (Dawson & O'Connor, 1991; O'Brien & Porter, 1994). These differences in preference are found at all levels of science education including primary (Yang, Andre & Whigham, 2001), middle (Jones, Howe & Rua, 2000), secondary (Gardner, 1975) and tertiary levels of study (Lips, 1992). The difference appears to be related to socialisation factors (Hill, Petus & Hedin, 1990) with males having more physical science out-of-school experiences and responding positively to the relevance of physical science course work (Jones, et al., 2000; Sullins, Hernandez, Fuller, & Tashiro, 1995). Females, it is claimed, place more importance on humanitarian interests, and are therefore more concerned with family issues, as well as being involved in more biology-based out of school experiences (Lips, 1992; Jones, et al., 2000). A number of methods have been suggested to change females apparent lack of interest in studying the physical sciences, for example, increasing general public understanding of science, and promoting equal employment opportunities in science by increasing the day-to-day human interaction in science professions (Cronin & Roger, 1999).

Compared with research on the influence of gender on attitude to science and scientific attitude, research on the influence of ethnicity on student attitude-towards-enrolling in a science course is sparse (but see, Greenfield, 1996). There is some evidence to suggest that ethnicity influences attitude-towards-enrolling in science, in conjunction with gender. For example, boys of non-white ethnic origin are more likely to think that science is not appropriate for girls, than any other ethnic or gender group (Greenfield, 1996).

It seems that the major salient beliefs contributing to student attitude-towards-enrolling in science subjects are vocational in nature. That is, enrolment choice, as might be expected, is dependent primarily on the perceived relevance of the course to the students' choice of vocation (Koballa, 1988b). Typically, students base their career choices on a number of psychological factors including perceived work environments (Young, Fraser & Woolnough, 1997), financial security (Lewis & Collins, 2001), and experiences in workplace environments (Robertson, 2000). Despite differences in gender attitude-towards-enrolling in the physical sciences, traditional attitudes regarding the gender stereotyping of scientific and technical vocations are no longer considered by students to be relevant (Dawson & O'Connor, 1991).

2.2.2 *Influence of Student Learning Experiences on Attitude-Towards-Enrolling in a Science Course*

Learning experiences have been reported to directly influence student attitude-towards-enrolling in science subjects, with interest in studying science at tertiary level often developed through positive learning experiences in secondary school (Robertson, 2000; Reid & Skryabina, 2002). It is somewhat surprising that primary school science experiences seem to have little long-term effect on student attitude-towards-enrolling in tertiary science. For instance, non-science majors enjoy science at the primary school level, but consider science at secondary school to be tedious due to the large amount of content (requiring mass memorisation) and a paucity of 'hands-on' learning experiences (Gogolin & Swartz, 1992; Gardner, 1975). Students who enjoyed upper secondary school science experiences, reported that factors such as clarity of instruction, teachers' organisational ability, good mathematics teaching and opportunities for independent learning, increased their interest in science (Koballa, 1990; Woolnough et al., 1997). Interestingly, engineering students seem to prefer a more learner-centred approach, whereas biology students prefer a teacher-centred style of teaching (Woolnough, 1994).

It has been reported that certain interventions designed to improve student understanding of science, also improves attitude-towards-enrolling in science (Harwood & McMahon, 1997; Jarvis & Pell, 2001; Yalcinalp, Ömer & Özkan, 1995). Approaches reported to be effective include the use of multimedia techniques (Harwood & McMahon, 1997) and computer assisted instruction (Yalcinalp, Ömer & Özkan, 1995). Changing the learning environment of a classroom, however, produces mixed results with some students unsure about the value of learner-centred teaching approaches (Woolnough et al., 1997). For example, some students found project work and self-designed experiments increased their desire to study science, whereas others considered this to result in a more disorganised classroom resulting in confusion and undermining their future plans to study science. Hence, some teaching interventions can decrease interest in studying science if, in the course of their study, the students become anxious about studying science (Gogolin & Swartz, 1992; Jarvis & Pell, 2001; Sunburg, Dinin & Li, 1994). Again a learner-centred approach seems to be influential – especially if it involves off-site or informal learning activities. For example, the use of an informal learning environment involving a space and aeronautics simulation, was intended to encourage student interest in science. In fact the intervention had the opposite effect for a small number of students, who were anxious about the experience, which translated to an increased anxiety about studying science (Jarvis & Pell, 2001).

As suggested above, students' secondary school learning experiences are strongly dependent on their perceptions of their teachers (Gogolin & Swartz, 1992). Other factors contributing to student anxiety include instruction at an inappropriate level; too high and students confidence is undermined, too low and capable students become bored and restless (Sunburg, Dinin & Li, 1994). For example, non-science majors' interest in science increased after studying a simplified science course, but science-majors studying a more complex course became more anxious about studying science - resulting in decreased interest in studying science (Gogolin & Swartz, 1992)

There are a number of non-classroom learning experiences that apparently influence student attitude-towards-studying science. Students may not consider such experiences to be 'learning' but less formal science learning environments like extra-curricula activities, including science clubs, seem to encourage interest in science (George & Kaplan, 1988; Woolnough et. al., 1997; Young, Fraser & Woolnough, 1997). Learning experiences in other classes may influence students' decision to take chemistry, rather than chemistry classroom learning experiences. For example, students who have positive learning experiences in biology, are more likely to take biology rather than chemistry, due to their positive biology experiences, rather than negative chemistry experiences (Barker, 2001).

2.2.3 The Influence of Student Attitude-Towards-Science on Attitude-Towards-Enrolling in a Science Course

The relationship between student attitude-towards-science and attitude-towards-enrolling in science is dependent on their intended major. For example, for students predisposed to science (science or engineering students), there is no significant relationship between attitude-towards-science and attitude-towards-enrolling in science (Gardner, 1975; Wilson, Ackerman & Malave, 2000). That is students who have a positive attitude-towards-science are equally likely to have a positive attitude-towards-enrolling in science as those students who have a negative attitude-toward-science. However, in groups of students with a variety of scientific interests and abilities (such as non-majors), attitude-towards-science influences students attitude-towards-enrolling in science courses. That is, students with a positive attitude-toward-science are more likely to have a positive attitude-towards-enrolling in science than those with a negative attitude-towards-science (Haladyba, Olsen & Shaughnessy, 1982). For example, in physics classes in both secondary and tertiary institutions, student perceptions of the status of physics influenced their decisions about studying physics (Reid & Skryabina, 2002). Furthermore, students' views of the socialisation skills of scientists influence their subsequent career choices, which in turn influences their attitude-towards-enrolling in science (Lips, 1992). That is, university students who believed that scientists were more sociable, were also more likely to pursue education in science courses. Thus it seems that negative perceptions about scientists' social skills, may influence students' enrolment choices.

2.2.4 The Influence of Student Science Self-Efficacy on Attitude-Towards-Enrolling in a Science Course

As might be expected, students' efficacious beliefs influence their attitude-towards-studying specific disciplines (Lent, Larkin & Brown, 1986). Interestingly, this is independent of the discipline. Students who perceive themselves to be competent in a subject are, naturally, more likely to consider enrolling in the subject (Young, Fraser & Woolnough, 1997), and are more likely to be interested in a career related to that subject (Lips, 1992). Self-efficacy also influences the extent to which students persist in a science field (Lent, Larkin & Brown, 1984). Students with high self-efficacy attribute their success to effort, and thus are more likely to persist in science. In contrast, students with low self-efficacy blame failure on a perceived lack of ability in the discipline or task, and are less likely to continue in studying science (Nauta, Epperson & Waggoner, 1999). There is evidence to suggest that some students have a high self-efficacy, but lack ability in a subject (Chang & Bell, 2002), with students wanting course work to be more challenging, despite being unable to grasp simple concepts. In addition, self-efficacy beliefs may influence student interest in studying science (Betz & Hackett, 1981). In particular, self-efficacy mediates the relationship between achievement and interest, in that achievement in science leads to higher science self-efficacy which in turn serves to strengthen students' academic goals (Lapan, Shaughnessy & Boggs, 1996).

Just as mathematics self-efficacy has been reported to influence science self-efficacy, it also may influence student attitude-towards-enrolling in science (Betz & Hackett, 1981,1983; Matsui, Matsui & Ohnishi, 1990). For example, at the college level, attitude-towards-enrolling in science is influenced by student mathematics self-efficacy (Betz & Hackett, 1983). Historically, for females, attitude-towards-studying science and career interest in science vocations are reported to be influenced by their mathematics self-efficacy (Betz & Hackett, 1983). Such a link has been observed, for example, in Japan, where females traditionally do not study science – although it is possible ethnicity or cultural mores also are influential factors (Matsui, Matsui & Ohnishi, 1990).

2.3 Student Control Beliefs about Enrolling in Science

There is a paucity of research on the influence of compulsory science courses on student enrolment choices. Nonetheless, students have reportedly identified a number of barriers to studying science at the tertiary level (Crawley & Black, 1992). Interest in science is a barrier to studying science effectively. Students who are not interested in science perceive that achieving a passing grade in science is difficult due to low motivation as a result of lack of interest in the content of their science courses (Haladyba, Olsen & Shaughnessy, 1982). Despite both genders believing that females are capable of studying science, motherhood is a perceived barrier to studying science. For example, male tertiary level science students consider that females would find it difficult to balance motherhood with a career in science (Lips, 1992). Fear of failure also contributes to control beliefs. In other words, students that believe that they may fail their science courses are reluctant to enrol in science (Crawley & Black, 1992). Other factors influential on student control beliefs include simple organisational factors such as course clashes and a perception that science study is more time intensive than subjects in the humanities. Remarkably, there is little research on the influence of learning experiences on perceived barriers to studying science.

2.4 Student Perception of Associates Attitude-Towards-Science and their Influence on Subjective Norm

The literature suggests that parents, teachers, relatives, and, to a lesser degree, peers, influence student science behaviour, including enrolment in, and active participation in, science classes (Koballa, 1988a,b; Ray, 1991). In this section, I discuss the influence that parents', peers', and mentors' attitude-towards-science and the media's portrayal of science have on students' normative beliefs.

2.4.1 The Influence of Parental Attitude-Towards-Science on Student Subjective Norm

The effect of parental support on student achievement has been researched extensively (see, e.g., Schibeci, 1989; Schibeci & Riley, 1986). However, research into the influence of parental attitude-towards-science on student science-attitude and science-behaviour is comparatively limited. Some research suggests that home background is unrelated to student attitude (Schibeci, 1989), but other work suggests that parental attitude can influence attitude-towards-science and tertiary level student normative beliefs about studying science. For example, parents may influence students' beliefs by overt support of science-based extra-curricula activities, or through parental involvement in a scientific industry (George & Kaplan, 1997; Woolnough, 1994). It seems that the home environment of non-science majors provides little exposure to science or science-related activities (Gogolin & Swartz, 1992), whereas family support and home environment is influential in student attitude-towards-science at the secondary school level (Crawley & Black, 1992; Jones & Young, 1995).

Parental support has been identified as being the one of the most influential factors on student science-behaviour during elementary and middle schools, but the extent to which students respond to parental attitudes declines once they reach secondary school (Crawley & Black, 1992; Jarvis & Pell, 2002b; Jones & Young, 1995). It seems females are more likely than males to be influenced by parental opinion (Dawson & O'Conner, 1991). This may explain why females are less interested in physical sciences, as other research suggests that parents perceive physical science to be more important for males than females (Andre et al., 1999;

Koballa, 1990). Parental influence on control beliefs about enrolment choices also is influenced by ethnicity, and, for example, Korean secondary students' enrolment in science courses are related to parental views (Myeong & Crawley, 1993).

2.4.2 *The Influence of Peer Attitude-Towards-Science on Student Subjective Norm*

Research suggests that any link between peer attitude and student attitude towards science is tenuous. At the primary/elementary and middle school levels, the literature suggests that the educational expectations of friends are not causal to attitude. In fact, middle school students with a positive attitude-towards-science commonly have friends with less positive attitudes (Ray, 1991; Schibeci, 1989). However, at the tertiary level, and to some extent at the secondary level, students choose a peer group that reinforces their own background and interests. In other words, students with a background in science are likely to form peer relationships with students who also have a science background (Gogolin & Swartz, 1992; Talton & Simpson, 1985). Hence, as students' relationships with their peers develop and become stronger, student attitude-towards-science becomes similar to that of their peer group (Talton & Simpson, 1985).

Although peers seem to exert much less influence on students' science enrolment choices than parents (Kremer & Walber, 1981), research suggests that peers' attitude-towards-science has some effect in particular circumstances. For example, in boarding school situations peers become substitute families (Pannizone & Levins, 1997). The influence of peer social pressure increases in the early secondary school years, climaxing at about Year-9 (Jones, Porter & Young, 1996; Jones & Young, 1995; Talton & Simpson, 1985). In the later stages of their secondary schooling, students perceive their peers to be supportive generally; but such support does not necessarily related to student-peer shared career or enrolment choices (Pannizone & Levin, 1997). Thus the literature suggests that by the time students enter tertiary education, the influence of peers on students normative beliefs is not particularly significant (Tollefson, 2001).

2.4.3 *The Influence of Mentor Attitude-Towards-Science on Student Subjective Norm*

Remarkably, there are few recent reports in the literature of research into the impact of mentors or role models on students' science enrolment choices. What research that does exist is concerned with the influence teachers have on student science behaviour, including the level of student participation in science classes (Koballa, 1988a). Teaching methodology and teacher behaviour impacts on science behaviours as early as elementary school (Ray, 1991) and continues through to the secondary level (Koballa, 1988b). It appears that female students respond better to female science teachers, but studies of the interaction between female students and female scientists is less clear, with some research suggesting the impact is minimal (Koballa, 1988a), and other studies suggesting female scientists significantly influence subjective norm (Jarvis & Pell, 2002a).

Mentors are reported to influence enrolment decisions with, for example, first-year engineering students identifying family friends and senior family members as referents when making enrolment choices (Bodner et al., 2001). Other students identify teachers, school councillors, and future employers as people they would discuss enrolment choices with (Rennie & Dunne, 1994; Stead, 1985; Koballa, 1988b).

2.4.4 *The Influence of Societal Attitude-Towards-Science on Student Subjective Norm*

Research suggests that the public rely heavily on media reports and portrayals of science for information about science issues (Cross & Price, 1999; Fensham, 1999). This is not considered desirable, as in the view of some authors at least, the general public does not possess sufficient knowledge of science to evaluate scientific material presented to them via the media. As a consequence, societal attitudes and opinions tend to conform to media representations – however inaccurate and ill-informed such portrayals may be (Thompson & Bucat, 2001). To illustrate, Schibeci (1986) suggests that a scientist is perceived by the community as being a "dispassionate seeker of truth" who "suspends judgement and does not venture too far beyond his experimental observations" (p. 145). In other words, the community perceives that scientists focus on their scientific work, and do not consider what impact their science endeavours may have on society. Other stereotypes about scientists and science include the stereotypical 'mad scientist' and scientists as individuals that are insensitive to environmental issues. Students' views, like those of society as a whole, are subject to media influence. For example, it seems students' knowledge of biotechnology is limited to rather inaccurate media descriptions of topical issues such as genetic modification and cloning, with seemingly little appreciation of other more established and less controversial biotechnology techniques such as those used in brewing and bio-remediation (Dawson & Schibeci, 2001).

The fact that many students consider their teachers to be salient associates, suggests that student learning experiences may impact upon student normative beliefs (Koballa 1988a,b; Ray, 1991). Hence, it seems reasonable that positive science-learning experiences may act to moderate students' perceptions of social pressures on science–related issues. The converse of this is also likely true, as, for example, students with negative experiences with science teachers are less likely to study science. However, the literature suggests that the influence of learning experiences on subjective norm is not as significant as it is on student attitude-towards-enrolling in science (Ray, 1991).

2.5 Antecedents of Enrolment Choices

2.5.1 Attitude-Towards-Enrolling in Science

As mentioned above, students' enrolment choices at the tertiary level are related to their vocational interests and career aims (Lapan, Shaughnessy &Boggs, 1996). Vocational intentions thus act as useful indicators of enrolment choices at both the secondary and tertiary levels (Dawson & O'Connor, 1991). Students interested in perusing a career in science, or who believe studying science will help them succeed in other careers, elect to take science at secondary school (Koballa, 1988b; 1990). This choice subsequently influences options at the tertiary level with students' enrolment intentions at the beginning of their tertiary career having the most impact on their eventual enrolment choices (de Boer, 1984; Lapan, Shaughnessy & Boggs, 1996; Sullins, Hernandez, Fuller & Tashiro, 1995). As a consequence, students' long-term educational choices are in effect predetermined by decisions made in their early secondary school years (Sullins, et al., 1995).

Interest in science also is influential in enrolment intentions (Koballa, 1990) with students who have an interest of science often aspiring to be scientists (Crawley & Black, 1992; Stokking, 2000). These students tend to be more serious, achievement-orientated, conventional, and conformist, than students with less interest in science (Stokking, 2000). Consequently, students with an interest in science often have a higher science self-efficacy and are more academically able in science, both of which have been identified as factors influencing student enrolment choices (Dawson & O'Connor, 1991; Koballa, 1990; Rottinghaus, Lindley, Green. & Borgen, 2002). However, whilst students who enrol in science identify academic ability as an antecedent of their enrolment choices, those students who do not enrol in science identify other factors, such as interest in science, as being more important (Stokking, 2000). Learning experiences also impact upon enrolment choices with, for example, student apprehension about the amount of homework at secondary level involved in studying science a major factor in enrolment choice (Dawson & O'Connor, 1991; Koballa, 1988b).

It seems there are gender influences in attitude-towards-enrolling in science, with females more interested in the life sciences and males more interested in the physical sciences. However, any influence on subsequent enrolment choices is less clear, with some studies finding differences in student attitude-towards-enrolling in science based on gender (Dawson & O'Connor, 1991; Stead, 1985), and others finding no differences (de Boer, 1984).

2.5.2 Perceived Control over Enrolling in Science

The influence of control beliefs on enrolment choices has not been widely examined, although there is some evidence to suggest that students enrol in courses primarily as a compulsory component to a programme of study, as, for example, in engineering intermediates and the like (Bodner et al., 2001).

2.5.3 Subjective Norm

The literature suggests that subjective norm is significantly less important in determining enrolment choices at all educational levels compared with attitude-towards-enrolling in science (Butler, 1999; Crawley & Black, 1992; Dawson & O'Connor, 1991). However, there may be some less overt social pressures that influence enrolment choices, although these are typically not the primary factors that influence students' enrolment. (Hargrove, Creagh & Burgess, 2002; Reid & Skryabina, 2002). For example, the socio-economic status of students' families has been shown to influence enrolment choices in mathematics and English in both the US and Germany (Schnabel, Alfeld, Koller, & Baumert 2002). There are also some differences based on ethnicity. For example, subjective norm for Korean students is related to behaviour, suggesting that for Korean students at least, attitude-towards-enrolling in science influences their decision-making processes, and as mentioned above, parental pressure also influences Korean students' enrolment behaviour (Myeong & Crawley, 1993) with humanities students stating that parents dissuaded them from taking science. In Western countries, however, parental influences are minimal (Johnston & Selepeng, 2001; Joseph & Joseph, 1998), with the majority of students suggesting that their parents are generally supportive of any academic choices, rather than influential in decision making (Young, Fraser & Woolnough, 1997).

Peers appear to have more influence on students' enrolment choices than parents (Johnston & Selepeng, 2001), but as students tend to choose peer groups with similar interests it is unclear what is the most influential factor (Gogolin & Swartz, 1992; Jones & Young, 1995; Talton & Simpson, 1985). Females tend to be influenced more by friends than males, with girls responding to the perceptions of older students (Dawson & O'Connor, 1991) particularly in the context of boarding schools and single-sex institutions (Johnston & Selepeng, 2001; Panizzon & Levins, 1997).

Relationships with teachers tend to, for the most part, exert more influence on students' enrolment choices than either parents or peers (Joseph & Joseph, 2000; Myeong & Crawley, 1993; Young, Fraser & Woolnough, 1997). Students obtain course information from their schools through career councillors, and this information is an important factor in enrolment choice (Brennan, 2001, Joseph & Joseph, 2000). However, the extent to which teachers influence enrolment choices is not clear, with some studies identifying teachers as major referents (Johnston & Selepeng, 2001; Young, et al., 1997), and others suggesting that teachers have little influence on enrolment choices (Myeong & Crawley, 1993; Stokking, 2000).

2.6 Chapter Review

The review of the literature relevant to this research suggests that although research has been carried out within tertiary chemistry education, there is scope for a better understanding on what factors influence students' educational choices.

First-year chemistry classes have undergone some investigation through research into traditional methods of teaching in lecture, laboratory and to a lesser extent tutorial classes. This research examined students' dislike of traditional teaching methods, the use of new methods in teaching – such as learner-centred classrooms, as well as examining students' experiences at university more generally. A significant amount of research has been carried out on elements of the content of typical first-year chemistry courses. However, there is a clear gap in the research, with few studies linking students' perceptions of all three tertiary learning environments and of first-year chemistry courses as a whole.

Similarly, there is a need for investigation of student attitude-towards-science at the tertiary level. Although there was extensive research in the 1970s and 1980s on student attitude-towards-science, there has been little recent interest, especially at the tertiary level – due, in part, to the heavy criticism of the instrumentation used in earlier studies. Historically, there were some gender differences observed in attitude-towards-science, with males being more positive than females. However, more recent research suggests that this is no longer the case, although differences between students of different ethnicities have been observed. Additionally, there is some evidence to suggest that learning experiences have some influence on attitude-towards-science, through learning environments and classroom interventions designed to improve attitude-towards-science. Research on attitude-towards-science, in this case chemistry, needs to be carried out in order to update understanding of this issue. There is also a need to examine the relationship between learning experiences and attitude-towards-science, to gain further understanding of how attitudes are developed.

Unlike research into attitude-towards-science, science self-efficacy is a new research area. Traditionally dominated by mathematics self-efficacy, there is increasing awareness of the relevance of research into student science self-efficacy. This is especially important in light of the gender differences found in students' science self-efficacy. There is also recent awareness that learning experiences may impact upon students' science self-efficacy, as research findings on learning interventions show a change in science self-efficacy in specially designed courses. What is not clear is how first-year tertiary science experiences, such as those in chemistry classes, impact upon science self-efficacy.

Although there is some research reported on students' learning experiences, attitude-towards-science and science self-efficacy, there is a paucity of research bringing these ideas together to examine their influence on students' attitude-towards-enrolling in science. What research that does exist in these three areas suggests that at primary and secondary schools there is a relationship between learning experiences and attitude-towards-enrolling in science, and that students more disposed to studying science are less likely to be influenced by their attitude-towards-science. Of the three main antecedents of attitude-towards-enrolling in science, science-self-efficacy has received the most interest, with a clear relationship between these two variables established. Other research examining student attitude-towards-enrolling in science suggests that these attitudes develop early on in students' educational career, and are dominated by vocational beliefs. Additionally, there appears to be some gender differences occurring in attitudinal beliefs, with males drawn to physical sciences and females the natural sciences.

Of all the areas examined by this thesis, control beliefs are the least researched, perhaps since many of these are organisational factors, which researchers may feel they have little ability to impact upon. Similarly, normative beliefs about science are far less researched than attitudinal beliefs, although students who are interested in science subjects typically have parents who are supportive of them and involve them in extra-curricula science-related activities. These students also gravitate towards peer groups that have similar interests and are therefore supportive of their science choices. The importance of mentors in enrolment choices is less well understood as is the role of the media in influencing enrolment choices. What is not clear from this research is what students perceive about their salient associates attitude-towards-science and attitude-towards-students enrolling in science.

Research on science enrolments choices suggests the influential factors in students' science enrolment choices are primarily vocational or derived from the level of interest the student has in the subject. Control beliefs appear to be related to the level of compulsory subjects at tertiary level, where normative beliefs appear to have negligible effect. What is not understood is how learning experiences impact on students enrolment choices, and how attitudinal, control and normative beliefs interact to influence enrolment choices in a tertiary science context.

In summary, there is a need to understand the factors that influence science enrolment choices, especially at the tertiary level. Furthermore, given the specialist nature of tertiary level study this research needs to be focussed on a specific science subject, in this case chemistry.

2.7 Chapter Summary

This chapter shows that clearly there is a need for research on students learning experiences and the influence they have on their enrolment choices, beyond the issues identified for the department involved in this study as outlined in Chapter 1.

This chapter provided a review of the literature relevant to research questions. In the first instance learning experiences in science classrooms, attitude-towards-science and science self-efficacy were discussed in terms of recent literature. Following on from this the literature pertaining to attitude-towards-enrolling in second year chemistry was presented, followed by the literature about students' control beliefs. Next the literature on associates' attitude-towards-science was presented and finally the literature relating all these factors to enrolment choices was discussed. The following chapter, Chapter 3, examines the theoretical ideologies behind the research questions and gives a detailed discussion on the theoretical framework that guided this study, the *Modified Theory of Planned Behaviour* (MTPB).

CHAPTER 3
THEORETICAL FRAMEWORK

The purpose of this chapter, Chapter 3, is to present some of the theories that informed the research problem, outlined in Chapter 1 and explored through the literature review in Chapter 2. From this, the theoretical framework for the thesis is developed and presented here. The process of choosing an appropriate model as a framework for this study begins with a discussion on the basic beliefs and metaphysics of the researcher in terms of theories of learning and their relation to research in education. This is followed by definitions of terms used in the development of the theoretical framework, and a description of the theoretical models used in behavioural research. The chapter concludes with a description of the theoretical model used in this thesis, namely, a modification of the *Theory of Planned Behaviour* (TPB).

3.1 The Role of Theory in Research

The role of inclusiveness is important in research, as for researchers to seek to understand a problem all facets of the problem need to be considered (Cohen & Manion, 2000). Consequently, a method design that is inclusive covers all possible facets of a research problem - a feat not easily achieved. However, the use of theories, arisen from other research in similar areas, may help to make research methods more inclusive. As Cohen and Manion (1994) state:

> [Theory] is a source of new hypotheses and hitherto unasked questions; it identifies critical areas for further investigation; it discloses gaps in our knowledge; and enables a researcher to postulate the existence of previously unknown phenomena. (p. 15)

In this chapter, I discuss the theories that pertain to the research problem, presented in Chapter 1 (Section 1.3, p. 4), namely, to investigate enrolment choices of first-year chemistry students, and the influence first-year learning experiences have on enrolment choices.

3.2 Paradigms and Theories of Learning

Education and science education research involves the collection and interpretation of data to inform aspects of teaching and learning. However, as Guba and Lincoln (1989) point out, the development of the methodology for any research project is influenced by the researcher's metaphysical beliefs, including their views on how individuals learn or acquire knowledge. The researcher's belief system impacts on all stages of research including method development, data collection, data analysis and interpretation of the research findings (Tobin & Tippins, 1993). Hence it is important in any description of education research to begin with a discussion of the researcher's metaphysical beliefs.

3.2.1 Paradigms

A paradigm provides a reference from which actions are based and is defined by Lincoln and Guba (1985) as: "A distillation of what *we think* [original italics] about the world (but cannot prove). Our actions in the world, including actions that we take as inquirers, cannot occur without reference to those paradigms: 'As we think, so do we act'" (p. 15). Paradigms have three components, ontology, epistemology and methodology. Ontology is concerned with the beliefs about the nature of the reality. There are two main ontological belief systems, realist and relativist. Realists see truth as absolute and based on facts. In contrast, relativists hold that truth is a construction of the individual defined by the best possible fit, with many different fits possible. Much early education and social science research was based on a realist-ontology but more recently education researchers have based their inquiries on a relativist ontology.

Ontological beliefs provide the basis for epistemological beliefs - epistemology being concerned with the relationship between the knower and the knowledge. Individual's that subscribe to a realist ontology typically subscribe to an objectivist epistemology in that they believe that knowledge and the knower are (or can be) independent of each other. In contrast, relativists subscribe to a subjectivist epistemology believing that knowledge is a function of the knower; that is the knowledge is dependent on the constructions of the researcher.

An individual's ontological and epistemological beliefs provide a framework from which their methodology practices are derived. Methodology is the practical component of a paradigm, concerned with how an individual finds things out. Realist-objectivists typically use an interventionist methodology that attempts to remove all contextual influences - experimenting and manipulating until truth is discovered. Such an approach is based on scientific ideologies. In contrast, relativist-subjectivists employ a hermeneutic methodology in which the researchers and the other stakeholders come to an individual truth, which is a negotiated construction of the situation. A hermeneutic researcher thus aims to understand a situation by interpreting different data sources to find common themes.

3.2.2 Development of Interpretivist Research

As formerly stated, paradigms and research practice in education have changed. In order to understand the role of modern research in relation to previous research an understanding of paradigm shifts is necessary. Paradigm shifts can be tracked by changes in methodological practices. The foundations of thought for science and philosophy originated some 2000 years ago with the ideas of philosophers like Aristotle. This era, known as pre-positivism, was based on the concept that researchers were mere observers, and a divine being or God defined truth. Researchers thus observed situations or events in order to draw conclusions about the manner in which God structured the world. Events that were not easily explained were attributed to divine intervention. This resulted in a non-interventionist style of thought and consequently scientific research was relatively limited at this time.

The positivist era is arguably the most significant to date in terms of scientific development and discovery. Based on a realist ontology and objectivist epistemology, positivism introduced experimental methodologies into science and science moved from merely observing the world, to manipulating it. The manipulative approach also became popular in educational and social science research, resulting in a situation in which participants were treated as non-contextual beings and interventionist studies abounded. However, in recent times positivism has been subject to much criticism in education research. Few authors now believe that in research involving humans, there is no effect without cause, or that the world can be broken down into small independent pieces for analysis. It is now commonly accepted that the researcher inevitably influences the research and that context influences results (Lincoln & Guba, 1985). These new views on the importance of context subsequently influenced thinking in the postmodernist era, as researchers embraced context as an important facet of research. Significantly, for social science and education research, this resulted in the development of the interpretivist paradigm, which has at its foundation a constructivist epistemology (Tobin & Tippins, 1993). In constructivism, a type of subjectivist epistemology, truth is defined as an individual's construction of knowledge. This radically different view of learning saw students as active participants in the creation of knowledge rather than passive absorbers of knowledge. Consequently, the student's contextual background, which includes but is not restricted to, their cultural identity and their prior learning experiences, were seen to influence their construction of new knowledge (Wheatley, 1991).

Constructivist thinking gives way to a research paradigm that is less about judgement and more about evaluation (Guba & Lincoln, 1989) and constructivist-based research seeks to describe rather than manipulate a given educational setting. Constructivism is not without its critics with some authors arguing that belief in a lack of a quantifiable reality, and the subsequent questionability this imposes on scientific endeavour, fails to recognise the achievements of scientific research (Gross & Levitt, 1994). Other authors have argued that constructivists have failed to come to an agreement on and appropriate definition for constructivism (Matthews, 1998).

3.2.3 Variants of Constructivism

Constructivism is seen by many to be difficult to define. This may simply be due to careless use of the term 'constructivism', with many variants of constructivism simply referred to as constructivism. Good, Wandersee and St Julien. (1993) identified 15 different types of constructivism in the science education literature. However, these types of constructivism are essentially variations on a theme and

Wheatley (1991) points out that despite the use of adjectives to modify the meaning of the term constructivism, there is consensus on the fundamental basis of constructivism; that individuals construct knowledge in their own minds. Two variants of constructivism have received particular attention in the literature: radical constructivism and social constructivism (Solomon, 1994; Von Glasersfeld, 1993). Radical constructivists acknowledge the possible presence of truth, but argue that humans are unable to ever quantify truth beyond their own understanding; thus we can never know if an independent truth actually exists. Consequently, they define constructivism as broader than an epistemology, and see it more as a paradigm. According to radical constructivists, learners are unable to understand beyond their own constructions. Such a view has significant consequences for pedagogy and research methodology as, for example, it suggests that teachers' constructions are not actually accessible to their students. From a research point of view, results generated from education research consist of the readers' interpretations of the researchers' interpretation of the participants' viewpoint. There are many critics of radical constructivism (see, Matthews, 1998), and critics argue that this belief system does not allow for socially mediated constructs (Solomon, 1994).

Social constructivists believe individuals can come to agreement or a shared meaning of knowledge or issues under investigation (Solomon, 1994). For instance, a learner and teacher can come to agreement on a common socially defined meaning, such that their construct of the meaning is in effect the same. In other words, it is reasonable to suggest that participants can eventually come to agreement on a shared common understanding through the process of discourse. Although social constructivists accept many of the limitations of interpersonal interactions that form the basis of radical constructivism, it enables them as researchers, teachers, and learners to accept that some notion of shared understanding is possible. Radical constructivists dismiss this argument, considering it to be ontologically flawed in that social constructivism suggests that a known society exists beyond the mental construction of the individual - a proposition that is unacceptable to radical constructivists (Von Glasersfeld, 1993).

3.2.4 Metaphysical Beliefs of the Researcher

This researcher subscribes to a social constructivist view of knowledge acquisition, but considers constructivism to be an epistemology rather than paradigm, in agreement with Von Glasersfeld (1993) and in contrast to the views of Guba and Lincoln (1989). In other words, I see constructivism as a theory of knowing, rather than a theory of knowledge. On this basis I consider that ontological beliefs are less important than epistemological beliefs. I consider myself a subjectivist since I do not believe knowledge can be divorced from the knower. Consequently, the research reported in this thesis subscribes to an interpretivist approach in that the research objectives, theoretical framework and methodology employed are based on my interpretation of the issues under investigation. In terms of methodology, I used a multiple-methods approach in order to achieve data triangulation (see Section 4.3.3, p. 69). Nonetheless, I acknowledge that likelihood of some disparity between my interpretation and the participants' real beliefs.

There are two main contextual factors that I believe may have influenced the way that I have conducted the research reported here. The first is my background in science. I have spent the six years prior to my PhD studying and working in a science environment. Therefore I am familiar with many of the beliefs of the scientific community, one of the major stakeholders of this research. Secondly, my undergraduate training was undertaken at the institution involved in this study, and the research objectives came from my experiences as both a student and as a student demonstrator in chemistry laboratory classes.

3.3 Definition of Terms Used in this Thesis

It is useful and appropriate at this stage to define some of the terms used during the development of the theoretical framework for the study; chemistry, attitude, self-efficacy, and learning experiences.

3.3.1 Chemistry

Chemistry may be defined as a discipline of science, that is, the systemised knowledge, derived from observation, study and experimentation, of the composition and properties of substances and the reactions by which substances are produced from or converted into other substances, and their applications to a specified subject or field of activity (McKechnie, 1970). However, this definition divorces chemistry from the people who practice it. There is a large amount of evidence to suggest that society does not separate science from scientists, manifest by recent debates on, for example, biotechnology, where the ability of the scientists to act in an ethical manner is now being questioned (Dawson & Schibeci, 2001). If people equate agendas, and hence belief systems, with practitioners of science it is more appropriate to use a more holistic definition of chemistry incorporating not only knowledge, but the beliefs and values of chemists. Chemistry can be seen not only as a discipline but also as a culture. Therefore the definition of chemistry used in this study is based on a *chemistry culture*, that is, the learned patterns for thinking, feeling and acting that are transmitted via the acquisition of chemistry theory, skills and values.

3.3.2 Attitude

Attitude is a holistic and complex concept that is difficult to define. Pratkanis (1989) identifies a variety of definitions and models for the term attitude. Here the definition of Allport (1935) (cited in Horowitz & Bordens, 1995, p. 228) has been adopted, namely, "a mental and neutral state of readiness, organised through experience, exerting a directive and dynamic influence upon the individuals' response to all objects and situations with which it is related." Despite the historical origin of this definition, it is still currently used in social psychology and science education (Ajzen & Fishbein, 1980; Haladyna & Shaughnessy, 1982; Horowitz & Bordens, 1995) and is useful and appropriate here, since it relates attitude to individuals and their experiences, as well as incorporating the effect of attitude on behaviour. Allport's definition has been criticised as being inappropriate in cases for which the link between observed behaviour and verbalised attitude is weak (Pratkanis, 1989). However, this reservation is not relevant here in that it erroneously assumes a positivist cause-and-effect component to Allport's definition, whereas the definition appears to be more constructivist in nature in that it relates an individual's context to the influence on their response, that response be a behavioural action, an intention, or the formation of a new attitudinal belief.

Attitude is composed of three main components, the cognitive, conative, and affective (McGuire, 1989; Pratkanis, 1989; Shrigley, Koballa & Simpson, 1988). The cognitive component is based on knowledge beliefs, which are non-emotive. For example, 'chemistry study will help me get a better job'. Conative components are behaviours from which attitudes are derived and, arguably, have a cause-and-effect relationship with attitude. This proposition has its basis in positivism, despite research showing only weak correlation between attitude and behaviour (Shrigley, 1990). Affective beliefs are emotive beliefs, for example, 'studying chemistry is boring'. Affective beliefs are, arguably, the dominant beliefs contributing to attitude, with some authors suggesting that cognitive beliefs and behaviours are not, by definition, attitudinal beliefs (McGuire, 1989). This argument suggests that affective beliefs, (e.g., studying chemistry is boring) are more salient and relevant to attitudes (e.g., student attitude-towards-studying chemistry) than cognitive belief (e.g. chemistry study will help me get a better job) and behavioural beliefs (e.g. I am going to study chemistry). This three-component concept of attitude was adopted for this thesis as it provided a basis to understand students' attitude-towards-chemistry (see Section 3.5.3, p. 59).

Investigation of changes in attitude is commonly based on the *Elaboration Likelihood Model* (ELM) (Petty & Cacioppo, 1981). The ELM suggests that attitude change can occur via a central or a peripheral pathway. The central pathway results in an attitude change that is stable and predictive of behaviour (Shrigley & Koballa, 1992). A central pathway attitude change occurs if the individual is motivated to change and is able to process new information. To illustrate, consider a chemistry major and a non-major both exposed to a message from their lecturer that a particular second-year analytical chemistry course will help them gain employment upon graduation. Whilst the chemistry major may process this message, the non-major - not contemplating a career in chemistry, may not identify this as a personally relevant message. In other words, the effect of new information is dependent on the individual's current beliefs and attitudes. Hence, for new information to change a n individual's attitude, it must overcome the stage where the individual elaborates on the new information in context of his or her own attitudes and beliefs. At this stage the individual can dismiss the new information, and this can, in some cases, result in strengthening of previously held beliefs. For example, if the information about the second-year analytical course is presented in a complex manner, the student may think they are unable to carry out the tasks involved in the course and this may strengthen their belief that they should not study the course. Finally, before attitude change can occur, the individual must cognitively store the new information and make the new attitude more salient than the previous one. If all these stages occur then the new attitude is typically enduring and can be used to predict behaviour.

The peripheral pathway to attitude change produces attitudes that are less stable, often temporary, and that are less predictive of behaviour (Petty & Cacioppo, 1986; Shrigley & Koballa, 1992). The peripheral pathway creates attitudes that are associated with previous incidents and cues. For example, if a student thinks that his or her chemistry teachers are physically attractive then he/she may subconsciously choose to enrol in a chemistry course at second-year level because they associate chemistry with physical attractiveness. Although attitudes stimulated by peripheral cues such as physical attraction are often short-lived, they may stimulate cognitive processes that create central attitude change.

3.3.3 Self-Efficacy

The work of Albert Bandura forms the basis for the definition of self-efficacy as used in this thesis. Bandura (1986) defines self-efficacy as "people's judgements of their capabilities to organise and execute courses of action required to attain designated types of performance" (p. 391). A student may perceive that he/she is not good at mathematics and believe that he/she would struggle to solve the numerical problems required in a chemistry course. Such a student will have a low self-efficacy toward obtaining a passing grade in the chemistry course, which may then affect any decision about enrolling in further chemistry courses.

Although related to the concept of self-confidence, self-efficacy is distinguished from self-confidence in that the latter is task specific. For example, a student may be confident in his/her ability to undertake tertiary study generally, but may have low self-efficacy about undertaking a particular experiment in the chemistry laboratory.

Self-efficacy is a dynamic concept and an individual's self-efficacy is influenced by his/her performance attainments, vicarious experiences, physiological state, and experiences of social persuasion (Bandura, 1986). Performance attainment relates to the effect of behaviour on self-efficacy. When a person succeeds at a task that they perceived to be difficult, their self-efficacy increases. Similarly, if a student fails at what they consider is a simple task, or repeatedly fails at any task; his/her self-efficacy regarding future attempts to complete that task is reduced (de Boer, 1987). A key feature of self-efficacy is the individual's perception of the effort expended on the task. For example, if a student believes he/she expended a high level of effort on a task and still failed, then his/herself-efficacy will decrease. However, if a poor performance is perceived to be due to lack of effort, the students' self-efficacy may not be affected. Also if an individual has high self-efficacy with respect to the task, they may attribute failure to strategy rather than ability. For example, a student may believe that his/her poor performance in a first-year chemistry course was due to lack of effort; such student may still have high self-efficacy toward passing a second-year chemistry course.

Vicarious experiences also influence an individual's self-efficacy. If a student observes peers of similar ability succeeding at a task, this leads to an increase in the students' self-efficacy. In contrast if the same student observes a peer failing at a task, then their self-efficacy will decrease (Bandura, 1986). By decreasing the self-efficacy of the individual their behaviour to the task has changed, thus increasing the likelihood of perceived failure consequently confirming their inefficacious beliefs. For example if a student sees a peer, who they believe to have a lesser ability in chemistry, getting a high grade in the first-year course, but they get a low grade then their self-efficacy will decrease. Vicarious experiences are often used by an individual as a measurement of ability when factual evidence is unavailable.

Social persuasion can also influence an individual's self-efficacy, although the power of this is limited compared with vicarious experiences. Social persuasion only contributes to efficacious beliefs if the persuasion is realistic. Consider a student told by an academic they are likely to do well in a course. This may result in an initial increase in self-efficacy toward passing a first-year chemistry course. However, if the student subsequently fails the course, then their self-efficacy may decrease below their initial level. A students' physiological state also influences their self-efficacy. So, for example, a high stress situation like sitting a final examination produces physical stress on the body, which in turn lowers an individual's self-efficacy.

3.3.4 Learning Experiences

Learning experiences are defined as any experience in a tertiary chemistry environment that results in a belief formation about chemistry (as defined in Section 3.3.1, p. 48) - where that belief is attitudinal, knowledge, or skill based. Learning experiences thus are concerned with perceptions students have about course content, and the manner in which it is presented in the three different university learning contexts, namely, lectures, laboratory classes and tutorials.

3.4 Behaviour and Behavioural Change

The study of human choices is unequivocally complex, with a variety of thought processes both conscious and subconscious involved in an individual's decision-making (Horowitz & Bordens, 1995). To illustrate, consider a tertiary student's intentions to enrol in a second-year chemistry paper. It maybe reasonable to assume that a tertiary student who found his or her first-year chemistry class interesting, would be likely to enrol in a second-year chemistry course. However, other events, such as a full timetable of compulsory courses, may make such a course of action impossible. Predicting and explaining people's behavioural choices has been subject to extensive research. Such research has included the development of models and theories that attempt to encompass all aspects of people's decision-making (Ajzen, 1989; Crawley & Koballa, 1994; Lent, Brown & Hackett, 1994).

There are a number of models that have been developed to understand behaviour and behavioural change in science education (Shrigley & Koballa, 1992). In this work three models were evaluated; Hovland's *Learning Theory Model* (LTM), the *Social Cognitive Model* (SCM) of career and academic interest, and the *Theory of Planned Behaviour* (TPB) (Ajzen, 1989; Lent, Brown & Hackett, 1994; Shrigley & Koballa, 1992).

3.4.1 The Learning Theory Model

Much research into the effects of attitude on behaviour in science education is based on Hovland's LTM (Shrigley & Koballa, 1992). The LTM approach considers the question: Who (source) says what (message) to whom (recipient), how (method) and with what effect (attitude/behaviour)? Comparing each component of this question with attitudinal or behavioural changes enables the study of the effect of persuasive messages (e.g., lecture learning experiences) on attitudes and subsequent behaviour, (e.g., enrolment in second-year chemistry courses). However, there is very little current research based on the LTM because of its positivist origins. The LTM does not, for example, allow for contextual factors and assumes a cause-and-effect relationship between persuasive message and attitude. This simple model was not deemed appropriate for the present work because it does not take context into account nor does it consider internal influences, such as the effect of self-efficacy on behaviour change.

3.4.2 The Social Cognitive Model of Career and Academic Interest

The SCM was developed from Bandura's (1986) work on self-efficacy and used to explain behaviour based on a constructivist view of learning. The SCM is useful in that it relates learning experiences, self-efficacy and outcome expectations to behavioural choices, through interest, goals and actions all within contextual influences (Lent, Brown & Hackett, 1994). There has been considerable use of the SCM in the area of career choices in recent times in particular seeking to understand why students choose to enrol in secondary and tertiary education courses (Smith & Fouad, 1999; Lapan, Shaughnessy & Boggs, 1996; Lent, Brown & Gore, 1997). Thus the SCM would be quite appropriate for the work reported in this thesis. However, upon consideration, it was not used as a framework for the research because it was not clear how SCM would inform the research with respect to the effect of associates' attitudes and the influence of the compulsory nature of some of the courses.

3.4.3 Theory of Planned Behaviour

The *Theory of Planned Behaviour* (TPB) is an extension of Ajzen and Fishbeins (1980) *Theory of Reasoned Action* (TRA). The TRA and TPB were developed to explain weakness in the correlation between attitude and behaviour (Shrigley, 1990). The TPB suggests that behaviour is a result of intention that is in turn influenced by attitude-towards-the behaviour, perceived control over the behaviour (the individuals perception of the level of choice they have regarding the behaviour), and subjective norm (socialisation factor) (Figure 3.1).

The TPB has been used extensively in science education research but has a limitation in that it does not explicitly identify antecedents or potential antecedents of attitude-towards-behaviour and subjective norm. The TPB is, however, appropriate for use with a constructivist-based study in that it takes into account social and contextual factors and suggests that intention and subsequent behaviour are constructed based on a variety of factors. However, the TPB is limited in terms of answering the research questions regarding learning experiences and self-efficacy.

After due consideration of all three models the LTM was considered inappropriate, because of its positivist origins and simplistic cause and effect nature. The SCM and TPB were both considered more appropriate because they are based on constructivist beliefs, although it was recognised that neither model directly addresses the research questions for the study. The TPB was eventually

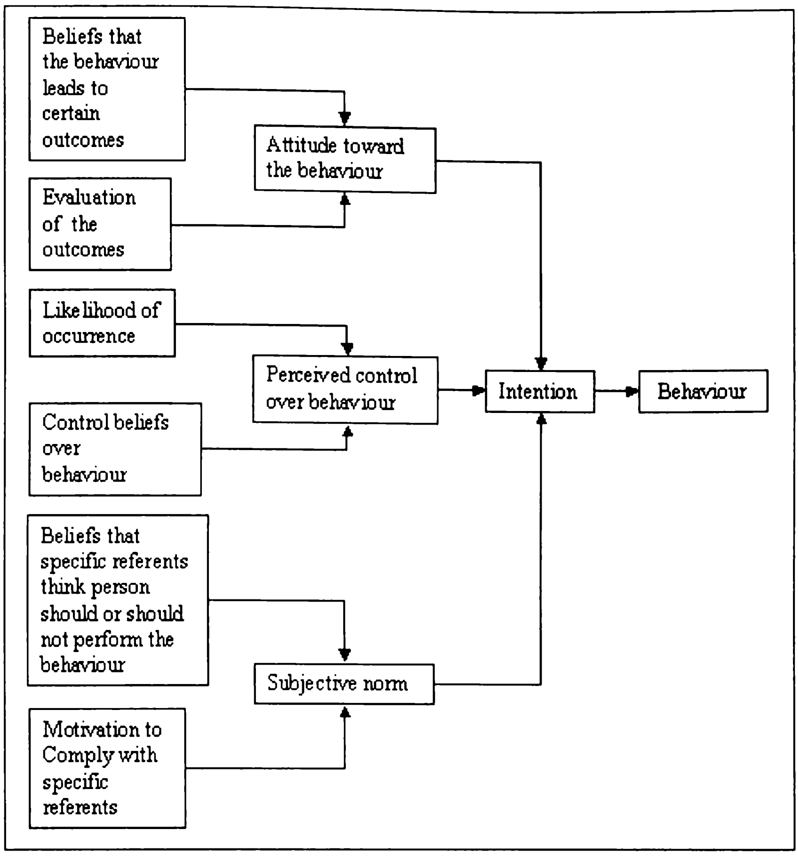

Figure 3.1

The *Theory of Planned Behaviour* (TPB). From Ajzen (1989).

chosen for fairly pragmatic reasons; namely, it was easier to modify and because of its wide use in science education literature.

3.5 Modified Theory of Planned Behaviour

The theoretical framework used for this study was a modified TPB, named the *Modified Theory of Planned Behaviour* (MTPB). The MTPB, which incorporates some concepts from SCM including the influence of self-efficacy and learning experiences on the TPB, is presented below (Figure 3.2). That is, the MTPB suggests that attitude-toward-enrolling in chemistry, perceived control over enrolling in second year chemistry and subjective norm contribute to student intentions to enrol in second year chemistry. Furthermore, learning experiences

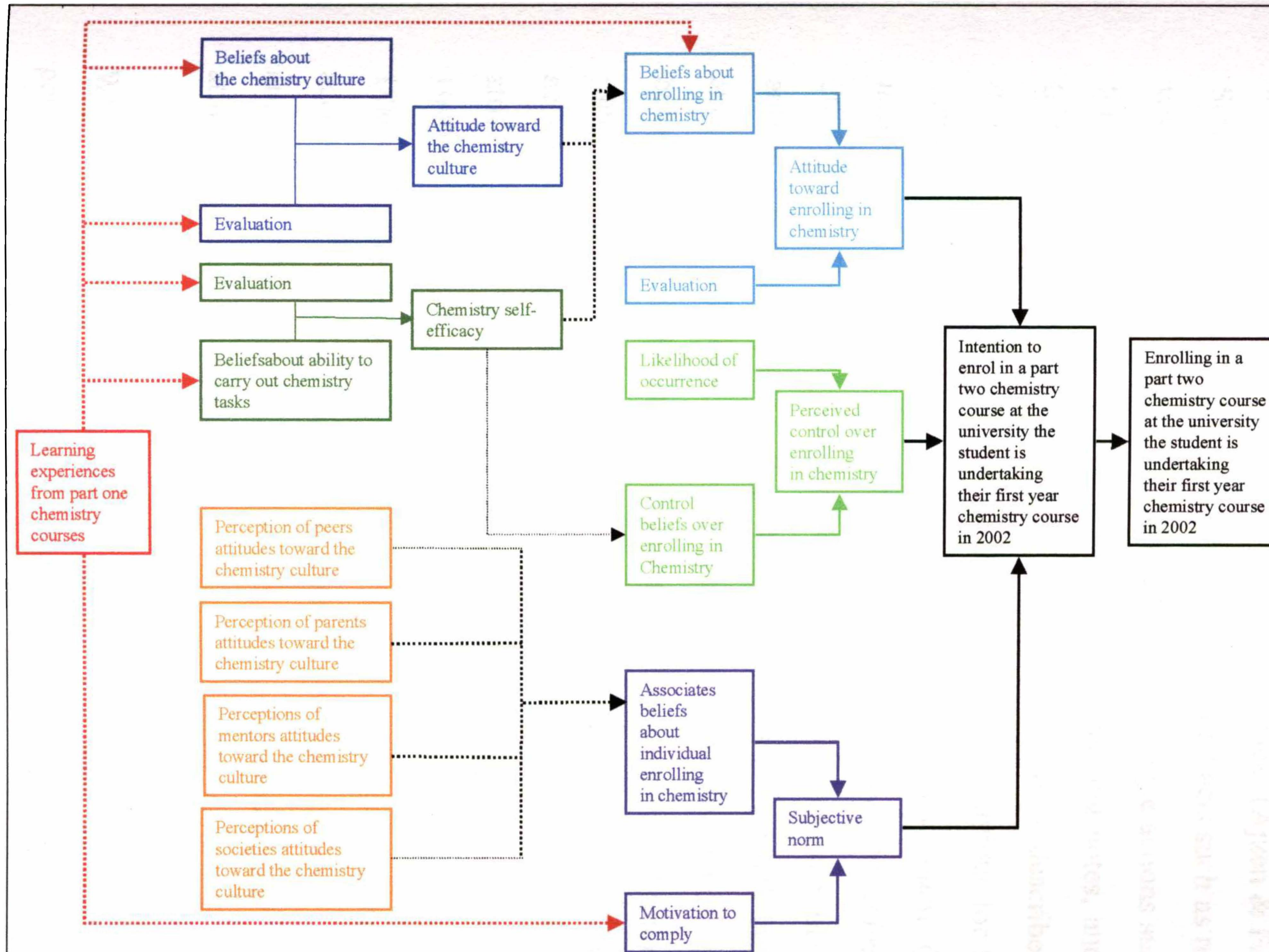

Figure 3.2

The *Modified Theory of Planned Behaviour* (MTPB). Based on the *Theory of Planned Behaviour* (TPB) from Ajzen (1989).

influence attitude-towards-enrolling in second year chemistry, both directly and indirectly through chemistry self-efficacy and attitude-towards-chemistry.

3.5.1 Behaviour

The focus of the MTPB is behaviour - behaviour classified as either a single action or as a behavioural category (Figure 3.2, black) (Ajzen & Fishbein, 1980). Single actions are behaviours that are singular target acts such as reading a book, whereas behavioural categories are a collection of single actions such as studying for a test, which might include reading a book, making notes, and so forth. In this inquiry behaviour was defined as a single action - described in terms of *action*, *target*, *context* and *time*. Thus the desired behaviour for this inquiry is defined as: *Enrolling* (action), *in a part two chemistry course* (target) *at the university the student is undertaking their first-year chemistry course* (context) *in 2002* (time).There has been much research reported in the literature on the antecedents of behaviour with particular emphasis on the link between attitude and behaviour (Shrigley, 1990). There seems little doubt that attitude effects behaviour, but this does not mean that attitude is the sole predicator of behaviour - and other factors are clearly influential - for example, an individual's ability to achieve the desired behaviour. Some authors suggest that attitude is behaviour, attitude follows behaviour, and attitude and behaviour are reciprocal (Shrigley, 1990). The attitude is behaviour proposition was first proposed by Larkin in the 1880s and was based on the conjecture that an individual's private thoughts are accessible to others, as they can be observed through behaviour. The view that attitude follows behaviour, likewise assumes that knowledge of an individual's attitudes can be learnt from observation of their behaviour.

Whilst behaviour is an aspect of attitude formation (Pratkanis, 1989) the perspective that attitude and behaviour are reciprocal, is perhaps more appropriate. However, the proposition that attitude is related to behaviour only through intention (which is the basis of the TPB) is borne out in science education studies more than the view that the relationship between attitude and behaviour is reciprocal in nature (see, e.g., Koballa, 1986). Like behaviour, intention can be described in terms of action, target context and time. Thus, for the purpose of this inquiry the intention is described as *the intention to enrol in a part two chemistry course at the university the student is undertaking their first-year chemistry course in 2002* (Figure 3.2, black). It is important to note that intention is not a static entity, and an individuals' intention(s) are subject to change, particularly if there is a large time gap between measuring the intention and observing the behaviour one believes arise as a result of that intention. For example, if in this inquiry the intention is measured at the end of the New Zealand academic year in October and behaviour was not observed until March the following year, then a students' experiences during the four-month semester break may influence his or her behaviour (e.g., because they worked in chemistry laboratory during the summer vacation).

3.5.2 Attitude-Towards-Behaviour

Attitude-towards-enrolling in second-year chemistry has been identified as one of the three antecedents of intention in this study (Figure 3.2, light blue). As mentioned above, attitude is considered to provide a direct and dynamic influence upon an individual's response. In this study, response is intention to enrol in a part two chemistry course at the university the student is undertaking their first-year chemistry course in 2002 (i.e., enrolling in second-year chemistry). It is important to distinguish between attitude-towards-enrolling in chemistry and attitude-towards-chemistry. Attitude-towards-chemistry can contribute to attitude-towards-enrolling-in-chemistry but is conceptually distinct. The difference is subtle and is best illustrated with an example. A student may believe having a second-year chemistry paper in their degree will help them get employment in the biological sciences (attitude-towards-enrolling in second-year chemistry), but have little interest in chemistry itself as a subject of as a career (attitude-towards-chemistry).

Antecedents of attitude-towards-enrolling in second-year chemistry are the individual's salient beliefs about enrolling in second-year chemistry. Beliefs can be categorised as salient and non-salient beliefs, where salient beliefs contribute to attitude, and non-salient beliefs do not (Ajzen & Fishbein, 1980). To illustrate, consider a student that holds a salient belief that studying chemistry is very difficult and thus his or her attitude-towards-enrolling in chemistry is negative. Such a student may also have a non-salient belief that chemistry majors have good career prospects, but this latter belief is less likely to contribute to the student's attitude-towards-enrolling-in-chemistry. Individuals also evaluate each of their salient beliefs, some being perceived to be more important than others. For example, if a student has the following salient beliefs about enrolling in chemistry; taking second-year chemistry will get me a good job, and chemistry study is boring; whether or not the student has a positive attitude-towards-enrolling-in-chemistry, will depend on the relative status attributed the two salient beliefs.

3.5.3 Antecedents of Beliefs About Enrolling in Second-Year Chemistry

The MTPB suggests that there are two main belief types that contribute to students' salient beliefs about enrolling in second-year chemistry: attitude-towards-chemistry (Figure 3.2, dark blue) and chemistry self-efficacy (Figure 3.2, dark green). Whilst these two factors likely contribute to attitude-towards-enrolling in second-year chemistry to some extent, the link is not definitive and it is therefore represented by dashed lines in Figure 3.2.

Defining attitude-towards-science or chemistry is problematic with Haladyna and Shaughnessy (1982), for example, providing six different definitions of attitude-towards-science; adoption of scientific attitudes, attitude-towards-a method of teaching science, scientific interests, attitude-towards-parts of the curriculum and attitude-towards-the subject of science. In this study I have chosen to define attitude-towards-chemistry as attitude-towards-the chemistry culture using the definitions of attitude and chemistry provided above. Like attitude-towards-enrolling in chemistry, attitude-towards-chemistry is determined by an individual's salient beliefs about chemistry. Using the definition of attitude and chemistry described above, four types of salient beliefs have been identified; beliefs about chemistry: beliefs about the people teaching the chemistry culture, beliefs about the knowledge and skills of chemistry, and beliefs about the values of the chemistry culture. Attitude-towards-chemistry likely contributes to students' salient beliefs about enrolling in second-year chemistry. For example, it is reasonable to suggest that a student who believes chemists are not environmentally aware may be less inclined to be associated with such a discipline.

The other antecedent of beliefs about enrolling in second-year chemistry identified in the MTPB is chemistry self-efficacy. The self-efficacy of interest in this work relates to students' perception of their ability to undertake a second-year chemistry course. Antecedents of chemistry self-efficacy are beliefs about studying chemistry - where those beliefs are based on the student's perception of their ability in carrying out a particular behaviour - in this case obtaining a passing grade in a second-year chemistry course. Therefore students' beliefs are dependent on their perceptions of the tasks that are required of them in a chemistry course, for example, applying chemistry theory to laboratory experiments.

3.5.4 Perceived Behavioural Control

Some student's may not perceive they have any choice regarding taking second-year chemistry course. The extent to which this is the case is termed *perceived behavioural control* and is defined as "the perceived ease or difficulty of performing the behaviour" (Ajzen, 1989, p. 251). Perceived behavioural control is determined by control beliefs, which are beliefs about the control a person has over their behaviour. To illustrate, consider a student who wishes to do an environmental science programme, for which a particular second-year chemistry paper is compulsory. Such a student has little or no control over enrolling in that second-year chemistry course. Control beliefs are formed either based on past experience, or anticipated problems (Ajzen, 1989). For example, a student may not consider enrolling in second-year chemistry after failing a first-year chemistry test, anticipating that they will not meet the entry requirements for second-year chemistry (past experience) or because the they have a full programme of compulsory courses, and so do not think that they will have the time to take another paper (anticipated problem). A student may have a number of control beliefs, but his/her perceived behavioural control is dependent only on the likelihood of the beliefs occurring. Thus, if it is unlikely that a second-year chemistry course will have a timetable clash with second-year biology course, then the control belief that a biologist cannot take second-year chemistry because it will clash with their biology programme will not be a large contributor to perceived behavioural control.

3.5.5 Antecedents of Perceived Behavioural Control

As mentioned above, chemistry self-efficacy is proposed to be an antecedent of perceived behavioural control in that if a student perceives he/she does not have the ability to meet the academic requirements to enrol in a course then the student will have a control belief that they cannot enrol in the course. It is important to note that there is a difference between self-efficacy derived control beliefs and attitude beliefs. Control beliefs are based on a perception of a barrier towards, in this case, studying chemistry, whereas attitude beliefs are based on a student's perception *about* studying chemistry. To illustrate consider two students, one whom believes he/she will not pass first-year chemistry, and the other that believes passing a second-year chemistry course will be very difficult. The first student has a control belief that he/she will not obtain a passing grade in a prerequisite course for second-year chemistry, and therefore will not be able to enrol in second-year chemistry. The second student has an attitude belief that it will require a lot of work to pass the second-year chemistry course; this is not a barrier to the student enrolling in the course, but is a belief that may impact on the student's enrolment decision making.

3.5.6 Subjective Norm

An individuals' behaviour is determined by more than just attitude, and is affected by social influences – termed subjective norm (purple, Figure 3.2). Subjective norm is an individual's perception of their associates' attitudes (e.g., peers, family, mentors) (Ajzen & Fishbein, 1980). An individuals' subjective norm is based on the relative importance of the normative beliefs of their salient associates (i.e., their associates' behavioural recommendations). Salient associates are associates whose normative beliefs are influential in determining subjective norm, where the impact of salient associates on an individual's subjective norm is dependent on the motivation an individual has to comply with each of their associates' attitudes. For example, a student's parents may think he or she should study chemistry, but the students' peers may think otherwise. If the student values his/her parents' views more than those of his/her peers, then his/her subjective norm would be to study chemistry.

3.5.7 Antecedents of Subjective Norm

In this work the notion of subjective norm has been expanded to assume that a normative belief can be formed not only by direct behaviour (e.g., my parents told me to take chemistry), but also by inference (e.g., my parents think chemists are responsible for many environmental disasters, therefore they would not like me to study chemistry). Consequently, it is appropriate to include media beliefs as contributing normative beliefs. Although it is nonsensical to claim, "the media thinks I should take chemistry" it is reasonable to assert, "the media portrays chemistry research as a valuable part of society, therefore I will be respected if I study chemistry." In this study major salient associates are parents, peers, mentors and society where mentors are defined as people who are role models for the students (e.g., previous teachers, family friends, employers, etc.).

3.5.8 Predicting Intention from its Antecedents

To recap, the three antecedents of intention are, attitude-towards-the behaviour, perceived behavioural control, and subjective norm. However, each of these components may predict a different behaviour. Consider, a student that believes chemistry is a valuable subject in their degree – such a student will likely have a positive attitude-towards-enrolling in chemistry – resulting in a prediction of intention to enrol in second-year chemistry. If the student has parents that are chemists or work in a chemistry-based industry, and the student perceives that his/her parents would like him/her to enrol in chemistry - this would likewise likely result in a prediction of an intention to enrol in second-year chemistry. However, the student may be enrolled in a highly structured specified programme that has no requirement for chemistry at the second-year level - this would result in a prediction of an intention not to enrol in second-year chemistry. Intention is thus determined by the relative importance an individual places on a number of potentially competing antecedents. So, if the above student values undertaking the animal behaviour programme highly, and their attitude-towards-enrolling in chemistry less so, and parents opinion even less, we can predict that the student will not intend to enrol in a second-year chemistry course.

3.5.9 Influence of Learning Experiences

A key research objective for this inquiry is to understand what influence first-year learning experiences in chemistry have on students' second-year chemistry enrolment behaviour. The MTPB suggests that these learning experiences will affect enrolments through a number of factors; attitude-towards-chemistry, chemistry self-efficacy, attitude-towards-enrolling in chemistry and these will in turn influence the evaluative components of the students' subjective norm and perceived behavioural control (Figure 3.2, red). Like antecedents of beliefs about enrolling in second-year chemistry, the relationship between learning experiences and all these components is tentative, and therefore is represented by dotted lines in Figure 3.2.

Learning experiences may influence a students' attitude-towards-chemistry in that new salient beliefs may be generated based on his/her observations of chemistry practitioners (i.e., academic and other teaching staff). For example, if an academic staff member encourages a student to dispose of waste chemicals carefully this may influence the student's attitude-towards-chemists and the environment. Learning experiences also influence chemistry self-efficacy in that a student's perception of their ability at chemistry tasks is strongly related to their experiences of in first-year chemistry. For example, a student that finds it difficult to write up a first-year laboratory experiment, may consequently think chemistry is a difficult subject to study. Such an experience lowers the student's self-efficacy about passing a chemistry course. Learning experiences will also directly affect attitude-towards-enrolling in second-year chemistry by generating new salient beliefs about enrolling in second-year chemistry. Consider a student, who enjoyed his/her first-year chemistry course. Such student would likely think that taking second-year chemistry would be enjoyable based on that experience. Students' learning experiences also influence the evaluation components of subjective norm and perceived behavioural control. Students will place more or less importance on these factors depending on their first-year chemistry learning experiences. For example, a student may be more inclined to take a compulsory chemistry course or may place more importance on his/her parents' opinion that second-year chemistry is a good thing to do, if the student has encountered positive learning experiences in his/her first-year chemistry course.

3.6 Chapter Review

Before beginning to investigate the research problem, namely what influence, if any, do first-year chemistry learning experiences have on students' enrolment choices, the ideology behind the research was constructed. This involved examining the ideology of the researcher, defining important terms used throughout the thesis, and deriving and describing the guiding theoretical framework, the MTPB.

As the researcher subscribes to a constructivist epistemology, which states that knowledge is a construction of the individual, all research was carried out within an interpretivist paradigm. That is, I acknowledge that the entire research process is influenced by my own beliefs, and that all analysis and findings are my interpretations.

As this research is carried out within a interpretivist framework it was necessary to outline the definitions of the terms that are used within this thesis. Attitude is derived from Allport's definition that incorporates behaviour, and the construction of attitude beliefs deemed to occur from both direct experiences and elaboration on those experiences (Horowitz & Bordens, 1995; Petty & Cacioppo, 1981). Understanding of self-efficacy was largely informed by the pivotal work of Albert Bandura, and was defined as the perceptions of ones own ability to carry out a specific task (Bandura, 1986). Finally, learning experiences were defined by the context of the inquiry (Chapter 1, Section 1.6, p. 6), and incorporate any experience a student had that involved learning chemistry within the university setting.

The major feature of this chapter was the description of the theoretical framework that guided the research, the MTPB. The MTPB has evolved around the notion that the major influence on student enrolment choices is their enrolment intentions. These enrolment intentions are influenced by their attitude-towards-enrolling in chemistry, their perceived behavioural control over enrolling in chemistry and their subjective norm about enrolling in chemistry. These are influenced by students' attitudinal, control and normative beliefs respectively. Attitude-towards-chemistry and chemistry self-efficacy both have some influence on attitudinal beliefs about enrolling in chemistry. Similarly, learning experiences can contribute to attitudinal beliefs about enrolling in chemistry, as well as efficacy and attitudinal beliefs about chemistry. It is the MTPB that provided the theoretical framework from which the methodology is derived (Chapter 4, p. 65).

3.7 Chapter Summary

This chapter discussed theories of learning and paradigms and provided definitions for a variety of terms used in the thesis: the notion of a chemistry culture, attitude, and self-efficacy. Next was a discussion of potential theoretical models along with a detailed discussion of the MTPB, the model used as a theoretical framework for the thesis. Chapter 4 that follows provides a detailed account of how methods used in this study, those methods being derived from the theoretical framework described above.

CHAPTER 4
METHODOLOGY

This chapter describes the methodology used in this inquiry. It builds upon the theoretical framework described in Chapter 3, in that it describes the methodology and derives the methods from the ideologies presented in Chapter 3. It begins with a definition of methodology that underpins this chapter, and then discusses this definition in terms of paradigm belief systems and specific methods. This is followed by the justification for methods used in this work and the chapter concludes with a discussion of the issues of validity and reliability and the means taken to ensure the trustworthiness of the study, along with a description of the ethical issues identified.

4.1 Methodology

The concept of methodology differs from that of method in that the former is considered to provide the underlying thinking behind the method (Guba & Lincoln, 1989). The definition of methodology used here is derived from Shulman's (1988) discussion of *disciplined inquiry*. Disciplined inquiry, refers to inquiry, namely, "ordered, regular or principled nature of investigation" (Shulman, 1988, p. 5), and to the principles of discipline:

> The manner in which they formulate their questions, how they define the content of the domains and organize that content conceptually, and the principles of discovery and verification that constitute the ground rules for creating and testing knowledge. (Shulman, 1988, p. 5)

This definition is useful and appropriate for this inquiry as it relates the methodology to the researcher, and is consistent with a belief that methodology represents the practical component of a paradigm as well as incorporating the notion that methodology involves understanding of the process of inquiry (Cohen, Manion & Morrison, 2000; Guba & Lincoln, 1989). This definition also suggests that methodology must consider the content domain, the way data is collected, and the validity of the conclusions. Therefore a discussion of methodology must consider all these factors.

4.2 Interpretivism and the Researcher's Influence on Methodology

As stated in Chapter 3, the methodology used in an inquiry represents the practical component of a paradigm belief system. Guba and Lincoln (1989) defined methodology as:

> The overall strategy for resolving the complete set of choices or options available to the inquirer. Far from being merely a matter of making selections among methods, methodology involves the researcher utterly – from unconscious worldview to enactment of that worldview via the inquiry process. (p. 183)

As stated previously (Chapter 3, Section 3.2.1, p. 43) there are two extremes of paradigm belief systems, positivism and interpretivist.

Positivists use inquiry methods that are based on discovery from which hypotheses are derived, and theories are then formulated. Specific methods are chosen to test the theories and these methods are implemented under controlled conditions on a representative or random sample of respondents. The 'instrumentation' is objective and the data analysis occurs after data collection to avoid 'contamination' by the researcher. The results are formulated, then compared with original hypotheses. If the results are found to be consistent, the theories are deemed to be verified. If the results are found to be inconsistent with the theories, the theories may then modified and then re-tested. Thus in positivistic research verification is based on an internally consistent validation process.

An interpretivist-based methodology, based on a constructivist epistemology, in contrast is more holistic in nature. From this viewpoint, the research process is seen to be influenced at all stages by different elements of the context - the researcher, the participants, and the context of the inquiry (Guba & Lincoln, 1989). Data analysis is not seen as independent of data collection, but as a 'dynamic partner' that is influenced by data collection and, in turn, influences subsequent data collection processes. Validation occurs at all stages of the inquiry, and the research design is not necessarily apparent until after data collection and analysis are complete. Reports about the inquiry are written in collaboration with research stakeholders including the participants. It is these latter constructivist-based principles that guided the methodology for the research reported in this thesis.

4.3 Method Design

Method design, and indeed methodology, is derived from the research questions, and the 'best' method employs a method typology that best addresses the research questions or objectives (Patton, 1990). Patton identifies a number of method typologies; those most relevant for this research are applied research and formative evaluation (Patton, 1990). Patton (1990) describes the purpose of applied research as "to generate potential solutions to human and societal problems. (p. 184)." From an applied research perspective, the purpose of this thesis is to understand the nature and sources of influences on students' enrolment choices. Formative evaluation aims to produce recommendations to help improve a 'situation': in this case - first and second semester first-year chemistry courses (in order to improve retention of chemistry students). Using a mixed typology influences the specific methods of the inquiry used in the study, as the inquiry must be academically rigorous, as well as being seen to be useful by stakeholders, such as academic staff.

4.3.1 Limitation of Methods

The choice of method is determined to some extent by the limitation of different tools. For example, the two key method categories, quantitative and qualitative methods, both have their inherent strengths and weaknesses. The large proportion of the population that can be accessed by quantitative research methods gives an overview of a situation and enables generalisations to be drawn about the whole population. However, quantitative methods typically do not access why and how situations have developed. Qualitative methods, which typically gather detailed data from few members of the population, can give this level of detail, but the small sample sizes limits the generalisability of the findings (Cohen, Manion & Morrison, 2000).

4.3.2 Triangulation of Data

Triangulation involves investigation of the research objectives or questions using a number of different tools (Malhotra, 1993). The main purpose of triangulation is to increase the validity of conclusions drawn from the study, and Patton (1990) identifies four different types of triangulation: data triangulation, investigator triangulation, theory triangulation, and methodological triangulation. Each type of triangulation involves using more than one type of research tool. For example, data triangulation uses different data sources, investigator triangulation uses different investigators, theory triangulation uses different theories in research design, and methodological triangulation uses different methods. Although triangulation offers many advantages – for example, as mentioned above, it adds to the validity of conclusions drawn from the data, it is not always practical (or necessary) to carry out all four forms of triangulation. The most common form of triangulation is methodological triangulation and inquiries employing this form of triangulation are commonly referred to as being of mixed-methodology.

4.3.3 Mixed-Methodology Approach

Mixed-methodology research involves using more than one type of method in the research design. Typically this involves the use of qualitative and quantitative methods at the same time. Proponents of mixed-methodology research argue that such an approach insures data triangulation (as discussed above) and results in a greater understanding of a given context (Gogolin & Swartz, 1992). Interestingly, Coll (2000) has compared this to mixed-methodological approaches common in science, for example, the use of multiple instrumental techniques to identify the structure of unknown chemicals. Proponents of a mixed-methodology approach suggest that similar advantages are achieved in social science research (Mason, 1993). In summary, using a mixture of qualitative, quantitative methods helps to minimise the impact of the inadequacies of individual methods on the research, as well as resulting in a better understanding of the context of the inquiry.

Historically, some researchers remain unconvinced of the merits of mixed-methodology research believing that mixing methodologies is epistemologically unsound (Ebye & Schmidt, 2001; Smith, 1983). These authors argue that quantitative and qualitative methods are derived from positivist and interpretivist paradigms respectively, and are therefore inherently incompatible. For example, Ebye and Schmidt (2001) argue that quantitative research cannot be interpretivist-based as they suggest that the notion of constructivism and quantification are contradictory. According to this view, psychometric analyses inherent in quantitative research are inconsistent with the assumption that the research and subject have different frames of reference. Although this is, from a constructivist viewpoint, an apparently reasonable statement, there is no allowance for shared meaning in this argument. Social-constructivists, however, allow for the possibility that both the researcher and the research participants can have a similar understanding of the concepts (Solomon, 1994). Other researchers suggest that quantitative and qualitative methods can be employed in the same research, but cannot be used for data triangulation as the methods are so different, meaning that the results cannot be directly compared although they do give different perspectives on a similar problem (Mason, 1993).

4.3.4 The Nature of Statistical Analysis and Quantitative Data

Quantitative methods of analysis, like qualitative methods, require careful consideration with respect to issues of validity. Examination of the literature on this issue reveals two areas of concern. First, is the question of how to treat data: specifically, is it valid to treat ordinal level data generated from surveys as interval data; and second, to what extent can we draw conclusions from tests of statistical significance?

In science education quantitative data is traditionally treated as if it were interval level data, and employing statistical methods of analysis such as the student t-test and ANOVA (see, e.g., Lent, Brown & Gore, 1997). However, data from education survey instruments is more commonly ordinal level and there are two assumptions inherent in treating ordinal level data as interval level data. First, it is assumed that any respondents with the same pole and strength of belief will mark the same response on a Likert or semantic differential scale. Second, it is assumed that the 'weighting' between each of the possible responses is equal for every respondent. Although statistical tests like Cronbach's α reliability investigate participant's responses as a whole, for an individual participant the validity of such an assumption is unknown. It is because of this that researchers like Argyrous (1997) suggest that to be statistically rigorous data generated from surveys should always be treated as ordinal level. However, treating data as ordinal level is not without problems. In surveys with relatively small numbers of respondents (ca. 100-200, as in this work), it becomes necessary to collapse data fields into rather meaningless groups in order to use ordinal level tests such as χ^2. Thus, treating data as interval level when it is in fact ordinal level, although suffering from some validity problems due to the above issues, enables researchers to use tests that are more appropriate for smaller samples.

Treating data as interval level means that tests such as ANOVA (and, in larger samples MANOVA) can be used. Such methods give results that are termed 'statistically significant'. There has been much discussion in the literature on the extent to which one can draw conclusions from statistically significant results (see, e.g., Carver, 1978). In reality, tests for statistical significance make assumptions that most data sets fail to meet. For example, tests of statistical significance require a truly random sample, with results forming a normal distribution around the mean value for a given parameter. There also is much confusion about the meaning of the term statistically significant, and much careless use of the term in the literature. A statistically significant difference means that there is a low probability that the null hypothesis is rejected (i.e., no difference between the variables). But this does not mean that there is a high probability that there is a difference between the variables. Carver (1978) provides an excellent discussion of this issue and goes on to note that statistical significance does not necessarily translate into educational significance. That is, a statistically significant finding does not necessarily mean that the results have consequences for education. In response to Carver and other critics of statistically significant tests, Rennie (1998) makes a number of recommendations to address the relationship between statistical significance and educational significance, and improve the interpretation and reporting of quantitative data. Rennie first recommends that researchers be careful about their use of terminology, particularly in the usage of the term *significant*. Although significant is routinely used by quantitative researchers to mean statistical significance, it is often used in a less formal sense to mean merely 'significant' (in other words 'important'). A more appropriate term may be *educationally significant* - referring to findings which are important to, or impact upon, education. Rennie (1998) suggests that researchers are clear about their meaning of significant, and encourages the use of prefixes such as 'statistically' and 'educationally', avoiding using the single term significant in an informal sense. Second, Rennie suggest that researchers ensure they provide sufficient information about their data in order to facilitate data interpretation. For example, means of variables should always be accompanied by standard deviations, and all quantitative data should include N values. Third, Rennie points out that data collection should be replicated wherever possible. If this is not feasible (for the usual reasons of economy, time etc., see Shulman, 1998), statistical methods that examine likelihood of replication, such as 'boot strap' and 'jack-knife' can be used. Rennie cautions that these methods are not good replacements for replication, but recognises the limitations of any research endeavour may preclude this. Finally, Rennie suggests that effect magnitudes be reported and interpreted in conjunction with tests of statistical significance. Analysis based on effect size (or effect magnitude) attempts to address concerns about the relationship between sample size and statistical significance. As Rennie puts it: "The larger the sample, the smaller the sampling error and the more likely that the calculated statistic will be statistically significant (pp. 240-241)." Consequently, a statistically significant finding is not necessarily a large observable effect, or even important in terms of the research questions/objectives. The corollary of this also is true; a large observable effect or an important finding

in terms of the research questions is not necessarily statistically significant. Simply put, a statistically significant finding suggests that the difference between variables is not zero; whereas statistical tests that examine strength of association give a measure of effect size - the higher the level of association - the larger is the effect. It is important to note that there are a number of statistical measures termed 'effect size', including Cohen's d, which is used in experimental research, and measures of association such as R^2 and, most common η^2. Reporting effect size values generally aids data interpretation but possesses both advantages and disadvantages. For example, unlike statistical significance, where findings with a $p<.05$ are generally deemed significant, there are no pre-determined η^2, R^2 or d values that suggests 'an effect'. It is up to the researcher to define what effect size is likely to be educationally significant within their own context. This makes interpretation of effect size analysis problematic for some researchers, as it introduces an concerns about subjectivity into quantitative research.
General

4.3.5 Longitudinal Research

As well as choosing a method in research design, the manner in which the method is administered needs to be considered. Research that is interventionist (whether the intervention is a contrived experimental situation or an evaluation of a current situation – as in this case) or that is interested in changes of attitude or beliefs, benefits from a longitudinal or cross-educational approach (Cohen, Manion & Morrison, 2000). Longitudinal research involves repeated measurement of the same sample, whereas cross-educational research (also known as cross-sectional research) takes unique samples from the population at each observation point. Often longitudinal (or cohort) research is seen as an ideal method, in that it is seen to be more suitable for 'causal' research and can, for example, be used to observe developmental change. Cohen and Manion (1994) suggested that longitudinal research is useful because it "shows how changing properties of individuals fit together into changing properties of social systems as a whole (p. 71). However, longitudinal research suffers from a number of disadvantages: it is very time consuming and hence expensive; there is often has a high attrition rate among participants; and, repeat testing may influence participants' responses. Despite these disadvantages, longitudinal research is still seen as useful, and many science education researchers strongly advocate the use of longitudinal methodologies (see, e.g., Schibeci, 1989).

4.4 Content Domain

Trochim (1999) recommends that when designing a research method, particular care should taken to ensure the content domain of the research is fully examined, where the content domain is defined as all issues relevant to the research problem. The research problem reported in this thesis is concerned with understanding the influence of chemistry learning experiences on student enrolment choices. The thesis comprises an investigation of first-year chemistry students' chemistry learning experiences and enrolment choices, including students enrolled in a second-year analytical chemistry course. The content domain of this thesis, and consequently the research questions were derived from the *Modified Theory Of Planned Behaviour* (MTPB) (Chapter 3, Section 3.5, Figure 3.2, p. 56). The MTPB was broken down into five compartments and the research questions are defined by these five components (Table 4.1). The first research question was defined from the modified precursors of the TPB: namely, learning experiences (red, Figure 3.2), attitude-towards-chemistry (dark blue, Figure 3.2) and chemistry self-efficacy (dark green, Figure 3.2). The second and third research questions were derived from attitude-towards-enrolling in second year chemistry (light blue, Figure 3.2) and perceived control over enrolling in second-year chemistry (light green, Figure 3.2) respectively. The fourth research question covered the components of the MTPB that relate to socialisation factors, that is associates attitude-towards-chemistry (orange, Figure 3.2) and subjective norm (purple, Figure 3.2). Finally, the fifth research question was derived to examine the impact of attitude-towards-enrolling in second-year chemistry (light blue, Figure 3.2), perceived control over enrolling in second-year chemistry (light green, Figure 3.2) and subjective norm (purple, Figure 3.2) on students' intention to enrol in second-year chemistry (black, Figure 3.2).

Table 4.1

Research hypotheses and exploration statements as derived from research questions and objectives.

1	**What are student first-year chemistry learning experiences, attitude-towards-chemistry and chemistry self-efficacy, how does student background influence these and what influence, if any does student first-year chemistry learning experiences have on attitude-towards-chemistry and chemistry self-efficacy?**		
i	What are student first-year chemistry learning experiences?	E_1:	Explore student first-year chemistry learning experiences
ii	What influence, if any, does student gender, ethnicity, socio-economic background and enrolment reasons have on their learning experiences?	H_1:	Students of different gender have different learning experiences
		H_2:	Students of different ethnicity have different learning experiences
		H_3:	Students of different socio-economic background have different learning experiences
		H_4:	Students of who enrolled in the course for different reasons have different learning experiences
iii	What is student attitude-towards-chemistry?	E_2:	Explore student attitude-towards-chemistry
iv	What influence, if any, does student gender, ethnicity, socio-economic background and enrolment reason have on attitude-towards-chemistry?	H_5:	Students of different gender have different attitude-towards-chemistry
		H_6:	Students of different ethnicity have different attitude-towards-chemistry
		H_7:	Students of different socio-economic background have different attitude-towards-chemistry
		H_8:	Students of who enrolled in the course for different reasons have different attitude-towards-chemistry
v	What is student chemistry self-efficacy?	E_3:	Explore student chemistry self-efficacy
vi	What influence, if any, does student gender, ethnicity, socio-economic background and enrolment reason have on chemistry self-efficacy?	H_9:	Students of different gender have different chemistry self-efficacy
		H_{10}:	Students of different ethnicity have different chemistry self-efficacy
		H_{11}:	Students of different socio-economic background have different chemistry self-efficacy
		H_{12}:	Students of who enrolled in the course for different reasons have different chemistry self-efficacy
vii	What influence, if any, does student attitude-towards-chemistry have on learning experiences?	H_{13}:	There is a relationship between student attitude-towards-chemistry and learning experiences
viii	What influence, if any does student chemistry self-efficacy have on learning experiences?	H_{14}:	There is a relationship between student chemistry self-efficacy and learning experiences

2	**What are student attitude-towards-enrolling in chemistry and what influence, if any, does student first-year learning experiences, attitude-towards-chemistry and chemistry self-efficacy have on student attitude-towards-enrolling in second-year chemistry?**		
i	What is student attitude-toward-enrolling in second-year chemistry?	E_4:	Explore student attitude-towards-enrolling in second-year chemistry
ii	What influence, if any, does student first-year learning experiences have on attitude-towards-enrolling in second-year chemistry?	H_{15}:	There is a relationship between student first-year learning experiences and attitude-towards-enrolling in second-year chemistry
iii	What influence, if any, does student attitude-towards-chemistry have on attitude-towards-enrolling in second-year chemistry?	H_{16}:	There is a relationship between student attitude-towards-chemistry and attitude-towards-enrolling in second-year chemistry
iv	What influence, if any, does student chemistry self-efficacy have on attitude-towards-enrolling in second-year chemistry?	H_{17}:	There is a relationship between student chemistry self-efficacy and attitude-towards-enrolling in second-year chemistry
3	**Do students hold control beliefs about enrolling in second-year chemistry, if so what are they, and what influence, if any, do student first-year learning experiences, attitude-toward-chemistry and chemistry self-efficacy have on student perceived control over enrolling in second-year chemistry?**		
i	Do students hold control beliefs about enrolling in second-year chemistry?	H_{18}:	Students hold control beliefs about enrolling in second-year chemistry
ii	If students hold control beliefs about enrolling in second-year chemistry, what is student perceived control over enrolling in second-year chemistry?	E_5:	Explore student perceived control over enrolling in second-year chemistry
iii	What influence, if any, does student first-year learning experiences have on perceived control over enrolling in second-year chemistry?	H_{19}:	There is a relationship between student first-year learning experiences and perceived control over enrolling in second-year chemistry
	What influence, if any, does student attitude-towards-chemistry have on perceived control over enrolling in second-year chemistry?	H_{20}:	There is a relationship between student attitude-towards-chemistry and perceived control over enrolling in second-year chemistry
	What influence, if any, does student chemistry self-efficacy have on perceived control over enrolling in second-year chemistry?	H_{21}:	There is a relationship between student chemistry self-efficacy and perceived control over enrolling in second-year chemistry
4	**What are student perceptions of associates attitude-towards-chemistry and normative beliefs and what influence, if any, does student perception of associates attitudes-towards-chemistry have on subjective norm?**		
i	What are student perceptions of associates attitude-towards-chemistry?	E_6:	Explore student perceptions of associates attitude-towards-chemistry
ii	What is student subjective norm?	E_7:	Explore student subjective norm
iii	What influence, if any, does student perception of associates attitude-towards-chemistry have on subjective norm?	H_{22}:	There is a relationship between student perceptions of associates attitude-towards-chemistry and subjective norm

5	**What influence, if any, does student attitude-towards-enrolling in second-year chemistry, perceived control over enrolling in second-year chemistry, and subjective norm, have on intentions to enrol in second-year chemistry?**		
i	What are student intentions to enrol in second-year chemistry?	E_8:	Explore student intentions to enrol in second year chemistry
ii	What influence, if any, does student attitude-towards-enrolling in second-year chemistry have on intentions to enrol in second-year chemistry?	H_{23}:	There is a relationship between student attitude-towards-enrolling in second-year chemistry and intentions to enrol in second-year chemistry
iii	What influence, if any, does student perceived control over enrolling in second-year chemistry have on intentions to enrol in second-year chemistry?	H_{24}:	There is a relationship between student perceived control over enrolling in second-year chemistry and intentions to enrol in second-year chemistry
iv	What influence, if any, does student subjective norm, have on intentions to enrol in second-year chemistry?	H_{25}:	There is a relationship between student subjective norm and intentions to enrol in second-year chemistry

Key: H_x = research hypothesis, E_x = Exploration Statement

Treating students' enrolment intentions as a function of the sum of the parts of the MTPB may appear to be based on behaviourist thinking: the study of human behaviour with little consideration of social institutions (Lee & Newby, 1989). This researcher acknowledges that the reasoning underpinning student enrolment choices are dynamic and situated within social contexts. Therefore events (either internal or external) that influence one component of the MTPB will likely influence all components. Therefore the MTPB is seen as a *guide* for understanding student enrolment choices, rather than a static, predetermined, tool which will explain all choices. As such, although each research question was examined separately, it is important to note that other factors have influenced some of the data presented.

Hypotheses and exploration statements were derived from the research questions (Table 4.1). Again, the purpose of these statements was to provide guidance in the data analysis. Although this method of data analysis is derived from an positivistic paradigm it is not inconsistent with an interpretivist ideology. Empirical research relies solely on the use of hypothesis statements in data analysis, where these statements are tested for truth. However, in this research, and indeed other interpretivist research, the hypothesis statements are used only to highlight specific areas of interest in the research, and are used as *guidance*, rather than specific testable statements.

For research question one student chemistry learning experiences, attitude-towards-chemistry and chemistry self-efficacy were investigated, along with the interrelationships between these concepts. Research question two is focused on student attitude-towards-enrolling in chemistry, and this was examined by investigating student attitude-towards-enrolling-in-chemistry, and how chemistry learning experiences, attitude-towards-chemistry, and chemistry self-efficacy influence student attitude-towards-enrolling in chemistry. Research question three is concerned with student control beliefs about enrolling in first-year chemistry; this was investigated by considering both control beliefs and examining what influence chemistry learning experiences in first-year chemistry classes exerted on control beliefs. Research question four aims to establish student perceptions of their associates attitude-towards-chemistry - since these may impact upon student normative beliefs. This involved investigating student perceptions of their associates' attitude-towards-chemistry, and student normative beliefs. Finally, research question five sought to investigate the influence of all the preceding components on student enrolment intentions.

The research did not extend into the relationship between enrolment intentions and enrolment choices due to New Zealand Privacy Laws, which prohibit the use of information beyond which that it was collected for. Consequently data collected on students enrolments by the university could not be made available for this research.

4.5 First-year Chemistry at the University of Waikato

In Chapter 1 (Section 1.6, p. 6) the context of the inquiry was presented. However, at this point it is useful to describe the provision of first-year chemistry at the University of Waikato in more detail. The University of Waikato offers three first-year chemistry courses, *Chemical Concepts* in the first semester of the academic year, *Chemical Change & Organic Compounds* in the second semester of the first-year, and *Chemical Hazards: Safety & Legislation* - offered biennially. In addition, an interdisciplinary subject, *Environmental Science*, offered at the first-year level is taught jointly by the Chemistry Department and Department of Earth Sciences. Both *Chemical Concepts* and *Chemical Change & Organic Compounds* are required for all but one of the second-year chemistry courses (an interdisciplinary geochemistry course). Consequently, students wanting to advance in chemistry are required to take both of these 'core' first-year chemistry courses. Both of the other first-year courses, *Chemical Hazards: Safety & Legislation* and *Environmental Science*, are non-advancing courses in chemistry, designed for specified programmes.

4.5.1 First Semester First-Year Chemistry

The first semester first-year chemistry course, *Chemical Concepts*, generally has an enrolment in the range 160 – 180, with students in a variety of science and engineering programmes - as well as intending chemistry majors. The course consists of 36 optional lectures, 12 three-hour compulsory laboratory classes, and 12 optional tutorials. The course covers two main topics (taught by two different academics): basic chemical concepts, including chemical equations, equilibria and solution chemistry; and, inorganic bonding, including the structure of the atom, the Periodic Table, and valence bond theory. The laboratory classes consist of practical experiments intended to complement the lecture material, and help students acquire basic practical chemistry techniques including volumetric analysis and redox chemistry. The tutorials have no fixed format, but typically cover problems provided on tutorial sheets given out at lectures. The tutorials also provide help with the write-up of laboratory work, and provide guidance for answering the two topic tests and final exam. Course assessment consists of a final exam contributing a maximum of 67% to the final grade, the laboratory component 12%, and two tests each worth 7%. Further details about the course content are available in Appendix A. For simplicity, this course will be termed the 'first-semester course' throughout the remainder of this thesis.

4.5.2 Second Semester First-Year Chemistry

The second semester course, *Chemical Change & Organic Compounds*, is structurally similar to the first semester course, with 36 optional lectures, 12 three-hour compulsory laboratory classes and 12 optional tutorials. In addition, the course is assessed in a similar manner with a final exam counting 67% of the grade, the laboratory component 12%, and two tests worth 7% each. However the course content is significantly different with one member of academic staff providing an introduction to physical chemistry, including thermodynamics and kinetics, and a second staff member teaching organic chemistry, including systematic nomenclature and functional group reactions, including examples from bio-organic chemistry. Throughout the remainder of this thesis, this course is referred to as the 'second semester course'.

4.5.3 Direct Entry into Second-Year Chemistry

Each year about 10 to 15 students are granted direct entry into a second-year course *Analytical Chemistry & Instrumental Techniques* based on their performance in an external Year-13 examination (New Zealand Bursary Chemistry). The analytical chemistry course consists of 36 optional lectures covering theoretical concepts underlying a variety of analytical instrumental methods, and a total of 36 hours laboratory work, intended to provide students with hands-on experience with a variety of instruments. These 'direct entry' students do different experiments from normal second-year students and, for example, do some experiments from the first-year *Chemical Concepts* course. In contrast with the first-year chemistry courses, the second-year analytical chemistry course is fully internally assessed, with the laboratory write-up contributing a maximum of 50% of the students' final grade. All of the direct entry students attend a compulsory weekly tutorial covering material presented in lectures for the *Chemical Concepts* course, but not covered at secondary school. The students, are not assessed on this material the intention is to help cover any gaps between the first semester course and high school chemistry. To get into any of the other second-year level chemistry courses, direct entry students must also pass the second semester course *Chemical Change & Organic Compounds*. Hence, to advance into second-year chemistry, students must have passed either

Chemical Concepts and *Chemical Change & Organic Compounds*, or *Chemical Concepts* and *Analytical Chemistry & Instrumental Techniques*.

4.6 Choice of Methods for the Research in this Thesis

The choice of method or methods for any educational inquiry must be based on the objectives of the research. Patton (1990, p. 196) suggests that "the challenge is to find out which information is most needed and most useful in a given situation, and then to employ those methods best suited to producing the needed information." The thesis aims to understand the influence of chemistry learning experiences on student enrolment choices, with an overall aim of understanding the high attrition rate in students studying chemistry from the start of their first-year of chemistry study and the start of the second-year. There is some anecdotal evidence that this decision is made by students at the end of the first semester, as there are significantly less students enrolled in the second semester course compared with the first semester course (despite both being prerequisites for second-year chemistry study). A longitudinal or cross-sectional approach would be appropriate since when the students make their decisions also is of interest. As pointed out above, the major inhibiting factor in a longitudinal approach is the timeframe and associated costs. However, the academic year at Waikato is of relatively short duration (i.e., 36 weeks), hence, in the case of this work a longitudinal approach was judged feasible and appropriate.

A mixed-methodology approach employing both quantitative and qualitative methods was employed for two main reasons: to benefit from the advantages of the two methodological approaches and in some cases to provide data triangulation (see above). The quantitative data thus sought to describe trends in some aspects of student enrolment, along with changes in parameters such as student attitude-towards-chemistry. However, quantitative data seldom allows researchers to understand reasons for trends or differences in parameters. Hence, qualitative methods also were employed to help the researcher develop an understanding of the reasons for any trends observed in the quantitative findings as well as to investigate elements of the research not easily investigated by quantitative methods.

Therefore the choice of approach for this study consisted of a mixed-methodology approach with both quantitative and qualitative components, as well as a longitudinal aspect. There were three data collection time-phases to the study; the start of the academic year, the end of the first-semester, and at the end of the second semester (i.e., the end of the academic year). Quantitative and qualitative methods were employed at all three data collection phases.

4.6.1 Quantitative Methods

Quantitative data in this study was obtained by several administrations of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ). The CAEQ contains scales for *chemistry learning experiences*, *attitude-towards-chemistry* and *chemistry self-efficacy*. The CAEQ was administered to all students enrolled in the first semester chemistry course during their laboratory classes, at two stages of this 12 week course, at week two and week nine. The first administration contained the *attitude-towards-chemistry* and *chemistry self-efficacy* scales but not the *learning experiences* scale (since the students had not at this point undergone any first-year chemistry learning experiences). The second administration employed all three scales, and in addition, students enrolled in the 12-week second semester course were surveyed using all three scales of the CAEQ towards the end of course, in week eight. Although the intention was to survey the students at the end of the courses, weeks nine and eight of the course were chosen for logistical reasons. First, the experiments scheduled for these classes were short in duration, and second there were fewer assessment activities at this time. These two reasons meant that administering the CAEQ would cause least inconvenience for students. As well as completing the subscales for CAEQ, the students were asked some demographic questions at the start of the year and the end of the second semester administrations. This included questions about gender, ethnicity, reasons for enrolling in the course, whether they had any friends or relatives they considered to be scientists, and secondary school experience. Data also were collected about their secondary school, in order to investigate socio-economic factors as New Zealand schools are classified according to a 'decile rating' a numerical measure of the local communities socio-economic conditions.

Full details on the development of the CAEQ and validation of the quantitative data are presented in Chapter 5.

4.6.2 Qualitative Methods

At the start of the year 19 students agreed to be involved in interviews. These students were chosen so as to provide a range of attributes, rather than to be representative of the class as a whole. Consequently seven were chemistry majors, four were engineering students, six were enrolled in a science specified programme, and two were enrolled in chemistry as a science support subject. Ten were male and nine were female, and the students were interviewed at three stages during the year; at the beginning of the academic year where all 19 were interviewed, the end of the first semester course, where 14 were interviewed and the end of the second semester course where nine were interviewed. This attrition was due to participants discontinuing their university studies, discontinuing in chemistry, and some choosing not to continue their involvement in the study – mostly due to work pressure. A detailed description of the participants involved in the interviews is provided in Chapter 4 (Section 4.8.2, p. 94).

4.7 Development of the Interview Protocol

4.7.1 Interview Methods

According to Patton (1990) there are four different types of interviews, conversational, guided, standardised open ended and fixed response. *Conversational interviews* as the name suggests are informal and unstructured. They are guided by both the interviewer and the participant, and questions are determined by trend of the conversation. The questions are usually more salient to the individual but are often different from participant to participant, which may make data interpretation and comparison problematic. *Guided interviews* are more structured than conversational interviews, with topics outlined by the interviewer (usually in advance). This makes data analysis easier since comparisons between participants are easier, but the method retains the relaxed and informal components of the conversational method. However, the lack of defined questions means that salient areas may be unintentionally omitted, and participants' views are not always directly comparable. *Standardised open-ended interviews* employ questions defined in advance, although participants are able to answer in the manner that they choose. This method makes comparison of responses between participants easier, but increases the formality of the interview and can make the situation less comfortable for some participants. Finally, *fixed interviews* use fixed questions and fixed responses, which enables direct comparison between participant's responses. This approach sacrifices some depth of inquiry, and in some cases forces participants to refine their beliefs to fit the predefined categories.

The interview method chosen for this study was a standardised open-ended interview, allowing the use of appropriate probing questions to further understand participants' views. This also enabled comparison between participants' responses, whilst ensuring areas of interest were not omitted. This method also allowed some freedom to explore participants' views in more depth depending on the nature of their responses to prompt questions.

4.7.2 Content Domain for the Interview Protocol

The content domain of the interview protocol was derived from the research objectives. Although chemistry learning experiences, attitude-towards-chemistry and chemistry self-efficacy were investigated using the CAEQ, they were also probed in interviews (thus providing triangulation). The interviews also sought additional data to the topics addressed by the CAEQ, such as students' beliefs about enrolling in chemistry. Responses were then used to examine students' attitude-towards-enrolling in chemistry, and their control beliefs about enrolling in chemistry. Students' subjective norm was likewise investigated in interviews as were perceptions of associates' attitude-towards-chemistry. Finally, there were questions on enrolment intentions. The interview protocols for each of the interviews are presented in the following tables. Table 4.2 contains questions used in the pilot study; Table 4.3 those used in interviews conducted at the start of the year; Table 4.4 those for the end of the first semester; and, Table 4.5 for the end of the second semester.

4.7.3 Pilot Study

The interview protocol for the inquiry was evaluated via a pilot study using a cohort of students of similar background to participants in the main inquiry. Other students who had recently made educational choices about studying second-year chemistry were also interviewed, resulting in a total of 18 participants (age range 17 – 30 years) in the pilot. All of the participants in the pilot had enrolled in at least one first-year chemistry course as part of their degree, and four were enrolled in the second semester chemistry course at the time of participation.

One student from the pilot had recently completed the first semester chemistry course, but chose not to enrol the second semester course. Ten identified themselves as chemistry majors; the remainder were enrolled either in another science major (biological sciences, materials and process engineering, Earth sciences, or computer sciences) or a multi-discipline specified programme (e.g., animal behaviour, marine science, biochemistry, and biotechnology). The gender balance was even, but the ethnicity distribution reflected the high percentage of New Zealand European students enrolled in science at the participating university with most participants identifying themselves and New Zealand European. One participant identified herself as being of Maori descent, and two participants identified themselves as Asian/Indian.

The interview pilot study was also a major component of the validation of the CAEQ, full details of which are provided in Chapter 5.

Table 4.2

Interview protocol used to examine the influence of university chemistry learning experiences on students' education choices - pilot study.

CAEQ evaluation	Were there any questions that you didn't understand on the questionnaire? Were there any beliefs that you had about the first-year chemistry classes that weren't on the questionnaire?
Peers attitude-towards-chemistry	What do think your friends think a person who works as a chemist does? What do you think your friends think the personality traits of a chemist would be? Do you think your friends think that chemists consider the effect on people when they design their research?
Parents attitude-towards-chemistry	What do you think your parents or guardians think a person who works as a chemist does? What do you think your parents or guardians think the personality traits of a chemist would be? Do you think your parents or guardians think that chemists consider the effect on people they design their research?
Mentor's attitude-towards-chemistry	Do you have a person you consider to be a mentor? (*prompt)* it could be a family friend, old boss or teacher, someone you consider to be a role model? What do you think your mentor thinks a person who works as a chemist does? What do you think your mentors think the personality traits of a chemist would be? Do you think your mentors think that chemists consider the effect on people when they design their research?
Media's portrayal of chemistry	How do you think the media portrays what a person who works as a chemist does? How do you think the media portrays the personality traits of a chemist? Do you think the media portrays chemists as considering the effect on people when they design their research?
Attitude-towards-enrolling in chemistry/ Control beliefs about enrolling in chemistry/ Subjective norm	What was the major factor that influenced your decision to enrol in first-year chemistry? If answer is control belief: If you didn't think that *insert control belief* would you enrol in the first semester chemistry paper[1]? What makes you say that? If answer is normative belief: If *insert normative reference* did not think you should enrol in the first semester chemistry paper[1] would have you enrolled in it? What makes you say that?
Subjective Norm	Do you think your family think you should be studying chemistry? Do you think your friends think you should be studying chemistry? Do you think your mentors think you should be studying chemistry?
Chemistry self-efficacy[2]	How easy do you think you are going to find it to pass a second-year chemistry course?
Chemistry learning experiences[2]	What parts of the first-year chemistry course do you enjoy? What parts of the first-year chemistry course did you not enjoy?
Attitude-towards-chemistry[2]	Do you agree or disagree with the statement "chemists are environmentally aware"? What makes you say that? Do you think chemistry research advances society? What makes you say that?

[1] In New Zealand a university course is commonly referred to as a paper

[2] These questions were only asked of participants currently enrolled in the first-year chemistry course

Table 4.3

Interview protocol used to examine the influence of university chemistry learning experiences on students' education choices – start of the year.

Attitude-towards-enrolling in chemistry/ Control beliefs about enrolling in chemistry/ Subjective norm	What was the major factor that influenced your decision to enrol in the first semester chemistry paper[1]? If answer is control belief: If you didn't think that *insert control belief* would you enrol in the first semester chemistry paper[1]? What makes you say that? If answer is normative belief: If *insert normative reference* did not think you should enrol in the first semester chemistry paper[1] would have you enrolled in it? What makes you say that?
Subjective Norm	Do you think your family think you should be studying chemistry? Do you think your friends think you should be studying chemistry? Do you have a person you consider to be a mentor? *(prompt)* it could be a family friend, old boss or teacher, someone you consider to be a role model? Do you think your mentors think you should be studying chemistry?
Enrolment intentions	Are you planning on enrolling the second semester chemistry paper[1]? Are you planning on enrolling in any second-year chemistry papers[1]?
Chemistry self-efficacy	How easy do you think you are going to find it to pass the first semester chemistry course?
Chemistry learning experiences	What parts of the course do you think you are going to enjoy? What parts of the course do you think you are not going to enjoy?
Attitude-towards-chemistry	Do you agree or disagree with the statement" chemists are environmentally aware"? What makes you say that? Do you think chemistry research advances society? What makes you say that?
Peers attitude-towards-chemistry	What do think your friends think a person who works as a chemist does? What do you think your friends think the personality traits of a chemist would be? Do you think your friends think that chemists consider the effect on people when they design their research?
Parents attitude-towards-chemistry	What do you think parents or guardians think a person who works as a chemist does? What do you think your parents or guardians think the personality traits of a chemist would be? Do you think your parents or guardians think that chemists consider the effect on people they design their research?
Mentor's attitude-towards-chemistry	What do you think your mentor thinks a person who works as a chemist does? What do you think your mentors think the personality traits of a chemist would be? Do you think your mentors think that chemists consider the effect on people when they design their research?
Media's portrayal of chemistry	How do you think the media portrays what a person who works as a chemist does? How do you think the media portrays the personality traits of a chemist? Do you think the media portrays chemists as considering the effect on people when they design their research?

[1] In New Zealand a university course is commonly referred to as a paper

Table 4.4

Interview protocol used to examine the influence of university chemistry learning experiences on students' education choices – end of first semester.

Enrolment intentions	Are you planning on enrolling in the second semester chemistry course?
Attitude-towards-enrolling in chemistry/ Control beliefs about enrolling in chemistry/ Subjective norm	What was the major factor that has influenced your decision to enrol/not to enrol in the second semester chemistry paper[1]? *If answer is control belief:* If you didn't think that *insert control belief* would you enrol in the first semester chemistry paper[1]? What makes you say that? *If answer is normative belief:* If *insert normative reference* did not think you should enrol in the first semester chemistry paper[1] would have you enrolled in it? What makes you say that?
Subjective Norm	Do you think your family thinks you should be studying chemistry? Do you think your friend's thinks you should be studying chemistry? Do you think your *insert mentor identified at start of the year* thinks you should be studying chemistry?
Enrolment intentions	Are you planning on enrolling in any second-year chemistry paper[1]s?
Chemistry self-efficacy	How easy do you think you are going to find it to pass the second semester chemistry course?
Chemistry learning experiences	Can you tell me what you thought about the 101[2] lecture course? Can you tell me what you thought about the 101[2] practical course? Can you tell me what you thought about the 101[2] tutorials?
Attitude-towards-Chemistry	Do you agree or disagree with the statement "chemists are environmentally aware"? What makes you say that? Do you think chemistry research advances society? What makes you say that?

[1] In New Zealand a university course is commonly referred to as a paper

[2] Abbreviation of the course code for the first semester course

Table 4.5

Interview protocol used to examine the influence of university chemistry learning experiences on students' education choices – end of second semester.

Enrolment intentions	Are you planning on enrolling in any second-year chemistry courses?
Attitude-towards-enrolling in chemistry/ Control beliefs about enrolling in chemistry/ Subjective norm	What was the major factor that influenced your decision to enrol/not enrol in a second-year chemistry course? *If answer is control belief:* If you didn't think that *insert control belief* would you enrol in the first semester chemistry paper[1]? What makes you say that? *If answer is normative belief:* If *insert normative reference* did not think you should enrol in the first semester chemistry paper[1] would have you enrolled in it? What makes you say that?
Subjective Norm	Do you think your family thinks you should be studying chemistry? Do you think your friend's thinks you should be studying chemistry? Do you think your *insert mentor identified at start of the year* thinks you should be studying chemistry?
Chemistry self-efficacy	How easy do you think you are going to find it to pass a second-year chemistry course?
Chemistry learning experiences	Can you tell me what you thought about the 101[2] lecture course? Can you tell me what you thought about the 101[2] practical course? Can you tell me what you thought about the 101[2] tutorials?
Attitude-towards-Chemistry	Do you agree or disagree with the statement "chemists are environmentally aware"? What makes you say that? Do you think chemistry research advances society? What makes you say that?
Chemistry learning experiences	Of the different lectures you've had throughout this year, which lecturing style do you like the most?Of the different lectures you've had throughout this year, which lecturing style did you like the least? Of the laboratory experiments you've done this year which would you say like the most? Of the laboratory experiments you've done this year which would you say like the least? Do you have any suggestions about ways that the lectures could be improved? Do you have any suggestions about ways that the practical classes could be improved? Do you have any suggestions about ways that the tutorials could be improved?

[1] In New Zealand a university course is commonly referred to as a paper

[2] Abbreviation of the course code for the second semester course

4.7.4 Chemistry Learning Experiences

Questions investigating students' chemistry learning experiences initially sought to determine participants' salient beliefs, and as a consequence were not very specific. So participants were asked what they enjoyed about first-year chemistry and what they did not enjoy, rather than, for example, did they enjoy the lecturing style of a particular lecturer discussing a particular topic (*Chemistry learning experiences*, Table 4.2). However, although this was reasonably effective in determining the most salient beliefs, it was rather limited in that it did not result in a wide range of chemistry learning experiences. For example, none of the participants referred to their tutorial classes. Consequently, for the first and second semester phases of the inquiry, the interviewees were asked what they thought about their chemistry learning experiences with the interviewer specifying each of the three learning potential experiences, lecture classes, laboratory classes, and tutorial classes (*Chemistry learning experiences,* Tables 4.4 - 4.5). However, the questions from the pilot study regarding learning experiences, that is, what the participants enjoyed about first-year chemistry, and what they did not enjoy, were also asked at the start of the year, as the students were not necessarily familiar with the tertiary environment and may not understand the functions of each activity (*Chemistry learning experiences,* Table 4.3).

At the end of the second semester (i.e., the end of the academic year), the students were asked about their preferred lecturing style, and what experiment they enjoyed most in their laboratory classes. The intention of these questions was to delve more deeply into their responses, since some of the students indicated that they found particular experiments and lecturing styles problematic in earlier interviews (*Chemistry learning experiences,* Table 4.5). This proved a useful probe for the student's chemistry learning experiences and was therefore incorporated into the final interviews. The students were also asked for recommendations on how to improve the courses.

4.7.5 *Attitude-Towards-Chemistry*

The main tool used to investigate student attitude-towards-chemistry was the CAEQ and there were only two questions included in the interview protocol. The two questions were derived from the CAEQ attitude-towards-chemistry scale. First, participants were questioned about the environmental awareness of chemists (from the attitude-towards-chemists subscale), and second they were asked about the role of chemistry in advancing society (from the attitude-towards-chemistry in society subscale). Interviewees were asked these questions in all three phases of the interview study (*Attitude-towards-chemistry,* Tables 4.3 - 4.5).

4.7.6 *Chemistry Self-Efficacy*

As with the attitudes-towards-chemistry component, student chemistry self-efficacy was investigated primarily using the CAEQ. However, one question was included in the interviews seeking participants' perceptions of their ability to pass a forthcoming chemistry course (*Chemistry self-efficacy*, Tables 4.2 - 4.5). For example, at the end of the first semester course the students were probed as to their perceptions of their ability to pass the second semester course. Participants were asked about their chemistry self-efficacy in relation to a subsequent course rather than 'second-year chemistry', in order to see any changes in the students' perception of their ability in chemistry as a whole, rather than their perception of, what would be at the start of the year, a significantly higher level course. In other words, at the beginning of the year it is reasonable to assume that students - even participants very confident about studying chemistry in general - might be more concerned about studying a course that they had no preparation for.

4.7.7 *Attitude-Towards-Enrolling in Chemistry and Perceived Control over Enrolling in Chemistry*

As mentioned above, students' second-year enrolment options are constrained by their first-year enrolment choices, because both core first-year chemistry courses are pre-requisites for all but one second-year chemistry course. Nonetheless, it was anticipated that students actually enrolled in the course for a variety of reasons. Consequently, at the start of each interview participants were questioned about their reasons for enrolling or not enrolling subsequent courses (*Attitude-towards-enrolling in chemistry/Control beliefs about enrolling in chemistry/Subjective norm*, Tables 4.2 - 4.5). The format of this question was developed from the ideas of Crawley and Koballa (1994), who suggest that questions on intentions are formulated using the structure of "what are the factors that influence the participant's intention to engage in a target behaviour." The participants' responses were then categorised as either attitude-towards-enrolling in chemistry, control beliefs or normative beliefs. Follow up questions were used to probe reasons for their beliefs.

4.7.8 Subjective Norm

The interviewees also were probed as to what they felt three cohorts of associates; namely peers, parents, and mentors, would think about them studying chemistry, with participants first asked to define their mentors (*Subjective norm*, Tables 4.2 - 4.5). For those who did not identify a mentor, no further questions were asked subsequently. Mentors were included to investigate if the students had other people in their lives (other than parents & peers) that provided advice on their educational and career decisions.

4.7.9 Perceptions of Associate Attitude-Towards-Chemistry

The interviewees were also probed as to their associates' attitude-towards-chemistry in order to investigate socialisation factors. As such, the social factors that could influence students' perceptions about chemistry were expanded from those individuals that were involved in providing advice in a social manner and this also included media influences (*Peers attitude-towards-chemistry, Parents attitude-towards-chemistry, Mentors attitude-towards-chemistry, Media portrayal of chemistry*, Table 4.3).

Participants were questioned on their perceptions of each of their associate groups (i.e., parents, peers, mentors, & the media) with respect to attitude-towards-chemistry, or in the case of the media - portrayal of chemistry. Attitude-towards-chemistry was based on the definition of chemistry, with questions including chemists as a group of people, the chemistry profession and the values of chemists. To investigate their perception of values of chemists, students were asked to comment on whether they perceived their associates would think that chemists would consider the impact on society when designing their research. This question was constructed to identify chemists separately from multi-national companies, and to prevent 'planting' of an idea in the participant. In the pilot study these questions were used at the start of the interviews, but as some participants were observed to be anxious about both the interview situation and the questions, these questions were moved to the end of the protocol in subsequent interviews – thus allowing participants to answer simpler questions first. Participants were only questioned about their associates' attitude-towards-chemistry once, at the start of the year. This was done in order to reduce the duration of the interviews at the end of first and second semesters, a time when students were under increased work pressure.

4.7.10 Enrolment Intentions

Participants also were asked about their enrolment intentions for the second semester and for their second-year courses. If their enrolment intentions changed at any stage from previous interview phases, then the participants were questioned as to why that change had occurred.

4.8 Sample Used in this Study

4.8.1 Quantitative Component

This study involved monitoring an intact class of students across both semesters of first-year chemistry: both quantitative and qualitative methods were used. The quantitative component involved three administrations of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ). The first administration occurred at the start of the academic year (n=126), and measured student attitude-towards-chemistry and chemistry self-efficacy. The learning experiences scale was not used in this administration, as the students had not yet been exposed to first-year chemistry learning. The second and third administrations used all three scales of the CAEQ, with the second administration conducted at the end of the first semester (n=102) and the third at the end of the second semester (n=84) (i.e., the end of the academic year). All three administrations were conducted during scheduled laboratory classes. Laboratory classes were chosen over tutorial and lecture classes in order to maximise the response rate since the laboratory classes are compulsory whereas tutorials are voluntary. An added advantage is that being of three hours duration, there is less pressure on the students to complete allocated tasks. Administration occurred in scheduled laboratory classes which had been found in the past to be short in duration. In addition, 19 students identified at the beginning of the academic year participated in interviews. Of these, 14 were re-interviewed at the end of the first semester, and nine at the end of the second semester. Full details of the respondents to the CAEQ are provided in Chapter 6, Section, 6.1.1, p.135), and full class demographics are provided in Appendix C.

4.8.2 Interview Participants

A group of students enrolled in the first-semester courses were interviewed in order to provide data triangulation and to provide insights into any trends elucidated from the quantitative data. A total of 19 students were interviewed with 47% participating in three interviews (at the beginning and end of the first semester, and the end of the second semester) with some attrition observed due to students discontinuing courses, and others failing to show for interviews. The participants were specifically chosen to reflect the diverse range of students enrolled in the two courses. Of the original participants, four students were engineering majors. Patrick[1], aged 18, was enrolled in a specified programme in materials and process engineering as part of the work-based BSc(Tech) (see Chapter 1, Section 1.6.3, p. 8 for a description of the BSc(Tech) degree). Patrick was hoping to transfer to a BE degree at the beginning of the second-year (the BE degree superseded the BTech degree at the start of the 2001 academic year) as his grade average in his Year-13 entrance examinations was just below the minimum entrance requirement to gain entry into the programme. Patrick appeared somewhat shy, but was very willing to talk during the interviews. Neil, and Jack, also 18-year old engineering students, were studying chemistry purely because it

[1] For the purposes of maintaining confidentiality all names used here are pseudonyms.

was part of their engineering programme. Both were talkative and confident during their interviews. Marcel, a 18-year-old male, was enrolled in an engineering intermediate programme, and intended transferring to another New Zealand university at the end of his first-year of tertiary study. Rather softly spoken, he seemed to lack confidence during interviews, but was more responsive when the tape recorder was turned off.

Seven of the interview participants were enrolled in a specified programme in science. Two, Alan aged 25 and Leanne 18 years old, were studying biochemistry - which has a high chemistry component, but does not necessarily lead to a major in chemistry. Alan, an able and highly articulate mature student, worked for five years before coming to university the first time at the time of the study. Leanne was outgoing and enthusiastic. She did Year-13 chemistry, and completed a foundation chemistry course over the preceding summer. Eleanor, an 18 year old, was studying chemistry as part of a specified programme in biotechnology. She initially enrolled in both the first and second semester courses, but did not attend any of the laboratory classes for the second semester chemistry courses. Laurence, identified himself as Maori, was enrolled in a conjoint social science and science degree, and originally enrolled in both first-year chemistry courses as optional courses. He subsequently chose not to study the second semester chemistry course. Karen, a bright, confident 18 year old enrolled in a specified programme in animal behaviour, was very confident about studying chemistry and she enrolled in both chemistry courses. In contrast, Celia and Felix enrolled only in the first semester course. Felix, a 20 year old computer science student, recently immigrated to New Zealand from England, but identified himself as being part-Maori. Lacking in confidence in chemistry, he seemed somewhat of a loner stating that he "didn't have any friends." Celia, was enrolled in a marine science programme - with the choice of studying either chemistry or calculus, she chose to study chemistry. Tabitha, 18 years old, was studying chemistry as a supporting subject for her biology major. She was quite assertive and stated that she was willing to be involved in the project, as long as it did not interfere with any other plans.

Seven of the interview participants were enrolled as chemistry majors. Kerrie and Kevin, both 18 years old, were interested in the interview process and happy to contribute to the study. Kerrie had an older sibling engaged in post-graduate study in the chemistry department involved in this study, and so was familiar with many of the staff in the department. Kevin was of average academic ability and, like Kerrie, was an enthusiastic participant. Kristen and Robert gained direct entry into the second-year analytical chemistry course, completing this course in place of the usual first-year course in the first semester. Both were 18 years old, and academically able students. Kristen was quite withdrawn, but Robert was very talkative. Samantha, another 18 year old, was offered a place in the analytical chemistry course like Kirsten and Robert, but turned it down. She also was an academically able student, but seemed rather diffident about her involvement in the interviews. Grace, a talkative 18-year old student of low academic ability enrolled in a bridging course, and Gary returning to study after one year in the work force, appeared very nonchalant about the interviews.

4.9 Data Analysis

4.9.1 Analysis of Quantitative Data

The quantitative findings reported in this thesis sought to draw upon recommendations by authors such as Rennie (1998) and Carver (1978) (see Section 4.3.4, p. 70). In the first instance ANOVA analysis was carried out in order to identify statistically significant results. This was followed by effect size analysis - carried out using η^2 values. All results with a confidence level of $p<.05$ were considered for further analysis, and η^2 values were reported for all these results. Based on the range of η^2 values produced in this research (0.00 – 0.18) and graphical analysis of statistically significant findings, an η^2 of greater than 0.1 was deemed statistically significant beyond statistical variation. Post hoc analysis using Scheffe's method was carried out on all results found to statistically significant by ANOVA, in order to isolate the origins of the statistically significant differences identified. Finally, all statistically significant results were plotted as histograms so that data-spread could be examined and any differences observed explained. From these four tests (viz., ANOVA, η^2, Scheffe's analysis and graphical analysis) results that were likely to be educationally significant were then elucidated and discussed with reference to the objectives of the inquiry. In summary, in order to be deemed educationally significant, the findings had to be statistically significant, and Scheffe's test had to provide evidence of a difference between independent items. In addition, differences between groups needed to be observable in histogram form, and η^2 needed to be above 0.10.

In the initial design of research it was planned to track changes in individual student responses through a repeated measures analysis. To this end, students were asked to put their student ID number on the questionnaires. However, a large proportion of the respondents refused to give this information, and those who did were not the same in each administration of the questionnaire. In total 33 of the 112 respondents who had the opportunity to complete all three administrations of the questionnaire were able to be tracked in this manner, which was deemed to smaller a proportion of the population to derive meaningful results.

The data was also subject to cluster analysis to see if there were any students who had consistently positive or negative learning experiences or attitude-towards-chemistry. This analysis did not give any meaningful results, and thus is not reported here.

4.9.2 Analysis of Qualitative Data

The qualitative data was analysed in two different ways. First the participants' responses were coded to identify the relevant component of a given research question, for example, chemistry learning experiences. Next, the responses in each coded section were grouped with similar responses and the major trends established. Any responses that did not fit in with this approach were examined to give the conclusions extra depth. The data were also analysed as a whole with each participant's responses summarised. The summaries were subsequently examined for similarities and differences, and any conclusions drawn compared with the conclusions from the previous data analysis method outlined above.

4.10 Principles of Verification and Validity

Validity of research is, like issues about paradigms and methods, often controversial with quantitative and qualitative methods typically having different standards and measures of validity (Guba & Lincoln 1989, Rennie 1998, Maxwell, 1992). However, despite method variations in the determination of research validity, the underlying concept is the same. Maxwell (1992) provides a useful definition of validity.

> Validity, in a broad sense, pertains to that relationship between an account and something outside of that account, whether this something is constructed as objective reality, the constructions of actors or a variety of other possible interpretations. (p. 283)

Maxwell (1992, p. 283) goes on to explain that validity "refers primarily to accounts, not to data or methods." That is, validity refers to the interpretations drawn from the data collected by the methods, but not the methods themselves. This is not to say that data or methods do not influence validity, as the process of data collection influences the quality of the data collected, and consequently the inferences and accounts drawn from the data. Guba and Lincoln (1989) identify four main issues in validity; credibility, transferability, dependability, and confirmability.

4.10.1 Credibility

Credibility of research is concerned with the extent to which the constructed reality of participants in the research mirrors the reconstructions attributed to them (Guba & Lincoln, 1989). A number of methods can be employed to improve the credibility of the inferences drawn from the data. The research should preferably involve prolonged engagement so that participants feel comfortable and are open and honest with the researcher. This reduces the likelihood of the participants deliberately misleading the researcher. Similarly, persistent observation allows the researcher to see whether the observations made are ongoing and accurate. One-off observations may result in inaccuracies as the researcher may inadvertently misinterpret the situation. As well as method considerations, data collected can also be examined to ensure credibility of interpretations. Participants can check their own responses to questions, or their responses can be compared with other questions of a similar nature to ensure that the viewpoints expressed are represented accurately. Finally, interpretations can be examined by discussing the conclusions with peers and by examining evidence for contradictory conclusions: this is termed negative case analysis. Negative case analysis not only improves the validity of the interpretations, but also gives greater depth to the research.

4.10.2 Transferability

Transferability is similar to the concept of generalisability used in positivist-based inquiries, and is concerned with the relationship between the data collected and the entire system under investigation (Guba & Lincoln, 1989). Unlike other measures of validity, transferability is the decision of the reader or receiver, rather than the researcher or reporter. It is the readers' responsibility to decide whether conclusions are appropriate or transferable to their own context. However, the researcher needs to provide a detailed description of the context of the research to help the receiver make transferability judgements.

4.10.3 Dependability and Confirmability

Dependability examines the methodology over time (Guba & Lincoln, 1989). Inferences are deemed dependable if comparisons are made from data drawn from similar methods. So, for example, each question in interviews should be structured in much the same way. This is not to say that methods must remain static, but does suggest that any method changes must be outlined and explained, and any inferences drawn should then consider the changes in these methods.

Confirmability is a concept similar to dependability and refers to the evidence for the relationship between the data and its interpretation. Guba & Lincoln (1989) suggests that research has confirmability when:

> The data can be tracked to their source, and that the logic used to assemble the interpretations into structurally coherent and corroborating wholes is both explicit and implicit in the narrative of a case study. (p. 243).

It is therefore up to the researcher to provide a detailed description of the methodology so that the reader can effectively 'audit' the process from data collection through to interpretation.

4.10.4 Maintaining Validity in this Study

The researcher sought to maintain validity of the data collected in this thesis by consideration of each of the four factors outlined above. First, the credibility of the interpretations has been examined by a number of methods. The research involved prolonged engagement and persistent observation of participants. As well as the longitudinal administration of the CAEQ, the researcher interviewed a cohort of students on up to three occasions throughout their academic year. As the study progressed the participants were noticeably more comfortable in the interviews. Similarly, by the time of the final administration of the CAEQ respondents were more comfortable about the questionnaire and, for example, interacted with the researcher by asking questions about the survey in the final administration.

Checking of respondents' data was carried out in two ways. First, the quantitative data was examined by a series of statistical methods to see if students responded to similar questions in the same way (Chapter 5, Section 5.5, p. 123). The qualitative data also were examined and compared with quantitative findings. The interview participants' completed questionnaires were identified and their responses compared with interview responses. To illustrate, Alan's response about the environmental awareness of chemists, suggested that he held a positive attitude, which when compared with his interview data was found to be consistent with statements he made at the start of the year: "Chemists couldn't be that naïve not to be aware about what's going on [environmentally]." Similarly Alan was positive in both interviews and relevant CAEQ questions about whether or not 'chemistry advances society' in the attitude-towards-chemistry scale. In addition, all interview transcripts were returned to the interview participants to allow them to examine and verify the data to ensure it accurately represented their viewpoints.

The transferability of the data can be established by comparisons of the reader's context with the descriptions of the context of this study given in Chapter 1, (Section 1.6, p 4). Furthermore, the issues of dependability and confirmability were addressed by providing detailed descriptions of the methodology used in the research (Chapters 4 & 5).

4.11 Ethical Issues for the Research in this Thesis

The study was carried out under the ethical guidelines of the Centre for Science and Technology Education Research (CSTER) at the University of Waikato. A full ethics proposal was written for the University of Waikato Human Research Ethics Committee before approaching any of the participants. There were three main ethical issues identified; maintaining anonymity for the participants, obtaining informed consent, and potential adverse impact upon the students' educational opportunities, by, for example, and taking up too much of their time.

The purpose of this research is to provide some formative evaluation of students' chemistry learning experiences. Hence, there was a clear intention to disseminate the findings from this study. This meant that the researcher needed to make all reasonable efforts protect the anonymity of the participants. This is particularly relevant as one of the supervisors of this research is a faculty member in the department. Therefore the participants in the interview part of the study remained anonymous to all but the researcher.

The CAEQ was administered in the laboratory classes in order to access a captive audience and improve response rate. This proved successful but it was important to avoid taking up too much of the students' time, potentially affecting their performance in the laboratory classes. Discussions with teaching staff identified the laboratory classes shortest in duration and the instrument was administered in these classes. Students were asked to complete the surveys before the class started, and those who chose not to be involved in the study were able to spend this time reading through their laboratory manual as they waited for the others to complete the questionnaire.

All survey respondents and interviewees were provided with information sheets describing the nature of the research, and were asked to sign consent forms confirming that they were happy to participate in the study. The students were given the opportunity to withdraw from the study and were informed that they did not have to answer every item in the survey or interviews. Interview participants who missed more than two appointments for interviews were deemed to have dropped out voluntarily and were not pursued.

One further ethical issue arose later in the research. When writing up the findings, it became evident that the findings might impact upon the teaching staff in the courses. For example, students might make some comments deemed to be critical of teaching staff, which might harm their academic reputation. Two measures were taken in order to minimise this. First, the chemistry learning experiences scales in the CAEQ were worded to elicit responses about the class as a whole rather than specific to a given lecturer (as might occur for example in a lecturer evaluation process). The findings of this thesis would be available to all members of the small academic community of the university (and New Zealand tertiary education scene). Consequently, any criticisms of specific lecture content might enable outsiders to identify specific members of staff. It was therefore decided to report the research findings in broad terms. For example, a comment criticising the teaching practice of one member of staff would be reported as dislike of a particular teaching style, rather than this specific teaching practice.

4.12 Chapter Review

As stated in Chapter 3 (Section 3.2.4, p. 47), this research was carried out within an interpretivist paradigm. As such, the methodology is derived from an interpretivist paradigm and is influenced by the research in all stages of the process – unlike positivistic research where the researcher has no influence on the inquiry.

A number of strategies were employed within the method design stages in order to ensure quality within the research. Data collected was triangulated using a mixed-methodology approach, incorporating both quantitative and qualitative methods. The choice of statistical analysis methods was based on issues of quality in quantitative research to address such concerns as the level of the data and the validity of reporting statistically significant findings.

The content domain was derived from the theoretical framework, and the objectives of the research. As such, a number of research questions were derived to examine the influence of learning experiences, attitude-towards-chemistry, and chemistry-self-efficacy on students' attitude-towards-enrolling in chemistry. As well the influence of attitude-towards-enrolling in chemistry, perceived behavioural control and subjective norm about enrolling in chemistry on students enrolment intentions and subsequent enrolment choices were researched. All of this is carried out within the context of studying first-year chemistry at the University of Waikato.

The study involved following an intact group of students throughout their first-year of science study at the University of Waikato. All students enrolled in the first-year chemistry courses were surveyed using the CAEQ at three occasions throughout the academic year - full details about the development of the CAEQ are presented in the following chapter, Chapter 5. Simultaneously a cohort of students was interviewed, again up to three times throughout the academic year.

The interview protocol used in this inquiry was constructed using a standardised open-ended interview structure with questions included on all aspects of the

MTPB. Consequently, students were questioned on their learning experiences, attitude-towards-chemistry, chemistry self-efficacy, attitude-towards-enrolling in chemistry, perceived behavioural control, subjective norm and enrolment choices. The interview protocol was piloted with a group of 18 students, where it revealed that the protocol was inclusive and the questions easy to understand.

Throughout the entire study, steps were carried out to ensure the findings of the study were valid. Credibility was ensured by prolonged engagement with the participants, interview responses were compared with questionnaire responses, and interview transcripts were returned to participants for verification. Full details of the context of the inquiry were provided to aid transferability, and dependability and confirmability were ensured by detailing the methodology of the study.

Finally, the methodology for the study was devised under the guidelines for ethical research, as set out by the CSTER Human Research Ethics Committee. The main ethical considerations included, informed consent of the participants, maintaining participant's confidentiality, and minimal impact on their learning. Full ethical approval was obtained from the committee before any field work involving the participants was carried out. Furthermore, throughout the study, an additional consideration was identified, and steps taken to ensure the research had no impact on the career of the academic staff involved in the study.

The methodology presented in this chapter, and the MTPB both informed the development of the CAEQ - as outlined in Chapter 5 (p. 106).

4.13 Chapter Summary

This chapter discussed the methodology for the thesis. It began with a discussion on what methodology is and some of the considerations in method design. The content domain for the thesis, the context of the study, and the method used to collect data was outlined. Next was a detailed discussion on the development of the interview protocol was presented. Following on from this, the methods of data analysis were discussed. Some issues of validity were presented, concluding with an examination of the ethical considerations pertaining to the research. The following chapter, Chapter 5, discusses the development of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ), which was the instrument used to collect quantitative data.

CHAPTER 5
DEVELOPMENT OF THE CHEMISTRY ATTITUDES AND EXPERIENCES QUESTIONNAIRE

This chapter reports on the development of a survey instrument, the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ), designed to measure attitude-towards-chemistry, chemistry self-efficacy and learning experiences of first-year chemistry students for whom chemistry had differing roles in their degree. The development of this instrument draws upon the theoretical framework outlined in Chapter 3, and the methodology outlined in Chapter 4. The chapter begins with an overview of difficulties encountered in the measurement of attitude-towards-science and chemistry and science, and chemistry self-efficacy. This is followed by a discussion of approaches that have been reported to maximise instrument validity. Next is a description of instrument development for the CAEQ including the development of scales, subscales, and items, along with a description of a description of a pilot study. The validation of the instrument and a final evaluation of its construct validity concludes the chapter.

5.1 The Need to Develop the CAEQ

The two most widely used instruments used to measure student attitude-towards-science are the *Scientific Attitudes Inventory II* (SAI II) (Moore & Foy, 1997) and *Test of Science Related Attitudes* (TOSRA) (Fraser, 1978). However, SAI II measures scientific attitude, which is different from attitude-towards-science in that SAI II measures the adoption of different attitudes that are part of the science culture. Scientific attitude is a response to statements such as: 'Scientists discover laws that tell us exactly what is going on in nature.' In contrast, attitude-towards-science is a response to statements such as: 'Working in a science job would be fun.' The SAI II has been used to examine the relationship between students' (predominantly at secondary school level) learning environment and attitude-towards-science, where it was revealed that for chemistry students a low conflict learning environment was correlated with a more positive attitude-towards-science (Lawrenz, 1976). However, the SAI II instrument has been subject to much criticism in the literature for its' lack of theoretical framework and concerns about its' validity (Munby, 1983, 1997). Validation and use of TOSRA reported in the literature shows it has higher validity than the SAI II instrument (Fraser & Butts, 1982). TOSRA has been used to examine the effect of group work in science, and, for example, students working in groups showed an improved attitude-towards-science (Lowe & Fisher, 2000). Although TOSRA possesses better validity than SAI II, it is based on a secondary school context and it is not appropriate for a tertiary environment. That is, TOSRA was developed for students who have very little knowledge about science; it is therefore inappropriate for students who are comparative specialists in science, and who may find the simplistic nature of the questions trivial and annoying. Additionally, scales such as the enjoyment of science 'lessons' are inappropriate for undergraduate students, because the term lesson could be taken to mean lecture, laboratory, or tutorial in the university environment. Thus for a tertiary level study TOSRA would require major revision which may influence the extent to which the instrument measures the domain of attitude-towards-science (Fraser, 1978), and would likely be longer.

There has been less research into tertiary students' science self-efficacy: a student's self-efficacy being his or her perception of their ability to undertake a specific scientific task or tasks. Although there has been some recent interest in the measurement of science self-efficacy (Andrew, 1998; Baldwin, Ebert-May & Burns, 1999), most self-efficacy research has been concerned with mathematics students (see, e.g., Lent, Larkin & Brown, 1986). Self-efficacy is task specific and so an instrument that measures science self-efficacy of, for example, nursing students, is not appropriate to measure the science self-efficacy of first-year chemistry students (Andrew, 1998).

Research into students' learning experiences, like studies of students' science self-efficacy, is limited. There is, however, a considerable body of literature on the measurement of student perceptions of their actual and preferred learning environment (see, e.g., Coll, Taylor, & Fisher, 2002; Nair & Fisher, 1999, 2001a,b,c; Fraser, 1994) and the relationship between student attitude and efficacy and perceptions of their learning environment (Haladyna, Olsen, &

Shaughnessy, 1982; Lorsbach & Jinks, 1999). There appears to be few, if any, reports in the literature about first-year chemistry students' learning experiences, but first-year physics students' learning experiences were investigated using a survey instrument based on anecdotal evidence and lacking a theoretical basis (White et al., 1995).

The paucity of instruments to measure attitude-towards-science, science self-efficacy and learning experiences of tertiary chemistry students thus necessitates the development of an instrument like the CAEQ in order to address the research questions for this study.

5.2 Construct Validity in Instrument Design

There is a large body of literature concerned with issues of validity encountered during the development of survey instruments. The legitimacy of drawing conclusions from survey instruments is usually evaluated by reference to internal validity (Burns, 1994). In their treatise on interpretivist research Guba and Lincoln (1989) suggest it is more appropriate to consider the credibility of data collection processes including instruments, where credibility is concerned with an instruments' ability to measure the constructed realities of the participants. Any researcher has self-defined constructs, termed theoretical constructs, which they believe an instrument actually measures and data obtained from instruments are interpreted in terms of researcher's own theoretical constructs. This is clearly a subjective process and researchers must establish if the instruments employed in their research actually measure their theoretical constructs. The consideration of this issue is termed *construct validity*. Addressing construct validity also is hampered by confusion in use of the term (Burns, 1994; Cronbach, 1989, Munby, 1997). Here the researcher use Trochim's (1999) definition of construct validity, namely, "the degree to which inferences can legitimately be made from the operationalisations in [a] study to the theoretical constructs on which those operationalisations were based" (p. 66).

Survey design in attitude-towards-science research in particular has been extensively criticised for lack of construct validity (Doran, Lawrenz & Helgeson, 1994; Munby 1982, 1997; Munby, Kitto & Wilson, 1976). Specific criticisms of instrument design with regard to construct validity include: instrument structure not being based on a well defined theoretical framework, omission of pilot testing - or testing using an inappropriate sample, confusing the extent of the conclusions that can be drawn from the and dimensionality results, and relying solely on a panel of experts as a measure of construct validity (Gardner, 1995, 1996; Krynowsky, 1988; Munby, 1997).

According to Trochim (1999) an instrument has high construct validity if it has both translation and criterion validity (Figure 5.1). Translation validity is the degree to which constructs are accurately translated into the operationalisation, in other words translation validity is concerned with the link between item design and administration. For example, do instrument items cover all aspects of the construct, and do participants ascribe the same meaning and interpretation to the items as the researcher? An instrument is deemed to possess translation validity if the theoretical constructs are well defined and inclusive (content validity), and if questions are good translations of the theoretical constructs (face validity). Criterion validity considers the operationalism, and an instrument is deemed to possess high criterion validity if the operationalism gives conclusions that are expected based on the theoretical constructs. For example, if the instrument gives results similar to another method that measures a similar construct (convergent validity), gives results different to another method that measures a different construct (discriminant validity), distinguishes between groups it is expected to distinguish between (concurrent validity), and predicts something it should theoretically predict (predictive validity). In summary, an instrument has high construct validity if it has a high content, face, concurrent, predicative, convergent and discriminant validity.

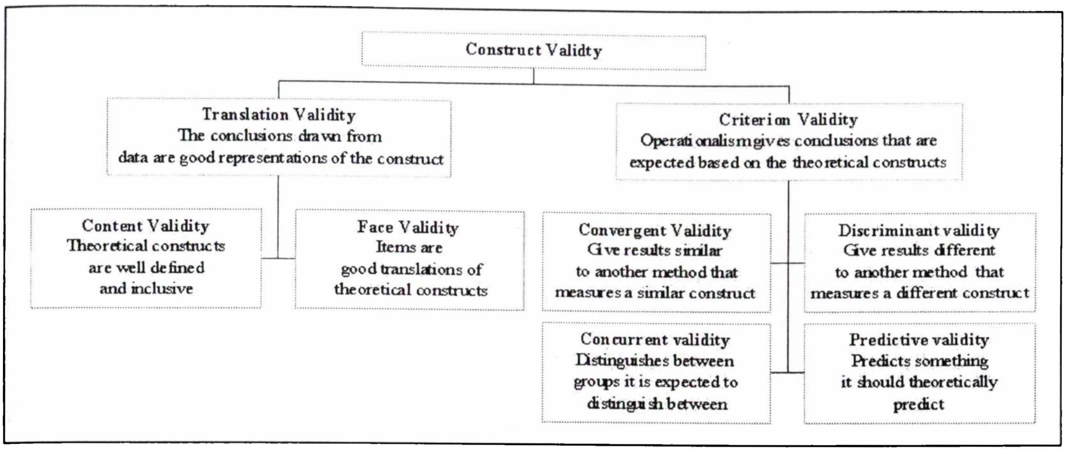

Figure 5.1

Framework for construct validity (after Trochim, 1999).

5.3 Methodology

Instrument development of the CAEQ was informed by Trochim's (1999) concept of construct validity described above. As a first step the researcher sought to maximise content validity by basing the instrument on a sound theoretical framework, by employing the inclusive definition of chemistry culture provided in Chapter 3 (Section, 3.3.1, p. 48), and by evaluating student perceptions of the full gambit of tertiary level chemistry learning experiences in first-year chemistry.

Face validity was established by the use of a panel of experts and a cohort of students representative of the intended population. A panel of experts technique was employed using a semi-structured interview protocol to ascertain the viewpoints of chemistry faculty and chemistry graduate students, in the development of scales, subscales and items, as well as in the final choice of questions for the instrument. As mentioned above, over-reliance on the panel of experts' technique as a sole measure of face validity and instrument validation has been criticised in the literature (Munby, 1982, 1997), and Burns (1994), argues that face validity must also determine comprehension by a representative sub-sample. Consequently, in addition to using a panel of experts to confirm that questionnaire items were a good representation of the constructs, the researcher used student interviews to confirm readability of items. Further to this, an expert in the teaching of NESB students examined the instrument, to ascertain the readability for students of whom English is a second language. Convergent and discriminant validity were examined by comparison with other instruments and by statistical analyses of data produced from the administration of the CAEQ; factor analysis, statistical discriminant validity, and reliability using Cronbach's α.

Convergent and discriminant validity were confirmed by factor analysis and evaluation of the reliability. It is worthwhile to note here that the reliability of a subscale is a measure of convergent validity but not discriminant validity, and statistical discriminant validity is a measure of discriminant validity but not convergent validity (Gardner 1995, 1996). Although not typically employed in attitude-towards-science research, statistical discriminant validity is often used in learning environment and self-efficacy quantitative analysis especially when factor analysis is not appropriate (Coll, Taylor & Fisher, 2002; Lent, Larkin & Brown, 1986). Statistical discriminant validity is "the extent to which a scale measures a unique dimension not covered by the other scales in the instrument" (Nair & Fisher, 2001a, p. 17). Low statistical discriminant validity, typically less than 0.30, suggest conceptually independent constructs, whereas higher statistical validity, typically greater than 0.60, suggest conceptually similar constructs. For completeness, the researcher determined the discriminant and convergent validity of all components using statistical discriminant validity, reliability, and factor analysis. The three scales of the instrument (i.e., attitude, self-efficacy and learning experiences) were subjected to principal axis factor analysis with oblique rotation to determine the rotated solution. Principal axis extraction was used rather than the standard principal component extraction as principal axis extraction, investigates the underlying dimensions of instrument data, which is consistent with the aims of factor analysis in instrument development, whereas principal component extraction minimises the number of factors generated whilst maximising amount of the variance accounted for (Malhotra, 1993). Oblique rotation was used rather than the standard Varimax rotation as the data was deemed to be correlated to some extent. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) was employed to ensure the appropriateness of the data for factor analysis, with factor analysis carried out on data with KMO values greater than 0.7. The number of factors chosen for rotation were based on scree plot analysis, whilst ensuring all factors had an eignvalue greater than 1. All resulting solutions were examined for the percentage of non-redundant residuals (difference greater than 0.05 between actual and calculated correlations) not described by the model. Reliability for the instrument was evaluated using Cronbach's α and statistical discriminant validity by examination of the average Pearson's correlation coefficient between the subscales within each scale.

Concurrent validity, based on the *Modified Theory of Planned Behaviour* (MTPB), suggests that the CAEQ instrument should be able to distinguish between chemistry majors and non-majors. Concurrent validity is thus confirmed if instrument subscales discriminate between two cohorts of this type. Likewise, according to the MTPB, attitude-towards-chemistry, and chemistry self-efficacy should both be influenced by chemistry learning experiences. The CAEQ can be considered to have predictive validity if the attitude and self-efficacy subscales correlate with the learning experiences scale.

5.4 Instrument Development

First I discuss the development of the scales, subscales and items for the CAEQ based on the definition of chemistry culture, attitude-towards-chemistry, chemistry self-efficacy and tertiary chemistry learning experiences as outlined in the theoretical framework and methodology described above. Following this I describe a pilot study in which the CAEQ was administered the a cohort of chemistry students at the end of the second semester of their first-year of chemistry. Statistical analyses of these data enabled refinement of the instrument, and instrument validation is described next, in which the refined instrument was administered at two different tertiary education institutions. Validation was followed by further examination of the instrument, including evaluation of concurrent and predictive validity, to ensure construct validity was maximised.

5.4.1 Development of Scales, Subscales and Items for the CAEQ

The initial development of the instrument was based upon the theoretical framework (Figure 3.2, p. 56), along with data from informal interviews with chemistry and science education faculty and chemistry students. The instrument comprised three scales; attitude-towards-chemistry, chemistry self-efficacy and chemistry learning experiences with subscales derived from definitions of attitude, self-efficacy, learning experiences and chemistry culture.

Attitude subscales identified were: *attitude-towards-chemistry transmitters*[2] (consisting of, attitude-towards-chemists), *attitude-towards-chemistry knowledge* (incorporating items on the nature of chemical theory, leisure interest in chemistry, and career interest in chemistry), *attitude-towards-chemistry methods* (including, attitude-towards-methods, understanding the purpose of chemistry, and recognition of chemical methods), *attitude-towards-chemistry values* (including, attitude-towards-chemistry values, attitude-towards-the role of chemistry in society, and recognition of chemistry values). Items were developed from previously reported instruments such as TOSRA (Andrew, 1998; Fraser, 1978, Moore & Foy, 1997; Wareing, 1982) and informal interviews with two members of chemistry faculty and six chemistry graduates. A total of 131 items were collected and assigned across the subscales. From this, five items for each subscale were deemed appropriate for tertiary level students, based on interviews with chemistry graduates and faculty. Interviewees were asked to comment on both the appropriateness of the item to the subscale and the readability of the item.

Subscales for chemistry self-efficacy were developed similarly from other instruments such as the *College Biology Self-Efficacy Instrument* (CBSEI) and interviews with chemistry graduates and faculty. This process was deemed appropriate for the following reasons. First, the CBSEI has higher construct validity than many other instruments and hence it makes sense to adapt and use modified chemistry-related items from this instrument (bearing in mind that it

[2]Transmitters are individuals that teach the learned patterns of the chemistry culture, in the case of this study, transmitters are chemistry faculty

was intended to develop an instrument relevant to chemistry students). Second the validity of such adapted items (and indeed all items) was checked by interviewing tertiary chemistry students and related stakeholders. These interviews were extensive and detailed questions were asked by both parties, namely, the interviewer and interviewees in order to clearly establish relevance and readability of the items. The chemistry self-efficacy items that came from this process were tentatively assigned to two subscales for chemistry knowledge, *learning chemistry theory self-efficacy,* and *applying chemistry theory self-efficacy*, and two for chemistry skills, *learning chemistry skills self-efficacy,* and *applying science skills self-efficacy.* Items for these subscales were derived largely from items from the rigorously developed CBSEI that could pertain to a class containing science majors, modified to a chemistry viewpoint (Baldwin, Ebert-Mays & Burns, 1999). Additional items were chosen and modified similarly from a variety of other instruments (Rowe, 1988; Schibeci, 1982). Self-efficacy is task based, therefore analysis of self-efficacy about a person (e.g., lecturer or tutor) makes no sense; hence, no items were included to address these perceptions. Likewise, analysis of self-efficacy about beliefs (e.g., values) is nonsensical. A total of 61 initial items were reduced to 20 (from interviews with chemistry graduates and faculty using similar techniques as described above) resulting in five items per subscale.

The learning experiences scale was divided into seven subscales based on the different class and transmitter types at New Zealand and comparable tertiary institutions: *lecture learning experiences, tutorial learning experiences, laboratory learning experiences, laboratory books learning experiences, lecturer learning experiences, tutor learning experiences*, and *demonstrator learning experiences.*[3] A total of 70 items were initially selected for this scale by modifying items from the *enjoyment of lessons* subscale of TOSRA to the different components of a tertiary chemistry course for each of the subscales. This was compared with data gathered from interviews with recent chemistry graduates employed as demonstrators in first-year chemistry laboratory classes,

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[3] Tutors are postgraduates that provide assistance during scheduled tutorial classes for problems provided in lectures, whereas demonstrators are graduates that provide assistance during laboratory classes.

and five items for each subscale retained, resulting in a total of 35 items for the learning experiences scale. The items retained were those judged by the interviewees to represent an adequate description of the various learning experiences for each of the subscales, and the interviewees also adjudged the items to be assigned to the correct subscale.

A semantic differential format was employed for the attitude-towards-chemistry and chemistry self-efficacy items in order to provide a measure of pole polarity, along with a measure of the strength of the belief. This was deemed appropriate since the instrument development is based on the TPB and strength of belief is an integral feature of the TPB (Ajzen, 1989). The adjectives at each end of the semantic differential scale were separated by seven lines, coded from 1 to 7 from left (negative attitude & low self-efficacy) to right (positive attitude & high self-efficacy). Items maintained the same polarity in order to minimise confusion, as the final instrument was fairly long. Items relating to student perceptions of their learning experiences utilised a 5-point Likert scale ranging from 1-5 (1=strongly disagree to 5=strongly agree). The Likert scale was utilised for these scales as the items related to specific contexts as recommended by Ostrom (1989). That is, when referring to specific contexts, such as a lecture class at a specific institution, people typically hold more clearly defined beliefs. For example, it is easy to agree or disagree with the statement "chemistry lectures at my institution are interesting." However, if the researcher is investigating concepts that are less contextualised, for example, chemistry lectures in general, then such beliefs are often less well defined, in which case the continuum style of semantic differential scales is more appropriate.

5.4.2 Pilot Study in the Development of the CAEQ

The CAEQ was administered to a first-year chemistry course at a New Zealand institution during the second half of the academic year (n=129) and took about 30 minutes to complete. Six factors (KMO 0.71, 20% non redundant residuals, n=129) consisting of a total of 22 items were isolated from the attitude-towards-chemistry scale of the instrument: *attitude-towards-chemists, skills of chemists, attitude-towards-chemistry in society, leisure interest in chemistry, career* *interest and chemists and the environment* (a single item subscale). The six factors are consistent with the theoretical framework, with skills of chemists encompassing the knowledge and skills component of the chemistry culture. Therefore the number of subscales was reduced to six without detriment to the instruments content validity.

The data from the factor analysis (KMO 0.85, 21% non redundant residuals, n=129) of the self-efficacy scale confirmed the four factors identified in the pilot study, namely, *learning chemistry theory self-efficacy, applying chemistry theory self-efficacy, learning chemistry skills self-efficacy,* and *applying science skills self-efficacy*, comprising of 17 items, with a high inter-correlation between factors. The data from the factor analysis of the learning experiences scale (KMO 0.75, 42% non redundant residuals, n=129) of the instrument revealed four factors, with items relating to the laboratory and tutorial subscales loading with very little inter-correlation. For example, the laboratory book and practical subscales load under the same factor as do the tutorial and tutors subscales. However, the subscales relating to lecturer/lecture experiences did not correlate as well. The data from the statistical discriminant validity analysis confirmed the results from the factor analysis. The attitude-towards-chemistry scale has an average inter-correlation of 0.24, which is sufficiently low to suggest the subscales are distinct. The inter-correlation, and hence suggested conceptual similarly, highlighted in the factor analysis of the self-efficacy data is confirmed in the statistical discriminant validity analysis, with an average inter-correlation of 0.57. The learning experiences scales (excluding the lecture and lecturer subscales) had an average inter-correlation of 0.35. Assessment of the reliability of subscales using Cronbach's α (Burns, 1994) resulted in a mean reliability for the instrument of 0.74 (n=129), slightly lower than related instruments[4] such as TOSRA (0.82, n=324-340) and the *College Biology Science Self-Efficacy Instrument* (0.88, n=1096), and showed adequate reliability for each subscale (excepting the lecture and lecturer subscales, which had reliabilities of 0.54 and

[4] There is a relationship between the number of items in a scale and the scales α-reliability, with scales with a higher number of items having a higher α-reliability. TOSRA has a similar number of items to the chemistry learning experiences subscales, and less than the attitude-towards-

0.56 respectively, reflecting the ambiguity identified during interviews, see below).

Nineteen students who had taken part in the pilot interview study completed the CAEQ (see Chapter 4, Section 4.8.2, p.94). The students reported that they found the CAEQ instrument to be highly readable and the items clear and unambiguous, with one exception from the learning experiences subscale. The interviews revealed that the instrument assumed the students had only one lecturer for the entire first-year course, which was not the case. Consequently, some participants became confused when asked a question that seemed to imply there was only one lecturer in the course. For example, a recent Earth sciences graduate said: "These ones and these ones (*pointing to lecture learning experiences questions on the CAEQ*), all depend on who is talking, and the manner they present the material in." This observation provides a possible explanation for the inconstancies in the lecture/lecturer subscales factor analysis, reliability and statistical discriminant validity data.

5.4.3 Validation of the Development of the CAEQ

The CAEQ was subsequently modified removing superfluous items based on the results of the pilot study, and the lecture/lecturer items modified to remove the ambiguity revealed in interviews. The instrument was again evaluated for face validity, using four students that completed the instrument and were subsequently interviewed. This revealed that the ambiguity in the lecture and lecturer subscales was removed. Before the final administration, the instrument was reviewed by an expert in non-English speaking students. The final version of the instrument is presented in Appendix B.

Convergent, discriminant, concurrent and predictive validity were confirmed by re-administration of the CAEQ to a different group of students from the pilot study from two New Zealand first-year chemistry courses at two different institutions – the University of Waikato, where the main study took place, and

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chemistry items of the CAEQ, whereas the College Biology Self-Efficacy Instrument has significantly less than the self-efficacy scale of the CAEQ.

one other university. In both cases the instrument was administered in two different stages of the academic year. It is important to note that this sample is different to the sample in the main body of this study, presented in Chapter's 6-8, as it includes data from another institution (This additional data collected was carried out to provide more data for the purposes of validation, it was not included in the research findings in this thesis because some interview data was gathered by a co-worker and is thus not my work). In the first administration, in the students' second and third weeks of tertiary chemistry study the students from both institutions completed the attitude-towards-chemistry and chemistry self-efficacy scales of the instrument only, having had no appreciable learning experiences at that stage (n=332, 42% response rate). At the end of their course (i.e., after their first tertiary chemistry learning experiences), the same group completed all three scales (n=337, 42% response rate). The two institutions involved are quite different in nature; one having around 200 applied science students enrolled in first-year chemistry, most of whom identified themselves as being of New Zealand European decent (73%) – it is this institution that is the main study for this thesis. The second institution had around 600 students in the first-year chemistry class, largely as a result of service-teaching for health sciences programmes. The chemistry class at this institution had a greater ethnic diversity than seen in the first institution, with 59% female, 52% and New Zealand European, 31% Asian/East Indian, 9% Maori [indigenous New Zealanders] or Pacific Islanders, and 8% other ethnicities. Overall the samples were similar in the two administrations, although some gender differences were observed with 42% of the respondents at the start of the year being male compared with only 35% at the end of the semester. Correspondingly 58% of the respondents were female at the start of the year, compared to 64% at the end of the semester. The ethnic structure of the samples were more consistent with 53% of the respondents at the start of the year of New Zealand European descent compared to 58% at the end of the semester. Similarly, at the start of the year 31% identified themselves as Asian/East Indian, 10% Maori/Pacific Islander and 6% other ethnicities, compared to 26% Asian/East Indian, 9% Maori/Pacific Islander and 6% other ethnicities at the end of the semester.

The data collected from three scales of the instrument (i.e., attitude, self-efficacy and learning experiences) at each administration were again subjected to factor analysis (Table 5.1, Table 5.2). The five factors isolated from the attitude-towards-chemistry scale of the instrument at the start of the year (KMO 0.87, 4% non-redundant residuals) and the end of the first semester (KMO 0.90, 7% non-redundant residuals) were consistent with the pilot study and the theoretical framework. The single item factor of *chemists and the environment* was not observed during validation, but the item correlates highly on the *attitude-towards-chemists* subscale and the *skills of chemists* subscale. Further analysis by reliability and discriminant validity data as well as factor analysis on the combined data sets from at the start of the year and the end of the semester administrations suggests that this item is of a similar construct to the *attitude-towards-chemists* subscale.

Table 5.1

Factor analysis for the validation of the *attitude-towards-chemistry* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) at the start of the year (n=332) and the end of the semester (n=339).[1]

Item	**Subscale**	**Start of the year**					**End of the semester**				
% Variance Explained		5.59	6.44	10.93	7.92	29.59	4.51	8.03	37.06	6.38	11.23
1	AC	**0.50**					**0.41**				
2	AC	**0.67**					**0.89**				
3	AC	**0.34**	0.33					0.49			
4	CS		**0.46**					**0.62**			
5	CS	0.32	**0.49**					**0.69**			
6	CS		**0.50**					**0.56**			
7	CS		**0.57**					**0.48**			
8	CS		**0.55**					**0.57**			
9	AS			**0.78**					**0.85**		
10	AS			**0.90**					**0.91**		
11	AS			**0.71**					**0.80**		
12	AS			**0.70**					**0.82**		
13	LI				**0.59**					**0.63**	
14	LI				**0.61**					**0.55**	0.31
20	LI				**0.57**					**0.62**	
21	LI				**0.44**					**0.39**	
15	CI										**0.36**
16	CI					**0.68**					**0.76**
17	CI					**0.87**					**0.73**
18	CI					**0.70**					**0.79**
19	CI					**0.77**					**0.71**

Key: AC = attitude-towards-chemists, CS = required skills of chemists, AS = attitude-toward-chemistry in society, LI = leisure interest in chemistry, CI = career interest in chemistry

[1] Solution is oblique pattern matrix, delta=0. Correlations less than 0.3 are omitted. Note: the self-efficacy scale data loaded as one factor.

Table 5.2

Factor analysis for the validation of the *learning experiences* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) and the end of the semester (n=339).[1]

Item	Subscale	% Variance explained			
		37.69	9.62	5.64	4.59
1	L1	**0.44**			
2	L2	**0.58**			
3	L3	**0.61**			
4	L4	**0.73**			
5	L5	**0.72**			
6	L6	**0.57**			
7	L7	**0.35**			
8	L8	**0.66**			
9	L9	**0.58**			
10	T1		**-0.41**	0.34	
11	T2		**-0.76**		
12	T3		**-0.42**		
13	T4		**-0.79**		
14	T5	0.37	**-0.53**		
15	T6		**-0.78**		
16	T7		**-0.61**		
17	T8		**-0.57**		
18	T9		**-0.80**		
19	P1			**0.60**	
21	P2			**0.69**	
22	P3			**0.75**	
23	P4			**0.65**	
24	P5			**0.66**	
26	P6			**0.64**	
27	P7			**0.73**	
29	P8			**0.34**	0.31
30	P9			**0.48**	
20	D1				**0.76**
25	D2	0.36			**0.40**
28	D3				**0.60**
31	D4				**0.68**

Key: L = lecture learning experiences, T = tutorial learning experiences, P = practical learning experiences, D = Demonstrator learning experiences

[1] Solution is oblique pattern matrix, delta=0. Correlations less than 0.3 are omitted.

The data from the factor analysis of the self-efficacy scale indicates that the four factors tentatively identified for the scale in the pilot study, collapsed to one factor at the start of the year (KMO 0.94, 25% non-redundant residuals) and at the end of the semester (KMO 0.95, 13% non-redundant residuals). The data from the factor analysis of the learning experiences scale after removing four questions indicates four main factors (KMO 0.93, 17% non-redundant residuals) with the lectures and lecturers subscales correlating under one factor - confirming that the original ambiguity in the items was now removed. Statistical discriminant validity analysis confirmed discriminant validity for the attitude (average at start of the year 0.38, end of the semester 0.33) and learning experiences scales (average 0.31) (Table 5.3). Both of these are at such a level as to suggest that their subscales are conceptually distinct. The results from the self-efficacy statistical discriminant validity also suggest that the previously defined self-efficacy constructs actually load as one factor, with at average inter-correlation of 0.80. Thus the factor analysis and statistical discriminant validity suggest that the CAEQ has high discriminant validity.

Assessment of the reliability of subscales using Cronbach's α (Burns, 1994) resulted in a mean reliability for the instrument of 0.74 at the start of the year (n=332) and 0.84 at the end of the semester (n=337), comparable with TOSRA (0.82, n=324-340) and the CBSEI (0.88, n=1096), and showed adequate reliability for all subscales - confirming convergent validity of the instrument (Table 5.3).

Table 5.3

Reliability (Cronbach's α) and statistical discriminant validity for the subscales of the *Chemistry Attitude and Experience Questionnaire* (CAEQ) (n=669)

Scales and subscales	**Reliability (Cronbach α)**		**Discriminant validity**	
	Start of the year	End of the semester	Start of the year	End of the semester
Attitude-towards-chemistry	0.76	0.80	0.38	0.33
Attitude-towards-chemists	0.66	0.72	0.41	0.17
Skills of chemists	0.74	0.78	0.45	0.33
Attitude-towards-the role of chemistry in society	0.86	0.93	0.32	0.35
Leisure interest in chemistry	0.83	0.73	0.30	0.44
Career interest in chemistry	0.69	0.85	0.42	0.38
Self-efficacy	0.93	0.96	-	-
Learning experiences		0.87		0.27
Lecture learning experiences	-	0.87	-	0.30
Tutorial and tutor learning experiences	-	0.90	-	0.04
Practical learning experiences	-	0.85	-	0.38
Demonstrator learning experiences	-	0.84	-	0.37
All scales	*0.76*	*0.84*	*0.38*	*0.31*

5.4.4 Construct Validity of the CAEQ

Construct validity for the CAEQ was further evaluated by examination of concurrent and predictive validity. Concurrent validity was confirmed by investigation of correlations of chemistry majors and non-majors showing that majors had a more positive attitude-towards-chemistry, a higher chemistry self-efficacy and were more positive about their learning experiences than non majors, with all differences across subscales for both administrations statistically significant ($p < .05$) (Table 5.4).

Table 5.4

Estimated means for subscales of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) at the start of the year (n=332) and the end of the semester (n=337).[1]

Subscale	Planning on enrolling in second-year chemistry		Not planning on enrolling in second-year chemistry		t	p
	Mean[1]	S.D.	Mean[1]	S.D.		
Start of the Year						
Attitude-towards-chemists	4.74	0.90	4.39	0.99	4.59	0.00
Skills of chemists	5.17	0.94	4.97	1.00	1.93	0.05
Attitude-towards-chemistry in society	5.83	0.89	5.62	1.00	2.10	0.04
Leisure interest in chemistry	4.42	1.27	3.97	1.26	3.34	0.00
Career interest in chemistry	5.09	1.09	4.29	1.29	6.05	0.00
Self-efficacy	4.69	0.97	4.43	1.16	2.19	0.03
End of the Semester						
Attitude-towards-chemists	4.74	0.97	4.33	1.08	3.54	0.00
Skills of chemists	5.18	1.07	4.79	1.05	3.09	0.00
Attitude-towards-chemistry in society	5.81	1.11	5.48	1.18	2.51	0.01
Leisure interest in chemistry	4.37	1.27	3.86	1.43	3.25	0.00
Career interest in chemistry	5.20	1.07	4.26	1.31	6.24	0.00
Self-efficacy	4.84	0.96	4.33	1.38	3.78	0.00
Lecture learning experiences	3.46	0.58	3.11	0.65	4.75	0.00
Tutorial learning experiences	3.56	0.62	3.32	0.69	2.95	0.00
Practical learning experiences	3.82	0.65	3.65	0.61	2.67	0.00
Demonstrator learning experiences	3.69	0.72	3.40	0.73	3.51	0.00

[1]All differences in estimated means are statistically significant ($p<.05$)

Note:
Attitudinal and self-efficacy responses were measured using a seven point semantic differential scale (1=negative, 7=positive), and learning experiences using a five point Likert scale (1=negative, 5=positive).

Predictive validity was likewise examined by correlations of the estimated mean response for the learning experiences subscales with the attitude and self-efficacy subscales using Pearson's correlation co-efficient. All the correlations were significant ($p < .01$) (Table 5.5). Therefore, as learning experiences subscales are influenced by attitude and self-efficacy (and vice-versa), the CAEQ predicts a result that it was designed to do so, and hence has high predictive validity.

5.5 Validation of Data from the Main Study

It is the researcher's view that questionnaires such as the CAEQ which show adequate construct validity in instrument development phases should be seen not as fixed instruments that must be adhered to, but more as a well-developed template in which to base a study on. For example, research carried out in universities that run optional drop-in tutorials rather than regularly scheduled tutorial classes may need to slightly modify tutorials items in the CAEQ to ensure face validity. It is also appropriate, and indeed necessary, that the data generated from any administration of an instrument is examined for other forms of construct validity using the full gambit of statistical techniques employed here. To address this issue, construct validity analyses were carried out on data generated from all three administrations of the CAEQ in this study (the CAEQ

Table 5.5

Pearson's Correlation between the *learning experiences* subscales for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ), with the *attitude-towards-chemistry* and *chemistry self-efficacy* subscales at the end of the semester (n=337).[1]

	Lecture learning experiences	**Tutorial learning experiences**	**Practical learning experiences**	**Demonstrator learning experiences**
Attitude-towards-chemists	0.43	0.30	0.39	0.38
Skills of chemists	0.43	0.27	0.45	0.38
Attitude-towards-chemistry in society	0.34	0.24	0.39	0.35
Career interest in chemistry	0.42	0.24	0.38	0.37
Leisure interest in chemistry	0.41	0.25	0.38	0.32
Self-efficacy	0.38	0.29	0.47	0.34

[1] all statistically significant at $p<.01$

was administered at the start of the year, the end of the first semester course and the end of the second semester course). All three data sets were examined using factor analysis, reliability, statistical discriminant validity, concurrent validity, and convergence validity. However, in this instance the orthogonal Varimax rotation was used as the data between the three administrations needed to be compared. That is, oblique rotations often give structures that are inherent to one particular context. Consequently these rotations are often unique and cannot be reconstructed in another context – in this case after a semester and year study of first-year chemistry (Rennie, 1997). These data generated from the administrations of the CAEQ were also compared with interviewee responses to ensure that responses were consistent (Chapter 4, Section 4.10.4, p. 100).

Examination of the attitude-towards-chemistry factor analysis (Table 5.6) suggests that the data from the study loaded on similar factors as indicated by the instrument development. Data from start of the year and the end of the first semester loaded in a similar manner with only two questions in each data set showing erroneous correlation patterns. Data from the second semester administration exhibited similar factor analysis results as the instrument development. As with the instrument development self-efficacy factor analysis was complex (Table 5.7), with all questions interrelated on two factors for the end of first semester and end of second semester datasets and three for the start of the year data set. Interestingly, the factor analysis of the learning experiences data sets showed five factors, with the previously unidentified factor predominantly containing questions about lecture and tutorial teaching practices (Table 5.8). Many of these questions no longer correlate on the lecture or tutorial subscales. Although analysis of this extra factor may prove to give some interesting results, it would be inappropriate to carry out this investigation as the factor has not undergone the rigorous analysis of the other factors. Removal of some items improves the factor analysis for both administrations (Table 5.9).

Table 5.6

Factor analysis for the validation of the *attitude-towards-chemistry* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) in all three administrations of this instrument in the main study.[1]

Item	**Subscale**	**Start of year** KMO=0.820 Non redundant residuals = 16% (n=126)					**End of first semester** KMO=0.776 Non redundant residuals = 26% (n=102)					**End of second semester** KMO=0.803 Non redundant residuals = 22% (n=84)				
% Variance Explained		6.68	5.84	30.08	10.05	8.16	9.10	6.23	12.32	6.65	33.24	8.90	5.46	9.98	6.22	38.06
1	AC	**0.59**						0.40		0.42		**0.73**				
2	AC	**0.72**					**0.46**	0.39				**0.79**				
3	AC	**0.49**	0.38	0.31			**0.63**					**0.45**			0.36	
4	CS		**0.32**			0.37	0.35	**0.37**	0.34			0.62	**0.36**		0.32	
5	CS	0.37					0.71					0.37	**0.35**	0.32		
6	CS		**0.35**			0.37		**0.61**		0.37			**0.75**			
7	CS		**0.58**				0.35	**0.61**					**0.50**			
8	CS		**0.55**					**0.56**					**0.35**			
9	AS			**0.62**			0.40		**0.62**					**0.79**		
10	AS			**0.70**					**0.88**					**0.87**		
11	AS			**0.81**					**0.81**					**0.79**		
12	AS			**0.71**					**0.81**					**0.79**		
15	CI	0.32					0.43			**0.37**	0.30				**0.42**	
16	CI				**0.48**					**0.74**					**0.67**	
17	CI				**0.77**					**0.78**				0.30	**0.76**	
18	CI				**0.68**					**0.77**				0.30	**0.70**	
19	CI				**0.71**					**0.74**					**0.70**	0.37
13	LI					**0.70**		0.33		0.58	**0.31**			0.41		**0.50**
14	LI					**0.75**				0.58	**0.57**				0.53	**0.67**
20	LI				0.34	**0.63**		0.31		0.39	**0.62**				0.32	**0.73**
21	LI					**0.54**					**0.53**					**0.53**

Key: AC = attitude-towards-chemists, CS = required skills of chemists, AS = attitude-towards-chemistry in society, LI = leisure interest in chemistry CI = career interest in chemistry

[1] Solution was rotated by Varimax rotation. Correlations less than 0.3 are omitted

Table 5.7

Factor analysis for the validation of the *chemistry self-efficacy* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) in all three administrations of this instrument in the main study.[1]

Item	Subscale	Start of the year KMO=0.835 Non redundant residuals=33% (n=126)			End of first semester KMO=0.878 Non redundant residuals=37% (n=102)		End of second semester KMO=0.891 Non redundant residuals=21% (n=84)		
% Variance Explained		44.19	10.61	6.51	49.06	13.20	50.48	7.77	6.86
1	SE	0.36	0.62		0.52	0.40	0.61	0.32	
2	SE	0.35	0.38		0.68		0.58	0.38	
3	SE		0.61		0.79			0.40	
4	SE	0.65	0.35		0.77		0.59		0.32
5	SE	0.65			0.76		0.73	0.40	
6	SE	0.33	0.30	0.36	0.62		0.71	0.31	
7	SE	0.53	0.65		0.70		0.82		
8	SE	0.65	0.47		0.74		0.71		0.42
9	SE			0.65		0.69	0.36	0.80	
10	SE		0.50	0.54	0.37	0.71			
11	SE	0.47	0.35	0.41	0.55	0.45	0.67	0.34	0.30
12	SE	0.62			0.34	0.67	0.42	0.45	0.37
13	SE			0.67		0.86		0.74	
14	SE	0.31	0.69	0.37	0.74	0.31	0.61		0.36
15	SE		0.49	0.53	0.58	0.64	0.58		0.42
16	SE	0.69			0.48	0.58		0.34	0.84
17	SE			0.72		0.68	0.32	0.63	0.47

[1] Solution was rotated by Varimax rotation. Correlations less than 0.3 are omitted

Table 5.8

Initial factor analysis for the validation of the *learning experiences* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) in all three administrations of this instrument in the main study[1].

Item	**Subscale**	**End of first semester** KMO=0.750 Non redundant residuals=34% (n=102)					**End of second semester** KMO=0.706 Non redundant residuals=34% (n=84)				
% Variance Explained		27.18	9.78	8.19	5.19	6.043	8.00	7.54	29.42	6.84	5.29
1	L			0.33		0.34	**0.38**				
2	L			0.32		0.39	**0.73**				
3	L					0.64					0.48
4	L	**0.36**				0.45	**0.74**			0.41	
5	L	**0.33**				0.66	**0.69**				0.49
6	L	**0.64**					**0.59**		0.38		
7	L	**0.38**						0.30			
8	L	**0.57**					**0.64**				
9	L	**0.48**		0.41			**0.63**				0.34
10	T		**0.56**					**0.79**			
11	T		**0.75**					**0.71**			
12	T					0.81		**0.46**			0.59
13	T		**0.55**				0.38		0.33		
14	T		**0.35**			0.74		**0.39**			0.65
15	T		**0.71**				0.40	**0.62**			
16	T		**0.40**			0.47		**0.58**			0.30
17	T					0.50					
18	T		**0.64**					**0.47**			0.38
19	P			**0.47**					**0.42**	0.35	
21	P			**0.44**					**0.30**	0.32	0.44
22	P			**0.82**					**0.50**		
23	P			**0.46**					**0.60**		
24	P	0.32		**0.53**					**0.70**		
26	P		0.37	**0.33**					**0.65**		
27	P			**0.67**					**0.70**		
29	P			**0.51**	0.31					0.74	
30	P			**0.56**						0.39	0.39
20	D				**0.68**						0.63
25	D				**0.40**						0.68
28	D				**0.61**					**0.64**	
31	D				**0.78**					**0.50**	

Key: L= Lecture Learning Experiences, T= Tutorial Learning Experiences,
P= Practical Learning Experiences and D= Demonstrator Learning Experiences

[1] Solution was rotated by Varimax rotation. Correlations less than 0.3 are omitted

Table 5.9

Final factor analysis for the validation of the *learning experiences* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) from the end of first semester and end of second semester administrations of this instrument in the main study.[1]

Item	Subscale	End of first semester KMO= 0.751, Non-redundant residuals=34% (n=102)				End of second semester KMO=0.702, Non-redundant residuals=44% (n=84)			
% Variance Explained		9.71	27.93	8.90	5.81	31.77	8.30	9.53	7.71
1	L	**0.44**				**0.39**			
2	L	**0.49**		0.31		**0.72**			
4	L	**0.50**				**0.73**			
5	L	**0.83**				**0.71**			0.41
6	L	**0.47**				**0.59**		0.37	
8	L	**0.45**				**0.63**			
9	L	**0.49**		0.44		**0.64**			
10	T		**0.55**				**0.85**		
11	T		**0.77**				**0.73**		
13	T		**0.57**			0.37			
14	T	0.68					**0.46**		0.60
15	T		**0.67**			0.38	**0.61**		
16	T	0.44	**0.33**				**0.60**		
18	T		**0.65**				**0.48**		0.30
19	P			**0.42**				**0.52**	
21	P			**0.47**				**0.40**	0.39
22	P			**0.79**			0.34	**0.55**	
23	P			**0.48**				**0.62**	
24	P			**0.60**				**0.60**	
26	P		0.39	**0.39**				**0.65**	
27	P			**0.71**				**0.73**	
20	D				**0.70**				**0.69**
25	D			0.31	**0.42**				**0.73**
28	D				**0.59**			0.41	
31	D				**0.81**			0.44	**0.31**

Key: L= Lecture Learning Experiences, T= Tutorial Learning Experiences, P= Practical Learning Experiences and D= Demonstrator Learning Experiences

[1] Solution was rotated by Varimax rotation. Correlations less than 0.3 are omitted

Analysis of the reliability data shows that adequate reliability was observed for all subscales in all administrations, with only the attitude-towards-chemists end of the first semester, required skills of chemists and tutorial learning experiences end of second semester data giving Cronbach α reliabilities below 0.7. All Cronbach α reliabilities were above 0.5 (Table 5.10). The mean reliability for each of scales in each of the administrations ranged from 0.75 for the end of first semester attitude-towards-chemistry to 0.94 for the end of first semester chemistry self-efficacy scale.

The statistical discriminant values for the attitude-towards-chemistry subscales were slightly higher that from the instrument validation. However, all values are below 0.50. In addition, the learning experiences data showed lower statistical discriminant validity values than the instrument development data, with a mean statistical discriminant validity of 0.41.

Table 5.10

Reliability (Cronbach's α) and statistical discriminant validity for the subscales of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for all three administrations of the instrument in the main study.

	Reliability (Cronbach α)			**Discriminant validity**		
	Start (n=126)	End of First semester (n=102)	End of Second semester (n=84)	Start (n=126)	End of First semester (n=102)	End of Second semester (n=84)
Attitude-towards-chemists	0.67	0.56	0.75	0.41	0.41	0.43
Attitude-towards-chemistry in society	0.84	0.88	0.92	0.39	0.33	0.43
Career interest in chemistry	0.80	0.85	0.86	0.45	0.45	0.51
Required Skills of chemists	0.66	0.78	0.75	0.43	0.46	0.53
Leisure interest in chemistry	0.76	0.72	0.76	0.31	0.42	0.43
Chemistry self-efficacy	0.93	0.94	0.79			
Lecture learning experiences		0.80	0.84		0.41	0.44
Tutorial learning experiences		0.82	0.68		0.39	0.45
Practical learning experiences		0.81	0.83		0.44	0.45
Demonstrator learning experiences		0.74	0.71		0.32	0.39

Analysis of concurrent validity looking at the difference in means between students planning on taking second-year chemistry and students not planning to take second-year chemistry, showed some unexpected results (Table 5.11). For example, there were no statistically significant differences between the two groups of students for the leisure interest in chemistry and career interest in chemistry subscales, for the administration at the end of the first semester. This also occurred for the required skills of chemists and the attitude-towards-chemistry in society subscales for the end of the second semester. The data from the self-efficacy scale, however, showed adequate concurrent validity for all administrations. However, for the learning experience subscales the concurrent validity was not as convincing, with none of the estimated mean responses between those students intending to enrol in second year chemistry and those not intending to enrol being statistically significant at the $p<.05$ level. The reason for this is not clear. It is possible that the assumption that the learning experiences are different for those students intending to enrol in second year chemistry and those not intending to enrol in second year chemistry is not valid for this institution. That is, whilst it is reasonable to assume that in general students taking chemistry in subsequent years would have different attitude-towards-chemistry, chemistry self-efficacy and chemistry learning experiences than those not planning to enrol in second-year chemistry, this may not hold true to specific institutions, or environments. Therefore the poor concurrent validity results alone do not imply the data collected is invalid, but that this finding should be considered in the context of the other validity tests.

Pearson's correlations were calculated for the attitude-towards-chemistry, chemistry self-efficacy and chemistry learning experiences scales in order to evaluate predictive validity. These correlations were significant in 78% (31 out of 40) of the cases, with three of the non-statistically significant findings coming from the demonstrator subscale (Table 5.12). Other non-significant correlations occurred at the end of first semester, with no correlation seen between attitude-towards-chemistry in society and practical learning experiences, and, for the second semester data set, there were no correlations seen between attitude-towards-chemistry in society and attitude-towards-chemists and lecture learning experiences.

Table 5.11

Estimated means for subscales for the Chemistry Attitudes and Experiences Questionnaire (CAEQ).

	Start of the year (n=126)						End of the first semester (n=102)						End of the second semester (n=84)					
	Enrolling[1]		Not Enrolling[2]		t	p	Enrolling[1]		Not Enrolling[2]		t	p	Enroling[1]		Not Enrolling[2]		t	p
	Mean	SD	Mean	SD			Mean	SD	Mean	SD			Mean	SD	Mean	SD		
Attitude-towards-chemists	4.67	0.87	4.17	1.08	2.22	0.03*	4.70	0.88	4.39	0.85	2.31	0.02*	4.80	0.91	4.61	1.45	2.08	0.04*
Required shills of chemists	5.20	0.87	4.76	0.74	2.16	0.03*	5.17	1.01	4.53	1.03	2.26	0.03*	5.12	0.95	4.83	0.61	1.83	0.07
Attitude-towards-chemistry in society	5.74	0.86	5.25	0.86	2.54	0.02*	5.75	0.95	5.13	0.54	2.04	0.05*	5.51	1.03	5.58	0.79	1.20	0.23
Leisure interest in chemistry	4.32	1.40	4.15	1.21	0.55	0.60	4.26	1.36	2.79	0.84	0.80	0.43	4.22	1.40	4.21	0.91	2.10	0.04*
Career interest in chemistry	5.11	0.86	4.31	0.96	3.74	0.00*	5.14	0.96	3.80	0.69	1.86	0.07	5.00	1.13	4.60	1.17	2.74	0.01*
Chemistry self-efficacy	4.46	0.92	3.91	0.90	2.45	0.02*	4.50	0.91	3.69	1.05	3.79	0.00*	4.63	1.48	3.99	1.51	2.51	0.02*
Lecture learning experiences							3.69	0.59	3.79	0.51	1.56	0.12	3.66	0.68	3.63	0.26	1.52	0.13
Tutorial learning experiences							3.34	0.59	3.46	0.43	0.13	0.90	3.48	0.60	3.54	0.84	1.15	0.25
Practical learning experiences							3.79	0.54	4.13	0.60	1.15	0.25	3.79	0.81	3.59	0.88	0.58	0.67
Demonstrator learning experiences							3.53	0.50	3.58	0.76	1.06	0.35	3.57	0.62	3.69	0.51	0.91	0.46

*statistically significantly different at $p<.05$
[1] Planning on enrolling in second-year chemistry
[2] Not planning on enrolling in second-year chemistry

Note:
Attitudinal and self-efficacy responses were measured using a seven point semantic differential scale (1=negative, 7=positive), and learning experiences using a five point Likert scale (1=negative, 5=positive).

Table 5.12

Pearson's Correlation between *learning experiences* subscales for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ), with *attitude-towards-chemistry* and *chemistry self-efficacy* subscales in the second and third administrations of the instrument in the main study.

	End of first semester (n=102)				**End of second semester** (n=84)			
	Lecture	Tutorial	Practical	Demon-strator	Lecture	Tutorial	Practical	Demon-strator
Attitude-towards-chemists	0.32*	0.27*	0.41*	0.24*	0.20	0.29*	0.37*	0.13
Required skills of chemists	0.42*	0.31*	0.36*	0.19	0.37*	0.36*	0.44*	0.28*
Attitude-towards-chemistry in society	0.22*	0.23*	0.17	0.04	0.19	0.32*	0.41*	0.17
Leisure interest in chemistry	0.26*	0.18*	0.31*	0.24*	0.34*	0.27*	0.32*	0.32*
Career interest in chemistry	0.25*	0.20*	0.29*	0.18	0.38*	0.38*	0.46*	0.42*
Self-efficacy	0.51*	0.37*	0.55*	0.28*	0.41*	0.32*	0.39*	0.23

*statistically significant at p<.05

In summary, although there are few minor inconsistencies in the construct validity analysis, for the most part all of the subscales show high construct validity. The demonstrator subscale is the one subscale consistently less valid meaning that interpretation of data from this subscale needs to be treated with caution. Consequently, the findings from the data collected from the demonstrator learning experiences subscale are not presented within this thesis.

5.6 Chapter Review

The CAEQ was developed to measure attitude-towards-chemistry, chemistry self-efficacy and tertiary level learning experiences of tertiary students, whilst addressing many of the validity issues that have plagued quantitative research of this nature. The instrument was developed from a theoretical framework based on the TPB and definitions of chemistry, attitude and self-efficacy, thereby addressing many of Krynowsky's (1988) and Munby's (1997) concerns about lack of theoretical grounding in similar instruments. Face validity was investigated by using the panel of experts and the readability of the instrument and student comprehension by interviewing a cohort of students after they had completed the instrument. Following Munby's (1997) and Trochims (1999) recommendations, convergent and discriminant validity were evaluated by factor, reliability, and statistical discriminant validity analysis and all subscales gave statistically significant differences for students planning and not planning on taking chemistry in their second year, thus confirming concurrent validity. The learning experiences subscales showed statistically significant correlations with all attitude-towards-chemistry and chemistry self-efficacy subscales, indicating that the instrument also possesses high predictive validity.

As the final version of the CAEQ has high content, face, convergent, discriminant, concurrent and predictive validity it is most likely to give data from which valid conclusions can be drawn from the theoretical constructs for the subscales. This means that the CAEQ is likely to be a useful tool for examining the influence of learning experiences, attitude-towards-chemistry and chemistry self-efficacy on students' enrolment choices.

The data collected during the main study component of this inquiry also showed adequate content, face, convergent, discriminant, concurrent and predictive validity for all but the demonstrators learning experiences scale. As such, this data will be useful in determining the influence first-year chemistry has on students' enrolment choices (Chapter 6, p.134).

5.7 Chapter Summary

This chapter discussed the development of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ). First, some of the issues in questionnaire development were discussed, and then the development procedures were outlined. Data from the pilot study of the CAEQ was discussed and then the validation of the instrument was examined. Finally, the validity of the data from the three administrations of the CAEQ was examined. Chapter 6, which follows reports on the research findings for the first research question.

CHAPTER 6
RESEARCH FINDINGS: LEARNING EXPERIENCES AND THEIR INFLUENCE ON ATTITUDE-TOWARDS-CHEMISTRY AND CHEMISTRY SELF-EFFICACY

This chapter presents the results for the first research question:

1. What are student first-year chemistry learning experiences, attitude-towards-chemistry and chemistry self-efficacy, how does student background influence these and what influence, if any does student first-year chemistry learning experiences have on attitude-towards-chemistry and chemistry self-efficacy?
    i. What are student first-year chemistry learning experiences?
    ii. What influence, if any, does student gender, ethnicity, socio-economic background and enrolment reasons have on their learning experiences?
    iii. What is student attitude-towards-chemistry?
    iv. What influence, if any, does student gender, ethnicity, socio-economic background and enrolment reason have on attitude-towards-chemistry?
    v. What is student chemistry self-efficacy?
    vi. What influence, if any, does student gender, ethnicity, socio-economic background and enrolment reason have on chemistry self-efficacy?
    vii. What influence, if any, does student attitude-towards-chemistry have on learning experiences?
    viii. What influence, if any does student chemistry self-efficacy have on learning experiences?

A description of the sample used in this study is presented first, followed by the results from the learning experiences subscales from the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ), and the interview data about student learning experiences. Next are the findings - quantitative and qualitative, for student attitude-towards-chemistry, and the influence of learning experiences on student attitude-towards-chemistry. This is followed by a description of the findings about student chemistry self-efficacy from the three administrations of the CAEQ and the interview data.

6.1 Administration of the CAEQ Instrument

6.1.1 Sample Used in the Study

The sample used in this study was the entire first year chemistry class of at the University of Waikato. This sample differs slightly to that involved in the validation of the CAEQ, where the instrument was administered in another institution for validation purposes. To recap briefly, the chemistry department involved in this study offers two first-year chemistry courses, *Chemical Concepts*, presented in the first semester, and *Chemical Change & Organic Concepts*, in the second semester. The first semester course covers aqueous chemistry and bonding for inorganic substances, whereas the second course covers physical and organic chemistry. Both courses consist of 12 compulsory three-hour laboratory classes, 36 lectures and 12 tutorials. Students are required to pass the laboratory component, and must obtain a minimum of 40% in the examination to pass either of the courses. Full details of the course content are provided in Appendix B.

6.1.2 Response Rates Achieved in the Administration of the CAEQ

The response rate for the CAEQ varied with each administration. One hundred and twenty six students completed the CAEQ at the start of the year, a response rate of 70%. At the end of the first semester 109 students completed the instrument, a response rate of 56%. Two reasons were identified for this variation: first, was a habitual drop in enrolments during the second semester, and second, work pressures in the laboratory classes at the end of the year. The second administration of the instrument was held toward the end of the scheduled laboratory classes and students were under pressure to complete and hand in their laboratory books, and were thus less inclined to complete the questionnaire. In order to improve the response rate, the data collection at the end of second semester occurred slightly earlier in the course. A higher response rate was deemed desirable since enrolments are generally lower for the second semester course (112 compared to 180 in the first semester course at the time of the study). Eighty-four students completed the CAEQ at the end of the second semester - a response rate of 75%.

6.1.3 Demographics for the Three Administrations of the CAEQ

In all three administrations the respondents were asked their student ID number, with the proviso that this would not be used to access confidential information. Therefore, it seemed that the demographics questions needed to be included in the questionnaire only once. However, a number of respondents in each administration did not provide this number. Additionally, a proportion of the respondents to the second administration had not completed the questionnaire in the first administration. Consequently, the demographic data for this administration is limited. Because of this, demographic questions were included in the third administration. The figures presented below refer to the first and third administrations (Table 6.1). Of those that responded 68 at the start of the year and 69% at the end of the second semester identified themselves as being of New Zealand European decent, similar to the demographics for the total course enrolment. Of the remainder, 12 %at the start of the year and 13% at the end of the second semester identified themselves as Maori or Pacific Islander, and 11% at the start of the year and-8% at the end of the second semester as being of Asian or Indian ethnicity. The gender balance was reasonably even, with 49% of the respondents at the start of the year and 49% at the end of the second semester female.

Table 6.1

Demographics of the respondents to the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) at the start of the year (n=126), the end of the first semester (n=109), and the end of the second semester (n=84).

	Start of first semester (%)	**End of first semester (%)**	**End of second semester (%)**
Response rate	70.0	56.7	75.0
Ethnicity			
New Zealand European	68.3	52.9	69.0
Maori/Pacific Islander	11.9	8.8	13.1
Asian/Indian[1]	11.1	4.9	8.3
Other	2.4	1.0	1.2
No response	6.3	32.4	8.3
Gender			
Male	49.2	35.3	47.6
Female	46.0	33.3	44.0
No response	4.8	31.4	8.3
Decile rating of contributing school[4]			
Overseas student	5.6	3.9	3.6
Low decile school	38.9	26.5	36.9
High decile school	47.6	38.2	44.0
No response	7.9	31.4	15.5
Enrolment reason			
Chemistry major	22.2	20.6	21.4
Science degree (support)	22.2	13.7	16.7
Science degree (compulsory))	39.7	25.5	34.5
Interest	10.3	6.9	14.3
Other	0.8	0.0	4.8
No response	4.8	33.3	8.3

[1] Indian students in New Zealand are typically immigrants from the Fijian Islands, rather than India.

About half of the respondents came from higher decile schools[4] (48% a the start of the year and 44% at the end of the second semester), with 39% of the respondents at the start of the year and 44% at the end of the second semester students from low decile schools and 6% at the start of the year and 4% at the end of the second semester from schools outside New Zealand. Again, this was in proportion to the class demographics (with, e.g., 41% of the students coming from low decile schools). The sample was slightly biased towards students for

[4] All schools in New Zealand are given decile ratings - a measurement of the socio-economic conditions of the local community. Schools with lower decile ratings (1-5) receive more government funding under the premise they receive less financial support from the community.

whom first-year chemistry was a compulsory subject with a corresponding lesser number of students who studied chemistry as a supporting subject. For example, 47% of the students were enrolled in the course as a supporting subject in the first semester course and 25% in the second semester course, whereas in the first administration 22% of the students enrolled for this reason and 17% in the second administration. Some 22% of the respondents were enrolled in the course as chemistry majors, compared to 19% of the first semester class and 25% of the second semester class. Forty percent of the respondents were studying chemistry as a compulsory component to another course compared to 27% in the first semester course and 22% of the second semester course.

The variation in demographic data occurs because even though the same class was sampled each time, individual respondents varied for each of the three administrations (along with variation in response rates for the demographic questions). Nonetheless, the data show that the sampling in each case is in reasonable agreement with the whole class demographics and hence the sampling is a reasonable representation of the class as a whole.

6.1.4 Presentation of Research Findings

The research findings are presented in this chapter, Chapter 6, and the next two chapters, Chapters 7 and 8 (Table 6.2). Findings are presented indicating the research objective, and hypothesis or exploration statement being examined. Research findings for the first research question, examining the influence of first-year chemistry experiences on student attitude-towards-chemistry and chemistry self-efficacy, are presented in the following sections of this chapter. In Chapter 7 the research findings for research questions two, three and four are presented. Finally, in Chapter 8 the findings for research question five are discussed.

Table 6.2

Chapters in which the research findings for each of the five research questions for this study are presented.

Research Question		Chapter
1	What are student first-year chemistry learning experiences, attitude-towards-chemistry and chemistry self-efficacy, how does student background influence these and what influence, if any does student first-year chemistry learning experiences have on attitude-towards-chemistry and chemistry self-efficacy?	Chapter 6
2	What are student attitude-towards-enrolling in chemistry and what influence, if any, does student first-year learning experiences, attitude-towards-chemistry and chemistry self-efficacy have on student attitude-towards-enrolling in second-year chemistry?	Chapter 7
3	Do students hold control beliefs about enrolling in second-year chemistry, if so what are they, and what influence, if any, do student first-year learning experiences, attitude-toward-chemistry and chemistry self-efficacy have on student perceived control over enrolling in second-year chemistry?	Chapter 7
4	What are student perceptions of associates attitude-towards-chemistry and normative beliefs and what influence, if any, does student perception of associates attitudes-towards-chemistry have on subjective norm?	Chapter 7
5	What influence, if any, does student attitude-towards-enrolling in second-year chemistry, perceived control over enrolling in second-year chemistry, and subjective norm, have on intentions to enrol in second-year chemistry?	Chapter 8

6.2 First-Year Chemistry Learning Experiences

1.i	What are student first-year chemistry learning experiences?

1.ii	What influence, if any, does student gender, ethnicity, socio-economic background and enrolment reasons have on their learning experiences?

Students' perceptions of their first-year learning experiences were investigated by quantitative and qualitative methods. This section contains the research findings for the administration of the CAEQ instrument and includes an analysis of the findings based on the different demographic backgrounds of the students. In addition, student perceptions of their learning experiences for the two courses are compared to see if the students had a preference for one of courses. Responses to interviews about student learning experiences are provided after the quantitative findings.

The respondents were asked to provide a response to each item in the 'learning experiences' scale of the CAEQ using a 5-point Likert scale from strongly agree to strongly disagree (5 and 1 respectively). From this response, a value for each subscale - termed the subscale response - was calculated from the mean response to the relevant items. Summary statistical data were then calculated resulting in an estimated mean. The term 'estimated mean' is used here in order to show the researchers' understanding that these data are ordinal level and not ratio/interval level. This issue is discussed in more detail in Chapter 4 (Section 4.3.4, p. 70) As detailed in the methodology the quantitative data were analysed in a number of ways (Chapter 4, Section 4.9.1, p. 96) Data were examined by ANOVA and results that were statistically significant at the $p<0.05$ level were further examined. Subsequently, statistically significant results were analysed by Scheffes post-hoc method to determine where the statistically significant differences occurred. At this stage the data was analysed by η^2 to given an indication of the effect size, and data were plotted as histograms.

6.2.1 *Quantitative Findings for First-Year Learning Experiences at the End of the First Semester*

E_1: Explore student first-year chemistry learning experiences

The respondents were overall positive[5] about their first semester learning experiences. The estimated means for the learning experiences sub-scales were: 3.44 for lectures, 3.78 for tutorials and 3.54 for laboratory classes. The spread of the responses (Figure 6.1), suggests that relatively few respondents felt that they had very negative experiences in any of these three environments. The respondents were most positive about their learning experiences in their tutorial and laboratory classes.

The estimated mean responses were tested by ANOVA analysis and the differences are statistically significant ($p<0.01$, Table 6.3). Post-hoc analysis of the ANOVA results using the Scheffe method found that the estimated mean response for the *tutorial learning experiences* subscale was statistically

[5] For a 5-point Likert scale, a response of greater than 3.0 is deemed to be positive

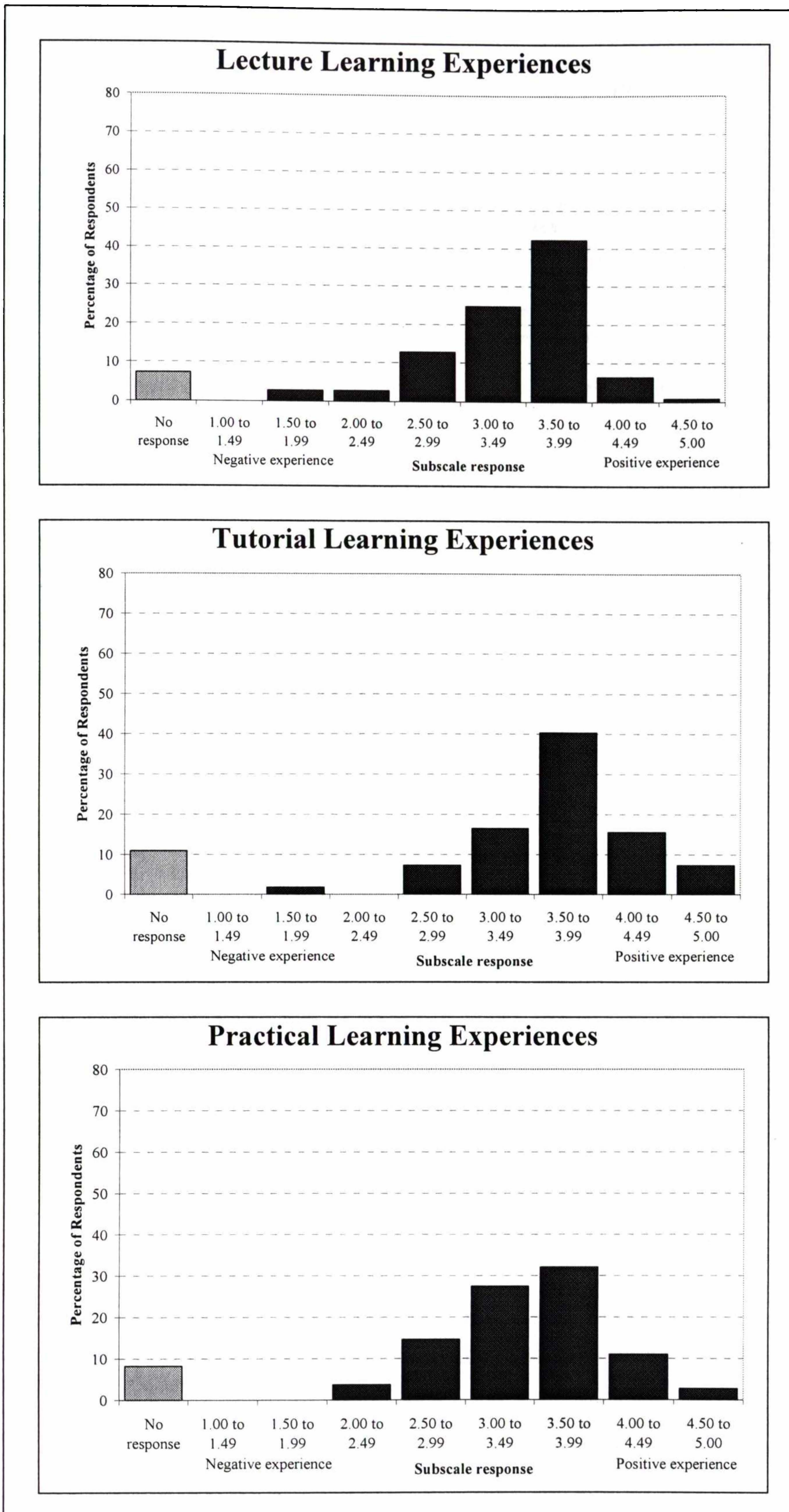

Figure 6.1

Graphical representation of the *learning experiences* subscales of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) - end of the first semester (n=109).

Table 6.3

Differences in the estimated mean responses for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) *learning experiences* subscales for the administration at the end of the first semester (n=109).

	Mean	Std.Dev	F	p	η^2
Lecture learning experiences	3.44	0.56	9.77	0.00	0.06
Tutorial learning experiences	3.78	0.55			
Laboratory learning experiences	3.54	0.56			

significantly different to both the *laboratory* and *lecture learning experiences* subscales estimated mean response (Table 6.4). However, size effect analysis (η^2 of 0.06) suggests that the observed effect is likely to be small. Graphical analysis reveals that although there was a full range of subscale responses for the three subscales, respondents were more likely to indicate very positive experiences for the *tutorial learning experiences* subscale (4.00 to 5.00).

H_1:	Students of different gender have different learning experiences
H_2:	Students of different ethnicity have different learning experiences
H_3:	Students of different socio-economic background have different learning experiences
H_4:	Students of who enrolled in the course for different reasons have different learning experiences

The first semester learning experiences data were further analysed using ANOVA to investigate what influence, if any, gender, ethnicity, socio-economic factors and reasons for enrolment exerted on students' learning experiences. The results of the statistical analyses show no statistically significant differences for any of these demographic groups.

Table 6.4

Post-hoc Scheffe analysis of the ANOVA data of the differences in *learning experiences* subscales for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) from the administration at the end of the first semester (n=109).

	Subsets (statistically significantly different at p<0.05)	
	1	2
Tutorial learning experiences	3.78	
Practical learning experiences		3.54
Lecture earning experiences		3.44
p. (within subset)	1.00	0.46

6.2.2 Quantitative Findings for First-Year Learning Experiences at the End of the Second Semester

E_1:	Explore student first-year chemistry learning experiences

The respondents were still overall positive about their learning experiences at the end of the second semester. Estimated mean responses were 3.61 for *lecture learning experiences*, and 3.81 and 3.61 for tutorial and *practical learning experiences* subscales respectively (Figure 6.2) with more than 50% of the subscale responses in the range 3.50 - 3.99. These data show an interesting trend, with the estimated means greater than 3.50, and a higher proportion of responses greater than 4.50 than at the beginning of the semester, for all three subscales.

ANOVA analysis of the three learning experiences subscales for the second semester shows statistically significant differences ($p<0.05$, Table 6.5). However, post-hoc Scheffe analysis suggests that when comparing differences individually, there are no statistically significant differences (Table 6.6). Furthermore, effect size analysis (η^2 0.03), suggests that the statistically significant differences identified by ANOVA analysis are likely due to statistical variation.

H_1:	Students of different gender have different learning experiences
H_2:	Students of different ethnicity have different learning experiences
H_3:	Students of different socio-economic background have different learning experiences
H_4:	Students of who enrolled the course for different reasons have different learning experiences

Further examination of the end of second semester learning experiences data suggests that although there are no significant differences based on gender, ethnicity and decile rating of contributing school, there are differences in the estimated mean responses for the *practical learning experiences* subscales, between groups of students based on enrolment reasons. For example, science support and interest students (students who chose to enrol in the course, but who are not chemistry majors) are less likely to have a subscale response between 3.50 and 3.99, and more likely to have a subscale response of between 2.50 and 3.49 for the *practical learning experiences* subscale (Table 6.7). Post-hoc

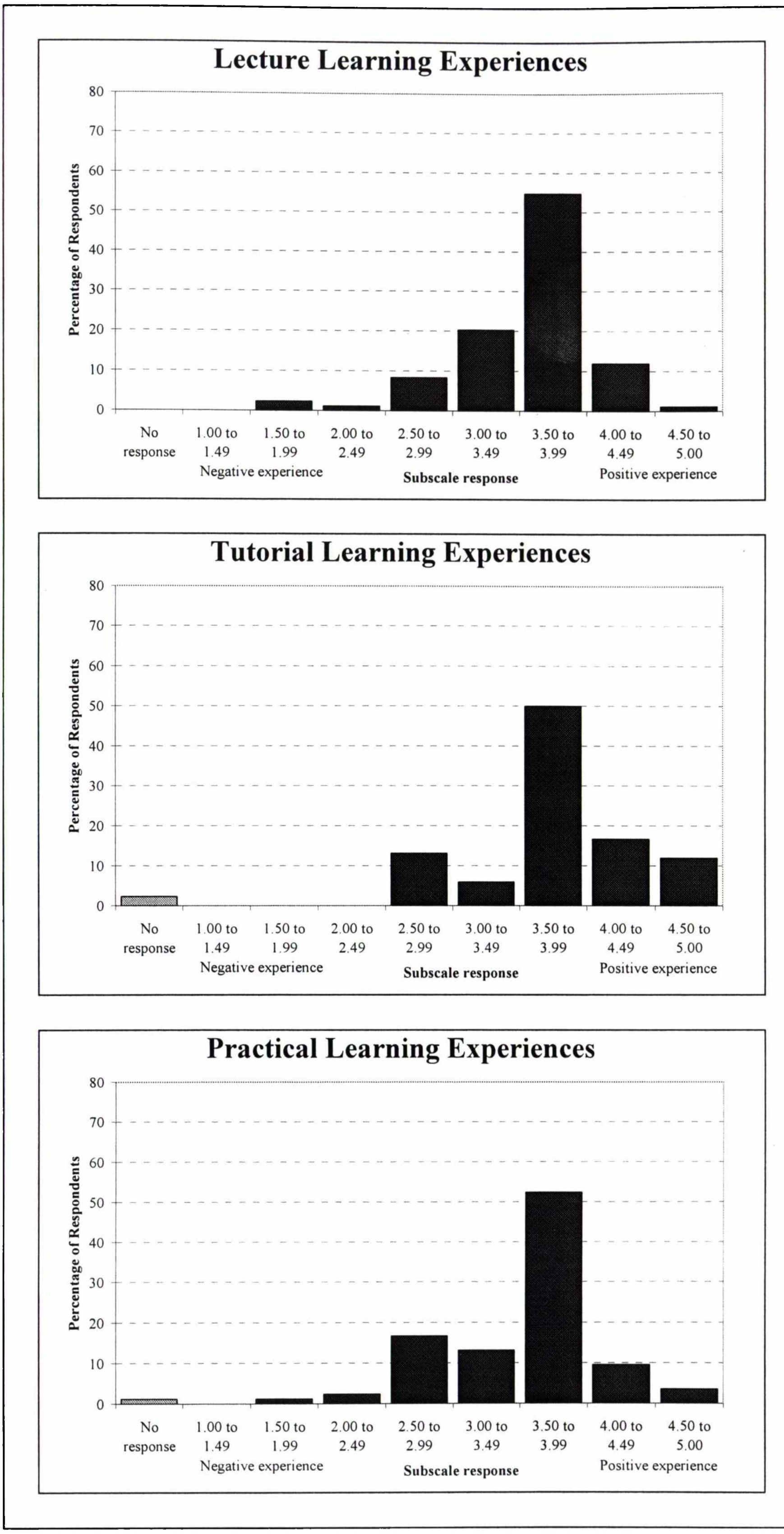

Figure 6.2

Graphical representation of the *learning experiences* subscales of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) - end of the second semester (n=84).

Table 6.5

Differences in the estimated mean responses to the *learning experiences* subscales for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) from the administration at the end of the second semester (n=84).

	Mean	Std.Dev	F	p	η^2
Lecture learning experiences	3.61	0.52	3.18	0.04	0.03
Tutorial learning experiences	3.81	0.69			
Practical learning experiences	3.61	0.57			

Table 6.6

Post-Hoc Scheffe analysis of the ANOVA analysis of the differences in the *learning experiences* subscales from the end of the second semester administration for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) (n=84).

	Subsets (statistically significantly different at p<0.05) 1
Tutorial learning experiences	3.81
Practical learning experiences	3.61
Lecture learning experiences	3.61
p. (within subset)	0.09

Scheffe analysis suggests that students who enrolled in the second semester course as a science support or interest course had less positive experiences than those for whom the second semester course was a compulsory course - as part of a chemistry or another science major (Table 6.8). Furthermore, effect size analyses (η^2 of 0.18) suggests that this result is likely a real reflection of student viewpoints rather than due solely to statistical variation. The spread of the data suggests that science support and interest students are less likely to have an subscale response between 3.50 and 3.99, and more likely to have a subscale response of between 2.50 and 3.49 (Figure 6.3). Therefore, students who enrol in the second semester chemistry course as a science support subject appear more likely to have negative experiences in their laboratory classes than other students enrolled in the course.

Table 6.7

Differences in the estimated mean responses to the *learning experiences* subscales for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents of different gender, ethnicity, decile rating of contributing school and enrolment reason from the administration at the end of the second semester (n=84).

	N	Lecture learning experiences				Tutorial learning experiences				Practical learning experiences			
		Mean	Std Dev.	F	p	Mean	Std Dev.	F	p	Mean	Std Dev.	F	p
Gender				1.06	0.31			0.00	0.98			0.65	0.42
Male	40	3.67	0.36			3.84	0.48			3.66	0.61		
Female	37	3.57	0.60			3.75	0.85			3.53	0.54		
Ethnicity				0.01	0.93			3.69	0.06			0.66	0.42
New Zealand European	58	3.63	0.53			3.73	0.72			3.55	0.54		
Other	18	3.62	0.36			4.01	0.53			3.73	0.70		
Decile rating of contributing school				1.11	0.30			0.00	0.96			0.31	0.58
Low decile school	31	3.52	0.50			3.87	0.56			3.55	0.67		
High decile school	37	3.71	0.49			3.77	0.82			3.63	0.53		
Enrolment reason				0.68	0.51			2.67	0.07			6.54	0.00*
Chemistry major	18	3.71	0.36			4.02	0.52			3.78	0.33		
Science support subject and interest	26	3.62	0.52			3.56	0.87			3.31	0.52		
Compulsory course	29	3.52	0.61			3.89	0.59			3.78	0.55		

* statistically significant at $p<0.01$

Table 6.8

Post-Hoc Scheffe analysis and η^2 of the ANOVA analysis of the differences between the *practical learning experiences* subscales for respondents who enrolled in the second semester course from the end of the first semester administration for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) (n=109).

	Subsets (statistically significantly different at $p<0.05$) 1	2	η^2
Science support subject and interest	3.31		0.18
Chemistry major		3.78	
Compulsory course		3.78	
p. (within subset)	1.00	1.00	

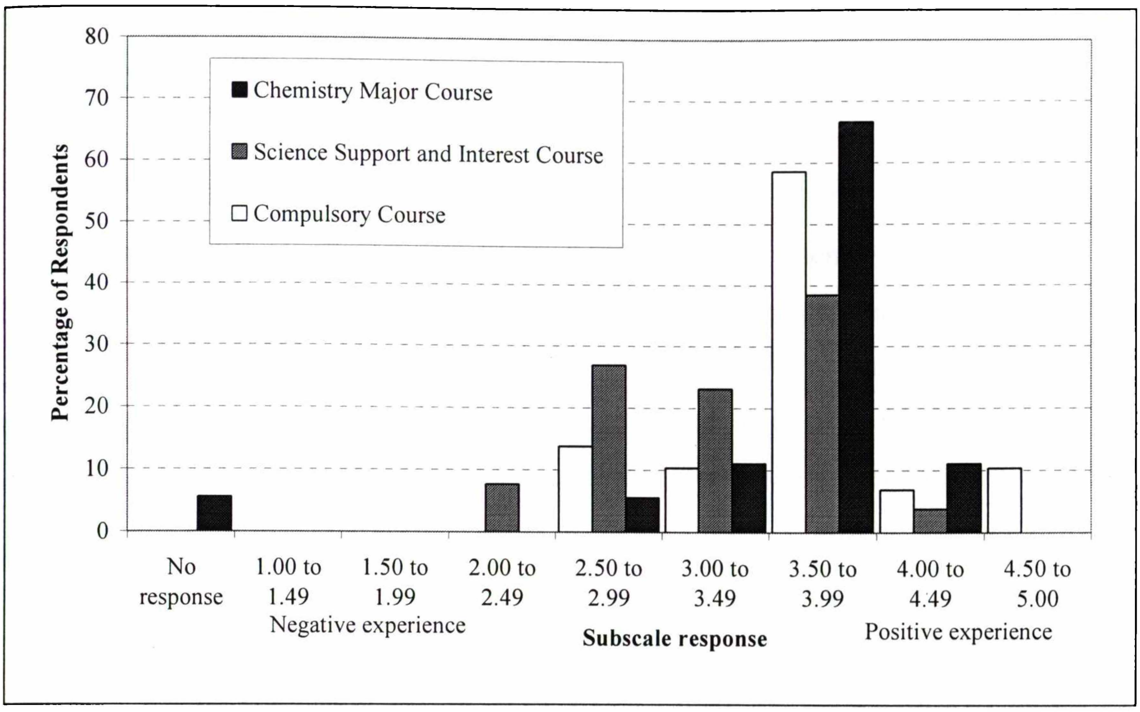

Figure 6.3

Graphical representation for the *practical learning experiences* subscale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents who were chemistry majors (n=22), enrolled in the course as a science support or interest course (n=23) and those for whom the course was a compulsory course of another degree (n=28) - end of the first semester.

6.2.3 Differences in Learning Experiences from the End of the First and Second Semester Courses

E_1: Explore student first-year chemistry learning experiences

Repeated measures GLM analysis comparing the first semester and second semester *learning experiences* subscales shows no significant difference for any of the three learning environments. This suggests that the students were no more positive about their learning experiences in either course.

6.2.4 Qualitative Findings for First-Year Chemistry Learning Experiences

E_1: Explore student first-year chemistry learning experiences

The interview protocol used to triangulate the quantitative data for the CAEQ is provided in Chapter 4 (Section 4.7, p. 83). The questions relating specifically to learning experiences are reproduced in Table 6.9, and the findings from the interviews are presented here.

6.2.5 Tertiary Learning Experiences

At the start of the year many of the participants were apprehensive about tertiary learning. The participants were particularly concerned about lectures and, for example, were concerned that it would be difficult to ask lecturers questions in large lecture classes. The reason for this concern stemmed from a perception of differences between mass lectures they expected to encounter, based on previous experiences in interactive small classes in high school. Similarly, a belief that they were expected to be more independent in the tertiary setting, caused apprehension for some participants. For example, Leanne, believed tertiary chemistry study would require her to "spend a lot of time on my own trying to study and get my head around things as well as adjusting to the fact you can't ask someone right then and there. If you have a problem, you have to wait till maybe tutorial time or when you can speak to a lecturer."

Other students were more concerned about the study skills required of them, including memorisation and learning approaches. Alan, a mature student returning to study after five years in the work force, specified memorisation of content as a particular concern:

> The whole memorising thing has got me a bit scared at the moment. I will have to remember all these things. I think that might be a bit challenging. Trying to sit down and study, and trying to remember it all might be a bit of a culture shock.

A few of the students coming from a schooling system heavily reliant on final summative examinations were worried about the assessment at university. In particular they were worried about appropriate ways to present assignments and how they would cope with '"passing tests." This was of less concern for the more academically able students like Robert who was looking forward to the opportunity to "learn more chemistry, and new chemistry."

Table 6.9

Interview protocol for first semester learning experiences.

Start of the year
1. What parts of the first-year chemistry course do you think you are going to enjoy?
2. What parts of the first-year chemistry course do you think you are not going to enjoy?

End of first semester
1. Can you tell me what you thought about the 101[1] lecture course?
2. Can you tell me what you thought about the 101[1] practical course?
3. Can you tell me what you thought about the 101[1] tutorials?

End of second semester
1. Can you tell me what you thought about the 102[2] lecture course?
2. Can you tell me what you thought about the 102[2] practical course?
3. Can you tell me what you thought about the 102[2] tutorials?
4. Of the different lectures you've had throughout this year, which lecturing style do you like the most?
5. Of the different lectures you've had throughout this year, which lecturing style do you like the least?
6. Of the laboratory experiments you've done this year which would you say like the most?
7. Of the laboratory experiments you've done this year which would you say like the least?
8. Do you have any suggestions about ways the lectures could be improved?
9. Do you have any suggestions about ways the practical classes could be improved?
10. Do you have any suggestions about ways the tutorials could be improved?

[1] Abbreviation of the course code for the first semester course
[2] Abbreviation of the course code for the second semester course

At the end of the first semester many of the students initial concerns had dissipated, as they became more familiar with the tertiary learning environment. At the end of the first semester, only two of the interview participants mentioned study skills as a problem - both in reference to aspects of their second semester course. Kerrie said she would not like "the work because I don't like organic [chemistry]." Interestingly, one of the interview participants who did the second-year analytical chemistry course (which is entirely internally assessed) was unhappy that there were no final examination: "I just like exams, that is all. I usually do way better in exams than tests I like sitting there, trying to figure out things." By the end of the second semester none of the participants had concerns about the study skills required for second-year chemistry courses.

6.2.6 Lecture Learning Experiences

At the beginning of the year, the interview participants voiced very little opinion about the lecture structure of the course beyond the concerns identified previously. Many of the participants identified organic chemistry as a course component that they expected to enjoy - although few were able to articulate what exactly they would enjoy about organic chemistry, beyond references to previous learning experiences: "I liked it at school," and "I find it interesting." Some of the participants thought that they would not like the inorganic component of the course - many associating this with memorisation of large amounts of content. Patrick, for example, said he would not like "inorganic I will struggle a bit with [inorganic]. I do have a bit of problem with the recollection of chemical names." Other interview participants suggested that the basic concepts and the aqueous chemistry component were less appealing because of the mathematical component. For example, Neil, an engineering student, after just one week of tertiary chemistry was particular unhappy: "The mathematics part, that just bugs me out. You go to chemistry to learn about chemicals, and you have to learn a whole bunch of maths to go with it, and it's like, man, I go to maths to learn about maths."

Although some of the interview participants thought they would not like the basic concepts and aqueous chemistry part of the first semester course: "Aqueous [chemistry], I don't really like that," others thought they would like it because the content was similar to their secondary school studies: "I like what are we doing at the moment, I think it's pretty much an overview of [Year-13] with a bit more added to it." Interestingly, none of the interview participants expressed concern about the physical chemistry part of the course, despite its high mathematical component.

At the end of the first semester and at end of the second semester the participants were focussed mainly on the structure of the two courses, rather than the content. Of the participants that mentioned course content during interviews, a number talked generally. For example, Samantha, an academically-able chemistry major, found the course "good, there was quite a bit of new material from like [Year-13], but it wasn't hard to understand." At the end of the second semester a number of participants identified organic chemistry as the part they found most interesting (for both first-year courses) - even those interview participants who did not think they would like organic chemistry at the start of the year. Patrick comments: "I said in one of the other interviews that I thought I would hate [organic chemistry], really loath it. But it's not too bad. It actually turned out to be really good." In contrast, other participants were particularly negative about physical chemistry commenting: "A lot of mathematics," "it was more physics and maths orientated," seeing physical chemistry to be "a bit more sort of textbook, like you don't encounter it as much," and saying "it was a bit alien, I couldn't relate to it really." Some of the interview participants found parts of the first semester course "hard to follow," and requiring a lot of work outside formal classes. Alan said "I didn't find the lectures as beneficial as the tutorials and the laboratories. They sort of give you a bit of understanding, they sort of talk about the topic, but I found I had to do a lot of work outside to understand it."

The interview participants felt that the course notes influenced their ability to understand the course, with most preferring to write some notes, rather than relying solely on a study guide that contained all the notes. For example, Patrick commented:

> When you are just sitting there and you've got all the notes in front of you and he's just talking away you just go off on tangents. With the study guide I am going to have to do a lot of revision to remember what happened, what he was talking about.

However, the alternative of writing down full notes was not considered desirable either. For example, Alan said "I don't have a problem sitting in a lecture writing notes, but [that lecturing style] was just unreal, [the lecturer] just writes so fast and expects us to write so fast." The majority of the participants preferred a lecturing style that used skeleton notes, which the students filled in during lectures. For example, Robert noted:

> If I'm going to it [i.e., the lecture] I don't mind a little bit of writing. I suppose because my writing isn't so neat, so I like printing better. But then if you do write it, you have the added benefit of already kind of studied it a bit. So I like a little bit of both, as long as everything is kept in the same book.

The interview participants felt inhibited about approaching lecturing staff: "It is off-putting to go and ask them for help if you are having difficulties with it." But one lecturer in particular was seen as highly approachable with a good relationship with students. Tabitha commented: "[the lecturer] is, a lot more personal and interacts a lot more with the students."

Some of the interview participants enjoyed the use of visual aids, with Celia commenting that she preferred lectures when the lecturer "brings in props and blows up balloons and makes it more real life, because you can relate to it." One student, Karen, liked it when the course material was contextualised to familiar examples: "He related everything to what we do. He put it in terms of alcohol, and going out, and it's like I know that, and then it's like, that's right." Other popular contexts, particularly for engineering students, were applied chemistry examples. For example, Jack said he liked lectures that discussed "finding out about petrochemicals, finding out where petrol comes from, how it's made in New Zealand, all the different things in nature that you find out using chemistry."

6.2.7 Laboratory Class Learning Experiences

At the beginning of the year the interview participants were looking forward to their laboratory classes, in particular the opportunity to "see it for yourself," and "do it all yourself." The interview participants believed they would enjoy the "hands on" nature of laboratory classes. For example, Kevin, a chemistry major, said "I just like doing hands on stuff, being able to mix chemicals."

Although many interview participants identified the laboratory classes as the most enjoyable part of the course, at the end of both semesters, they were much less positive about some specific experiments. In particular, the amount of time spent doing titrations in the first semester course was unpopular with an overwhelming number of participants. The accuracy and precision deemed necessary by the laboratory supervisors was seen as the major factor contributing to lack of enjoyment. Kevin an intending chemistry major, dropped out of his second semester chemistry course as a direct result of his experiences in the laboratory classes in the first semester course. He comments:

> I'm not sure what I thought we would be doing, but it is just titrations. Fun, fun! It is standardisation of things, it's having to do it so accurately that if you get it not within 0.04 of a mL you have to get three like that. I just don't like having to be so accurate. I mean I usually get it, but I don't like the repetitiveness.

The interview participants were more positive about the organic chemistry experiments enjoying the opportunity to use equipment not available at school, as seen in Jack's comment: "You get to use equipment that you don't really use back in high school. We used burettes and pipettes [i.e., at school], but with the organic you get to use different equipment, reflux condensers, separating funnels, etc." The interview participants were less positive about the physical chemistry laboratory experiments due to the amount of time spent measuring and waiting. For example, Kerrie said she did not like "the kinetics one from physical chemistry. Measuring the temperature was pretty boring, and you had to sit and do the temperature for a minute, for 45 minutes." Interestingly, despite the participants dislike for physical chemistry and titration experiments the most popular experiment from the two courses was an experiment in which they used an ion exchange column to measure the concentration of copper sulfate, an experiment in the physical chemistry laboratory classes involving titrations. The interview participants found this particular experiment easy and reiterated that they got to use equipment they had not used before. Robert noted that he liked using "new equipment [i.e., the ion-exchange column]. It was a little bit time consuming, but it was easy work. Like you set up two at a time and the titration was nice and easy." It is worthwhile to note that this experiment was carried out at end of the second semester, by which time the students were more proficient in the conduct of titrations. In addition, the supervisory staff involved were less concerned with precision in titration results in this experiment compared to previous experiments involving titrations.

Approachability of the staff also influenced the interview participants' perceptions of their laboratory classes. Some of the interview participants found the staff difficult to get along with, and one student, Tabitha, changing her laboratory class. She "enjoyed the labs quite well [after changing]. I've enjoyed them a lot more than my last semester labs, probably because my new lab demonstrator this semester was a lot more relaxed." Other interview participants commented on a shortage of supervisory staff, with, for example, Kerrie saying: "We only had two demonstrators and I thought we could have done with a bit more because everyone needed help and it was a bit hard getting around everyone in the class."

The interview participants generally found the laboratory classes confusing and believed that the classes could be improved by having introductory talks at the beginning of each class. For example, Patrick said:

> Perhaps a bit of a talk at the start with a bit of background theory. Like in a couple of the laboratories the supervisor showed us how to do some of the techniques that we used and some of the reactions that occurred and that was really good. The others when that didn't really occur, it was sort of mix this with this and stuff like than and I'll chuck five mLs of that in and hopefully I will get the right conclusion. Just a bit of talk at the start to get the basic theory, just about 10 minutes at the start. That would help me.

Similarly, the interview participants felt that the laboratory classes could be improved by some instruction on what was required for the experimental write-up, as well as help with post-class questions. One student, Jack, suggested this could be accomplished in tutorial classes by "allowing a little bit of tutorial time for lab write up and help." Others thought the laboratory classes in the first semester course could be improved by reducing the length of the experiments, and noted that the second semester course was better in that the shorter duration of experiments enabled the students to leave the classes early: "I enjoyed the practicals quite a bit. But three hours of chemistry practicals sometimes gets to be a bit too much."

6.2.8 Tutorial Class Learning Experiences

As mentioned above, tutorial classes are voluntary at the institution involved in this study. Participants that attended tutorials found them for the most part beneficial. The interview participants felt the problem sheets provided helped them prepare for tests and examinations. For example, Jack noted that the tutorials "were really helpful, the problems sets they gave me something to do, to work through and make sure I knew everything, and the tutorials just helped reinforce that." In fact, the problem sheets often contributed to the participants' attendance at the tutorials, as answer sheets were handed out at the tutorials. Some interview participants found that the tutorials were not relevant. For example, they felt the physical chemistry problems were not relevant to the material presented in lectures. To illustrate, Patrick stated: "Some of the questions are sort of just completely abstract from the lectures." In addition, the participants felt if they did not get a chance to do the problem sheets, then the tutorials were not as useful and thus they often did not attend tutorials. Felix comments:

> I went to some of them [i.e., tutorial classes]. I actually stopped going to them. I was finding that I wasn't getting the tutorial questions done by going to the tutorials. I was going and getting the answer sheet and going through it. But I wasn't finding time to go through the questions otherwise. I think the tutorials would probably be more beneficial if I was able to get through the questions first.

The participants overall thought the tutorials reinforced the lecture material, and helped explain some of the concepts that they found confusing in the lectures, as seen in Alan's comment:

> They were really helpful because we discuss the theory in the lectures and they provide us with examples of questions that we have to answer ourselves. Going away and having to answer them is quite difficult just from the lecture material, and in the tutorials we can go through and discuss them it makes things a bit clearer. Most of the tutorials I don't

bother going to for most of my subjects, but chemistry I make a real effort to go.

Like their learning experiences in the laboratory classes and lectures, the teaching staff influenced the participants' learning experiences in their tutorial classes. Interview participants who had the same person as both lecturer and tutors, found some of the same negative experiences in the lectures present in the tutorial classes as well. Tabitha found the tutorials "were quite good to help you understand, but my tutor was the lecturer. So I found it a little hard." One participant did not enjoy his tutorial classes as he thought the tutor "seemed to always pick on me, even if I didn't know the answer, which I didn't like. So I haven't been going for a while." Other participants had a better relationship with their tutor than the lecturers, and felt the tutor explained these concepts better. Patrick stated that the tutor "knows what he/she is talking about and if we have any questions he/she's able to answer them without any problem."

6.2.9 Direct Entry Students

The two direct entry students had very different learning experiences to students who completed the first semester first-year course. At the start of the year Robert stated: "I've really gone into second-year to learn something different. That's what I intend to get out of it." But both of these students found the lecture course boring seeing it as "different to the kind of chemistry we normally did when we were at school. It was more machines and how they worked." In addition, they were ambivalent about their laboratory classes stating that they preferred the second semester course "because your doing your own chemistry, sometimes with the [second-year laboratory class] you can just roll along with it and not take much notice. Someone's usually doing stuff for you and then you get printouts at the end of the lab."[6] However, Kirsten acknowledged that, "from school I had a perception of what chemistry would be, like experiments and stuff, and that was what the second-year course was." These students enjoyed their tutorial classes since they provided an opportunity to ask the tutor about other second-year

[6] As these classes involve expensive equipment, students typically observe technicians operating the instrumentation rather than carrying out this manipulation themselves

chemistry courses and keeping them up to date with what their peers were doing in the first-year class. Robert comments:

> They were all right. It was more keeping up to date with what the first-year students were doing, and it gave us a bit more advances to see what we are going to be taught in the future and if we had any problems with anything else he would go over it.

The direct entry students enjoyed the second semester course seeing it as an opportunity to return to studying more "normal" chemistry.

6.2.10 Understanding of Different Teaching Methods

It seems that the interview participants believe that tertiary chemistry learning experiences are determined by the academic staff and their preferred teaching style. For example Patrick noted that "each lecturer has their own style and you can't expect each lecturer to give up their style." So whilst some of the interview participants were positive about their learning experiences, finding, for example, that the course was well structured, they seldom expressed an opinion about affective aspects of learning such as enjoyment and interest. For example, Samantha said the first semester lectures were "good, it was all really relevant to the tests, it taught you everything you need to know and relevant to the labs as well," and saw laboratory classes as "good, the lab manual was clear and it set out how to do everything."

6.2.11 Summary

A summary of the key findings from the analysis of the learning experiences data is presented in Table 6.10. The students overall were positive about their learning experiences for both semesters, with the tutorial classes seen more positively. Tutorial classes were seen to be beneficial in helping prepare for tests and examinations. Interview data suggests that the students were concerned about tertiary level study at the start of the year, but as they became more familiar with learning in the tertiary environment experience they became less apprehensive. Organic chemistry was deemed most

Table 6.10

Summary of findings from data on learning experiences.

Quantitative findings for first-year learning experiences at the end of the first semester	
Lecture learning experiences, practical learning experiences, and tutorial learning experiences scales	– Students had positive learning experiences overall
Differences between scales	– Tutorial learning experiences statistically significantly more positive, but small effect size
Demographic differences	– None
Quantitative findings for first-year learning experiences at the end of the second semester	
Lecture learning experiences, practical learning experiences, and tutorial learning experiences scales	– Students had positive learning experiences overall
Differences between scales	– Statistically significantly different, but no post-hoc differences observed and small effect size
Demographic differences	– Students who enrol in course as a supporting subject are more likely to have negative experiences in their practical classes
Differences in experiences between first and second semester courses	– No statistically significant differences observed
Qualitative findings	

Tertiary learning experiences	– Concerned at start of year about:
	  – Not being able to ask questions in lectures,
	  – Independent learning,
	  – Study skills
	  – Assessment
	– Concerns reduced by end of first semester, with only study skills mentioned
	– No concerns about tertiary level learning noted at end of second semester.

Lecture learning experiences	– Anticipating organic chemistry, not liking inorganic chemistry and mixed views about basic chemistry concepts. No mention of physical chemistry – Liked organic chemistry, disliked physical chemistry. First semester course hard to follow – Some students liked to write notes in order to maintain attention in class, others liked notes all handed out in a study guide to keep them together. Many liked skeleton notes that were a mixture of both note styles

	– Some staff were difficult to approach, whereas others were not – Liked the use of relevant contexts and visual aids in lectures
Laboratory class learning experiences	– Looking forward to hands on chemistry at the start of the year – Most enjoyable part of the course – especially organic chemistry – Liked organic chemistry laboratories, as were able to use new equipment – Did not like experiments that focussed on titrations, precision, accuracy and measurement – Mixed views on physical chemistry – Approachability and availability of staff influenced experiences – Structure of the laboratory class and help with writing up laboratories could improve experiences
Tutorial learning experiences	– Tutorials helped with tests and examine preparation – if the questions were relevant – Tutorials reinforced lectures – Relationship with staff at tutorials impacted on student experiences
Direct entry students	– Lecture course boring – Prefer laboratory classes that were more 'hands on' – Tutorial classes seen as an opportunity to question lecturers about other aspects of chemistry and chemistry study
Understanding of teaching Methods	– Teaching methods dependent on academic staff's preferred teaching style

interesting and the students prefer some notes being provided, and lecture topics presented using multiple teaching methods including illustration using examples from familiar contexts. The least favourite topic was physical chemistry, and full detailed notes were not liked. Laboratory classes were looked forward to, as students anticipated using new equipment and the hands-on nature of laboratory classes. An over-emphasis on quantitative laboratory work, specifically titrations, and over-emphasis on precision and accuracy made students less positive about their laboratory classes at the end of both semesters. There were few differences in perceptions of learning experiences seen based on demographic groups, but science support students report less positive learning experiences during their second semester laboratory classes.

6.3 Attitude-Towards-Chemistry

1.iii	What is student attitude-towards-chemistry?
1.iv	What influence, if any, does student gender, ethnicity, socio-economic background and enrolment reason have on attitude-towards-chemistry?

Student attitude-towards-chemistry was investigated using the CAEQ and these data were again triangulated with interview data. The findings from the CAEQ are presented first, followed by a description of the findings from interviews.

Respondents were asked to provide a response to each item on the *attitude-towards-chemistry* scale of the CAEQ using a 7-point semantic differential scale (7 representing a positive attitude, and 1 a negative attitude). Again, estimated means were computed for each subscale from the subscale response (mean response) to the relevant items. Summary statistical data were then calculated based on the estimated mean responses.

6.3.1 Quantitative Findings for Attitude-Towards-Chemistry at the Start of the Year

E_2: Explore student attitude-towards-chemistry

At the start of the year students' attitude-towards-chemistry was positive[7] for each of the subscales: 4.58 for *attitude-towards-chemists*, 5.11 for *required skills of chemists*, 5.62 for *attitude-towards-chemistry in society*, 4.24 for *leisure interest in chemistry* and 4.97 for *career interest in chemistry* (Figure 6.4). Thus the estimated mean responses for all subscales suggested positive attitudes. The subscale with the lowest estimated mean response, indicating a less positive attitude, was reported for *leisure interest in chemistry*, in stark contrast with *attitude-towards-chemistry in society*. Interestingly, further examination of the spread of the data shows that the *attitude-towards-chemists* subscale was the only subscale where none of the respondents indicated a *very* positive attitude (a subscale response of greater than 6.00).

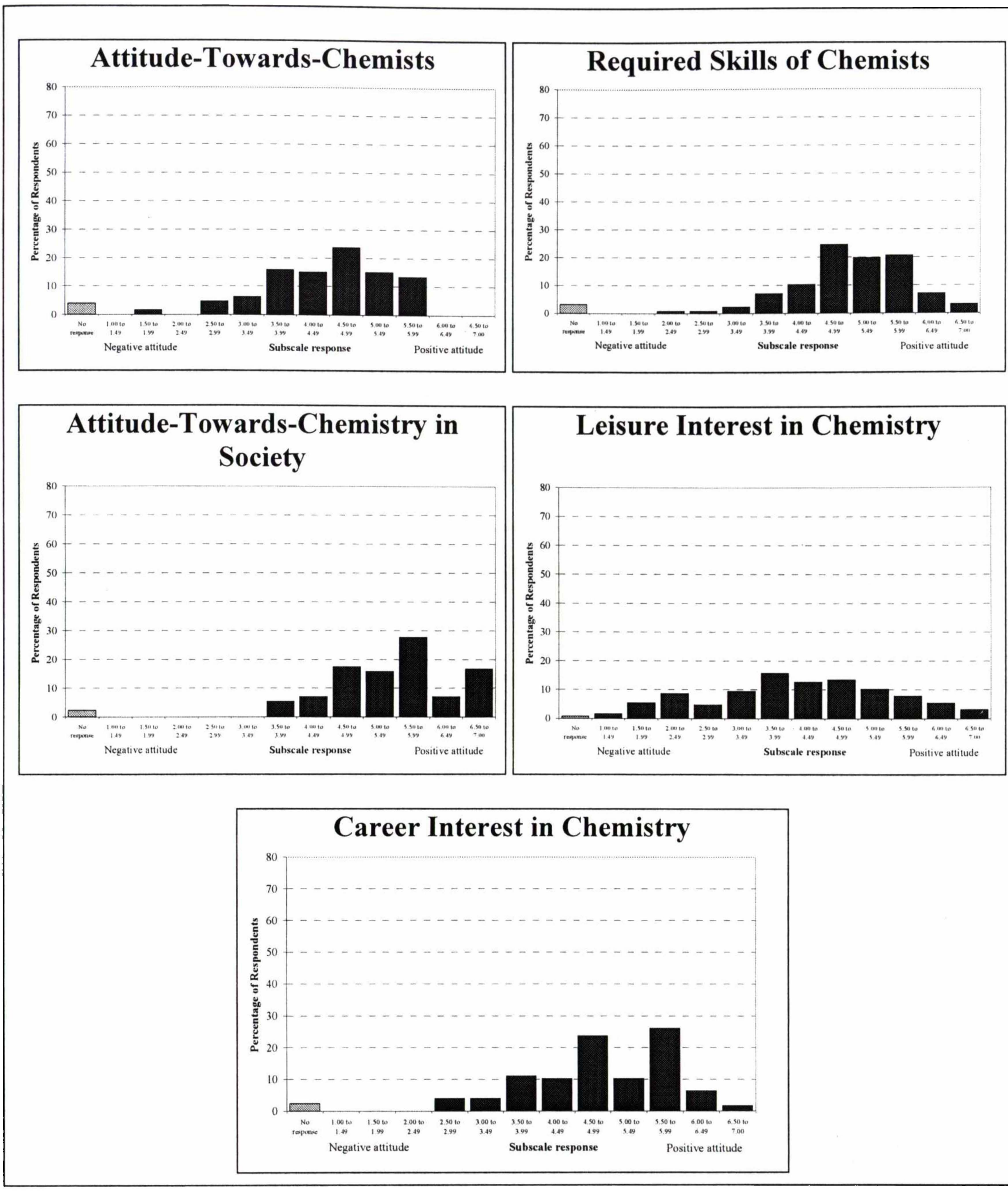

Figure 6.4

Graphical representation of the *attitude-towards-chemistry* subscales of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) - start of the year (n=126).

[7] Estimated means of greater than 4.00 are deemed to be positive

Comparison of the estimated mean responses for the subscales using ANOVA suggests that there is a significant difference between the estimated mean responses for the subscales (Table 6.11). Furthermore, post-hoc analysis (Table 6.12) implies that the *attitude-towards-chemistry in society* subscale estimated mean response is statistically significantly more positive than all other subscales, whilst the *leisure interest in chemistry* is statistically significantly less positive than all other subscales. Although there is no statistically significant difference between the *career interest in chemistry* subscale, and the *required skills of chemists/attitude-towards-chemists* subscales, *attitude-towards-chemists* is statistically significantly less positive than *required skills of chemists* (all statistically significant at $p<0.05$). The extent to which these relationships can be observed is indicated by the η^2 value ($\eta^2 = 0.18$), which suggests that a real observable effect may exist.

H_5:	Students of different gender have different attitude-towards-chemistry
H_6:	Students of different ethnicity have different attitude-towards-chemistry
H_7:	Students of different socio-economic background have different attitude-towards-chemistry
H_8:	Students of who enrolled in the course for different reasons have different attitude-towards-chemistry

Examination of differences in estimated means for *attitude-towards-chemistry* based on demographic groups shows that there are some differences based on gender for the *attitude-towards-chemistry in society* subscale, and enrolment reason for the *required skills of chemists* subscale (Table 6.13).

The η^2 value for the gender differences in the responses to the *attitude-towards-chemistry in society* subscale is low suggesting that the effect size is small. Examination of the spread of the data (Figure 6.5) shows that males have a mode (most common response) subscale response suggesting a very positive *attitude-towards-chemistry in society* (6.50 to 7.00). For female students, however, the mode subscale response is much lower, in the range of 5.50 to 5.99.

The ANOVA findings that suggest a difference in the *required skills of chemists* subscale for students' who enrolled in the first semester course for different reasons were examined by Post-hoc Scheffe analysis (Table 6.14). The findings of this analysis suggests that students for whom the course is compulsory have a

Table 6.11

Differences in the estimated mean responses to the *attitude-towards-chemistry* subscales for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) from the administration at the start of the year (n=126).

	Mean	Std.Dev	F	p	η^2
Attitude-towards-chemists	4.58	0.92	33.86	.00	0.18
Required Skills of chemists	5.11	0.85			
Attitude-towards-chemistry in society	5.62	0.86			
Leisure interest in chemistry	4.24	1.36			
Career interest in chemistry	4.97	0.92			

Table 6.12

Post-Hoc Scheffe analysis of the ANOVA analysis for the differences in the *attitude-towards-chemistry* subscales from the start of the year administration for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) (n=126).

	Subsets (statistically significantly different at p<0.05)			
	1	2	3	4
Attitude-towards-chemistry in society	5.62			
Required skills of chemists		5.11		
Career interest in chemistry		4.97	4.97	
Attitude-towards-chemists			4.58	4.58
Leisure interest in chemistry				4.24
p. (within subset)	1.00	0.88	0.05	0.15

less positive attitude-towards-the required skills of chemists than chemistry majors. The low η^2 value, however, indicates that the effect size is small, and, in fact, examination of the spread of the data suggests that chemistry majors were slightly more likely to have a subscale response suggesting very positive attitude-towards-the required skills of chemists (Figure 6.6). For example, 22% of chemistry majors indicated a subscale response greater than 6.00 compared to only 4% of students for whom the course was compulsory.

Table 6.13

Differences in the estimated mean responses to the *attitude-towards-chemists* subscales for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents of different gender, ethnicity, decile rating of contributing school and enrolment reason from the administration at the start of the year (n=126).

	N	Attitude-towards-chemists				Required skills of chemists				Attitude-towards-chemistry in society				Leisure interest in chemistry				Career interest in chemistry			
		Mean	Std. Dev.	F	p	Mean	Std. Dev.	F	p	Mean	Std. Dev.	F	p	Mean	Std. Dev.	F	p	Mean	Std. Dev.	F	p
Gender								1.79	0.18			5.40	0.02*			2.05	0.15			0.08	0.77
Male	62	4.51	0.97	0.78	0.38	5.20	0.78			5.79[2]	0.93			4.41	1.39			4.98	0.94		
Female	58	4.66	0.87			4.99	0.91			5.43	0.75			4.06	1.31			4.93	0.91		
Ethnicity								0.25	0.62			0.31	0.58			3.52	0.06			1.31	0.26
New Zealand European	86	4.54	0.94	2.78	0.10	5.07	0.84			5.59	0.88			4.09	1.33			4.92	0.95		
Other	32	4.86	0.70			5.17	0.89			5.69	0.81			4.61	1.35			5.14	0.76		
Decile rating of contributing school																					
Low decile school	49	4.70	0.94	1.31	0.25	5.07	0.96			5.59	0.86			4.40	1.31			5.01	0.91		
High decile school	60	4.50	0.86			5.07	0.79			5.65	0.85			3.99	1.34			4.89	0.89		
Enrolment Reason								3.43	0.04*			2.17	0.12			1.79	0.17			3.09	0.05
Chemistry major	28	4.81	0.61	1.08	0.34	5.40	0.92			5.83	0.78			4.53	1.37			5.28	0.75		
Science support subject and interest	41	4.54	0.90			5.14	0.68			5.71	0.77			4.38	1.36			5.00	0.78		
Compulsory science course	50	4.49	1.08			4.89[1]	0.90			5.43	0.97			3.98	1.33			4.74	1.07		

* Statistically significant at $p<0.05$

[1] $\eta^2 = 0.05$

[2] $\eta^2 = 0.05$

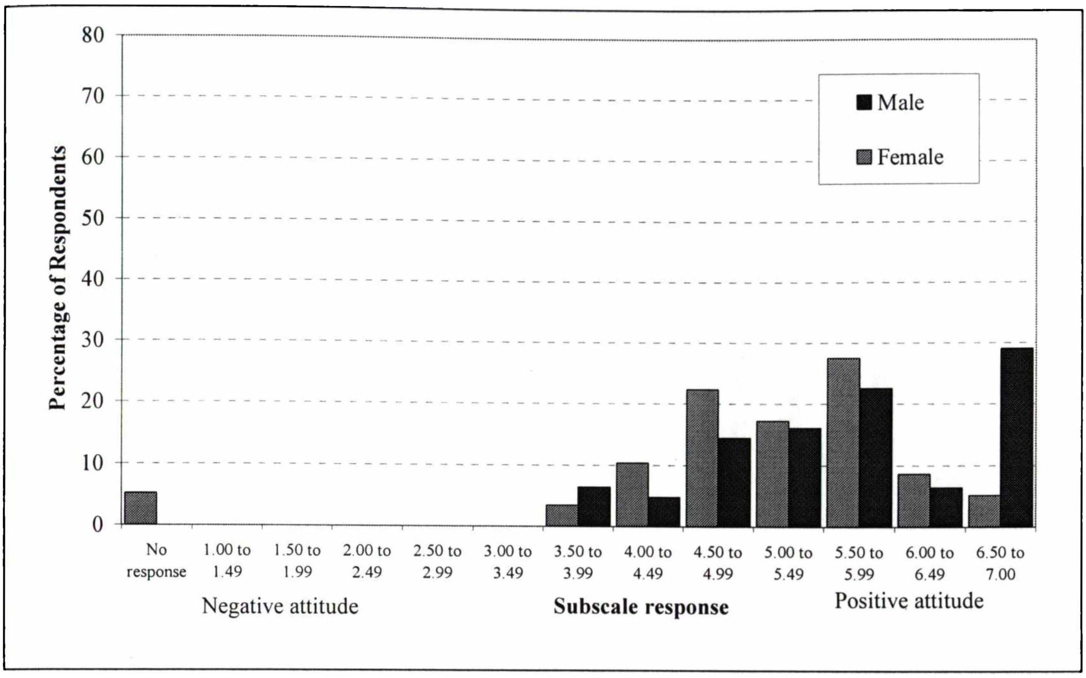

Figure 6.5

Graphical representation of the *attitude-towards- chemistry in society* subscale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for male (n=62) and female (n=58) respondents - start of the year.

Table 6.14

Post-hoc Scheffe analysis of the ANOVA analysis for the differences in the *required skills of chemists* subscale from the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) from respondents who were chemistry majors (n=28), enrolled in the course as a science support or interest course (n=41) and those for whom the course was a compulsory course of another degree (n=50) from the administration at the start of the year.

	Subsets (statistically significantly different at p<0.05)	
	1	2
Chemistry major	5.40	
Science support subject and interest	5.14	5.14
Compulsory course		4.89
p. (within subset)	0.41	0.45

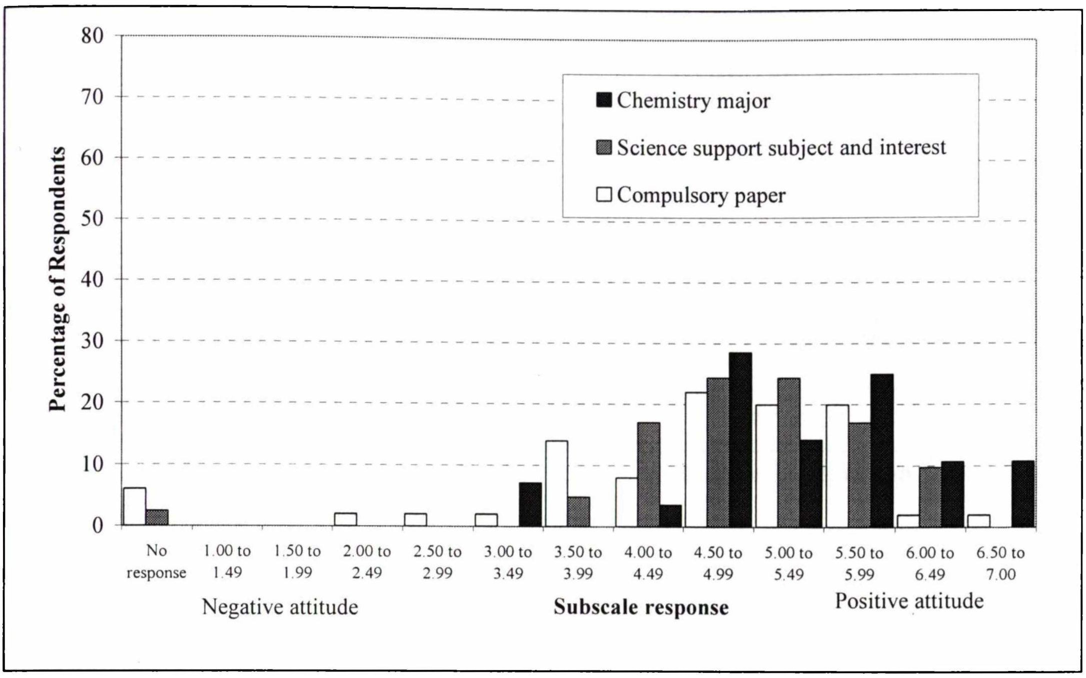

Figure 6.6

Graphical representation of the *required skills of chemists* subscales of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents who were chemistry majors (n=28), enrolled in the course as a science support or interest course (n=41) and those for whom the course was a compulsory course of another degree (n=50) - start of the year.

6.3.2 Quantitative Findings for Attitude-Towards-Chemistry at the End of the First Semester

E_2: Explore student attitude-towards-chemistry

The respondents had a positive attitude-towards-chemistry at the end of the first semester, with estimated mean responses of 4.55 for *attitude-towards-chemists*, 4.92 for *required skills of chemists*, 5.55 for *attitude-towards-chemistry in society*, 4.07 for *career interest in chemistry* and 4.93 for *leisure interest in chemistry* (Figure 6.7). These findings are consistent with the data for the subscales at the start of the year, where the data for most subscales (with the exception of *leisure interest in chemistry*) suggested that the students held a positive attitude-towards-chemistry. The data from the *leisure interest in chemistry* subscale showed an interesting bimodal distribution. Closer examination based on demographic data revealed that 71% of 'positive' responses were from chemistry majors, and 73% of 'negative' attitudinal responses belonged to non-majors.

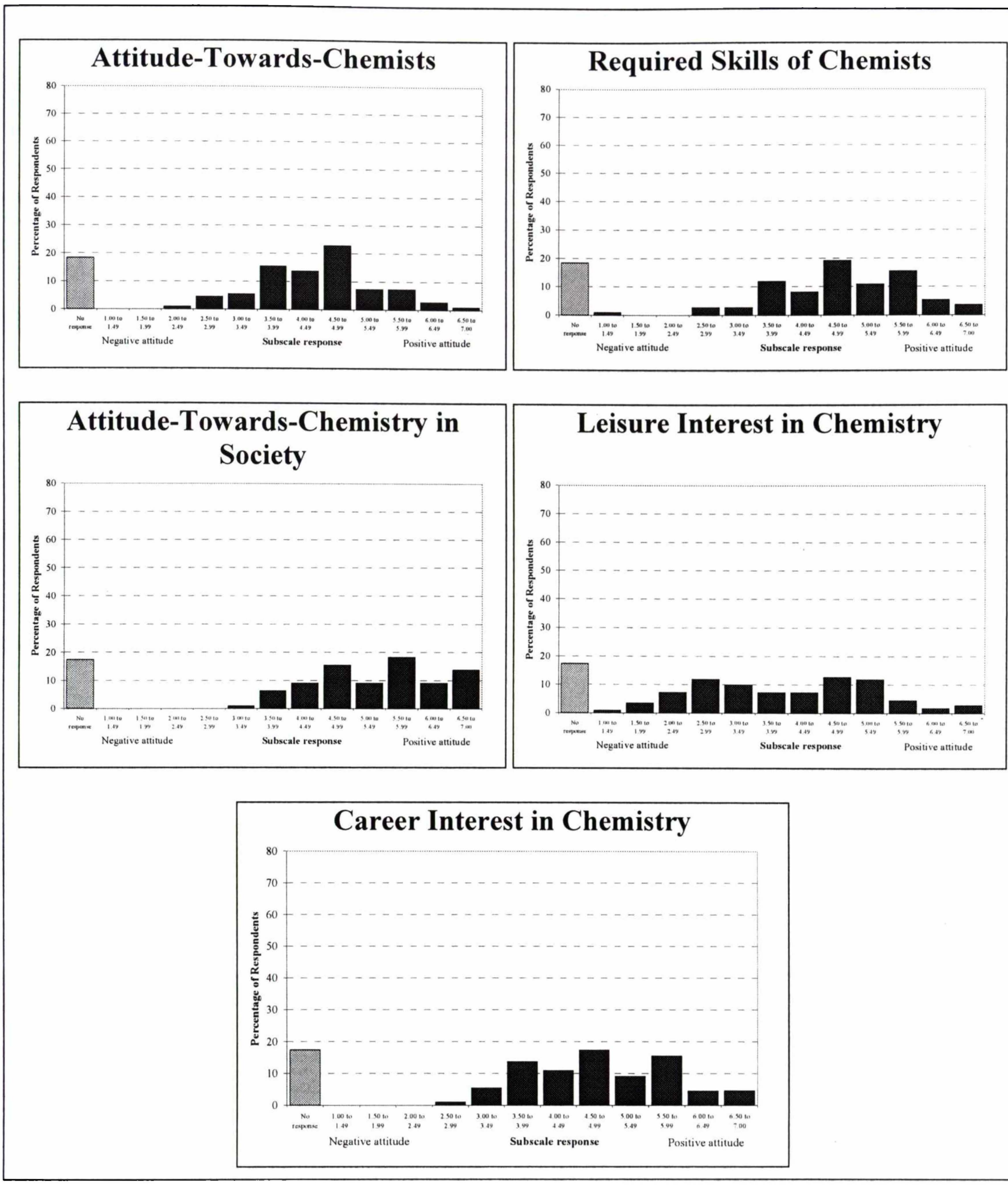

Figure 6.7

Graphical representation of the *attitude-towards-chemistry* subscales of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) - end of the first semester (n=109).

Differences in the estimate means between subscales show that, like the data from the beginning of the year, statistically significant differences were seen for the *attitude-towards-chemistry* subscales at the end of the first semester (Table 6.15). Post hoc analysis revealed that students were statistically significantly more positive for *attitude-towards-chemistry in society*, and less positive for *leisure interest in chemistry* (Table 6.16). However, unlike the start of the year, there were no statistically significant differences between the other subscales.

H_5:	Students of different gender have different attitude-towards-chemistry
H_6:	Students of different ethnicity have different attitude-towards-chemistry
H_7:	Students of different socio-economic background have different attitude-towards-chemistry
H_8:	Students of who enrolled in the course for different reasons have different attitude-towards-chemistry

Interestingly, there were no statistically significant differences seen for different demographic groups. This suggests that the previously observed statistically significant differences, namely gender differences in *attitude-toward-chemistry in society* and enrolment reason differences in *required skills of chemists*, are either due to statistical variation, or students' attitudes have become more homogenous as a result of their first semester of chemistry study.

6.3.3 Quantitative Findings for Attitude-Towards-Chemistry at the End of the Second Semester

E_2:	Explore student attitude-towards-chemistry

Student responses for the *attitude-towards-chemistry* subscales at the end of the second semester showed similar patterns to those observed at the start of the year and the end of the first semester (Figure 6.8). The estimated mean responses of the subscales were 4.68 for *attitude-towards-chemists*, 4.93 for *required skills of chemists*, 5.52 for *attitude-towards-chemistry in society*, 4.12 for *leisure interest in chemistry* and 4.76 for the *career interest in chemistry.* There were few very negative attitudes provided by respondents, with *leisure interest in chemistry* again the exception. The data from the *leisure interest in chemistry* subscale at the end of the second semester was less bimodal in appearance compared with the end of the first semester.

Table 6.15

Differences in the estimated mean responses to the *attitude-towards-chemistry* subscales for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) from the administration at the end of the first semester (n=109).

	Mean	Std.Dev	F	p	η^2
Attitude-towards-chemists	4.55	0.89	24.38	0.00	0.18
Required skills of chemists	4.92	1.00			
Attitude-towards-chemistry in society	5.55	0.96			
Leisure interest in chemistry	4.07	1.34			
Career interest in chemistry	4.93	0.98			

Table 6.16

Post-Hoc Scheffe analysis of the ANOVA analysis for the differences in the *attitude-towards-chemistry* subscales from the end of the first semester administration for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) (n=109).

	Subsets (statistically significantly different at p<0.05)		
	1	2	3
Attitude-towards-chemistry in society	5.55		
Career interest in chemistry		4.93	
Required skills of chemists		4.92	
Attitude-towards-chemists		4.55	4.55
Leisure interest in chemistry			4.07
p. (within subset)	1	0.21	0.06

ANOVA analysis of the subscales again showed statistically significant differences in the estimated mean responses (Table 6.17). Post hoc analysis showed that, like the start of the year and the end of the first semester, students' responses for *attitude-towards-chemistry in society* were more positive than for the other subscales, and *leisure interest in chemistry* was less positive than the other subscales (Table 6.18).

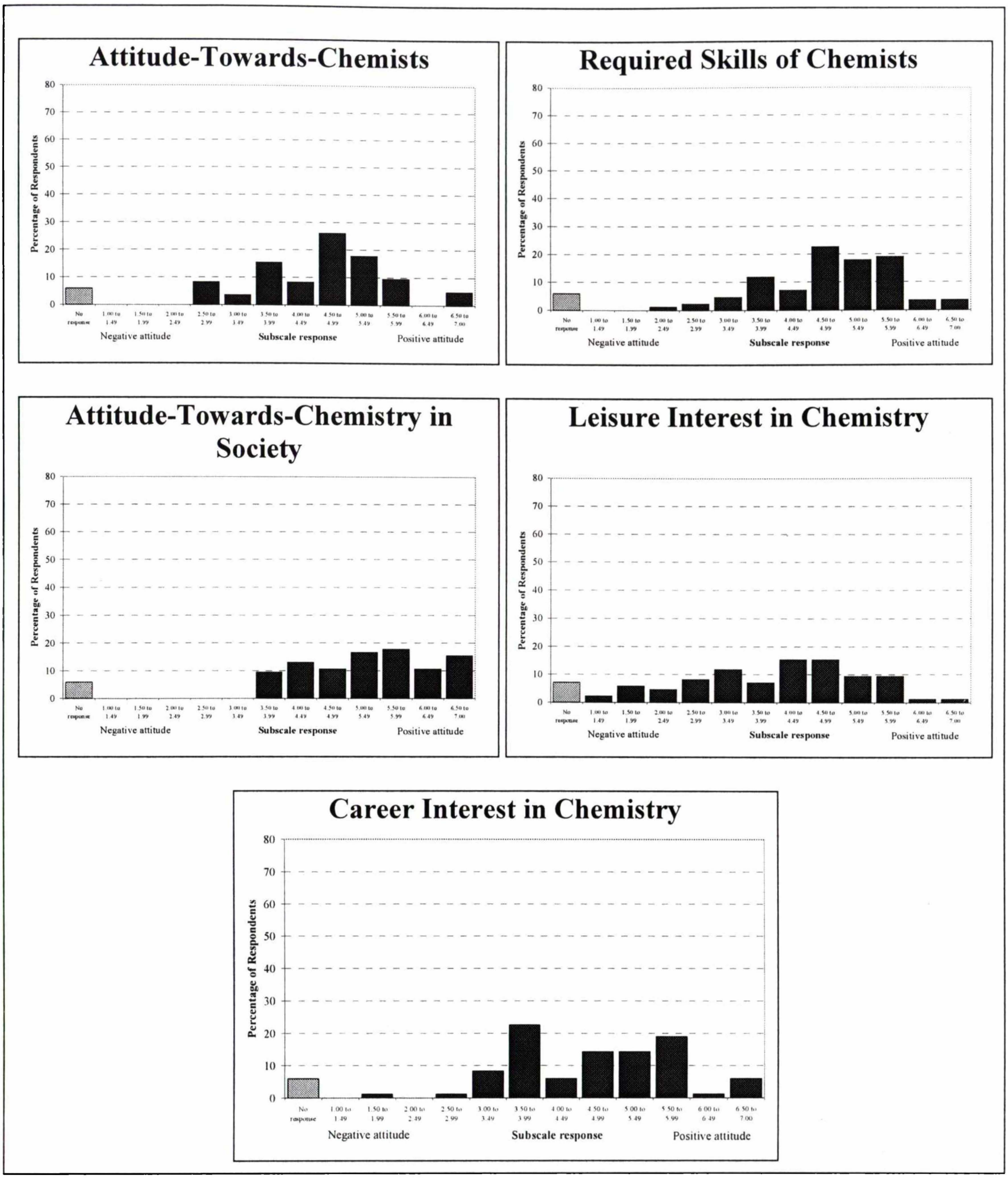

Figure 6.8

Graphical representation of the *attitude-towards-chemistry* subscales of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) - end of the second semester (n=84).

Table 6.17

Differences in the estimated mean responses to the *attitude-towards-chemistry* subscales for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) from the administration at the end of the second semester (n=84).

	Mean	Std.Dev	F	p	η^2
Attitude-towards-chemists	4.68	0.89	16.28	0.00	0.14
Required skills of chemists	4.93	1.00			
Attitude-towards-chemistry in society	5.52	0.96			
Leisure interest in chemistry	4.12	1.34			
Career interest in chemistry	4.76	0.98			

Table 6.18

Post-Hoc Scheffe analysis of the ANOVA analysis for the differences in the *attitude-towards-chemistry* subscales from the end of the first semester administration for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) (n=84).

	Subsets (statistically significantly different at p<0.05)		
	1	2	3
Attitude-towards-chemistry in society	5.52		
Required skills of chemists		4.93	
Career interest in chemistry		4.76	
Attitude-towards-chemists		4.68	
Leisure interest in chemistry			4.12
p. (within subset)	1.00	0.21	0.06

H_5:	Students of different gender have different attitude-towards-chemistry
H_6:	Students of different ethnicity have different attitude-towards-chemistry
H_7:	Students of different socio-economic background have different attitude-towards-chemistry
H_8:	Students of who enrolled in the course for different reasons have different attitude-towards-chemistry

In-depth analysis based on a demographic breakdown revealed a statistically significant difference between New Zealand European students and other ethnicities for *career interest in chemistry* (Table 6.19). Examination of the spread of the data shows that the two groups have different modes, with New Zealand European students having a mode response of between 5.50 and 5.99 and other ethnicities having a mode response of between 3.50 and 3.99 (Figure 6.9). Furthermore the η^2 value suggests that the effect size is large.

Table 6.19

ANOVA analysis of first semester *learning experiences* by gender, ethnicity, decile rating of contributing school and enrolment reason (n=84).

	N	Attitude-towards-chemists				Required skills of chemists				Attitude-towards-chemistry in society				Leisure interest in chemistry				Career interest in chemistry			
		Mean	Std. Dev.	F	p	Mean	Std. Dev.	F	p	Mean	Std. Dev.	F	p	Mean	Std. Dev.	F	p	Mean	Std. Dev.	F	p
Gender								0.11	0.75			0.17	0.68			0.18	0.68			1.95	0.17
Male	40	4.53	0.91	0.90	0.35	4.87	0.84			5.54	1.01			4.17	1.36			4.59	1.07		
Female	37	4.74	0.99			4.94	1.03			5.45	0.93			4.04	1.27			4.93	1.04		
Ethnicity								0.49	0.49			0.51	0.48			2.21	0.14			8.27	0.01*
New Zealand European	58	4.52	0.91	3.09	0.08	4.87	0.81			5.44	0.96			3.99	1.31			4.56[1]	1.03		
Other	18	4.96	1.03			5.04	1.28			5.63	0.99			4.51	1.29			5.36	0.97		
Decile rating of contributing school								0.72				0.07				0.58				0.58	
Low decile school	31	4.78	0.98	0.64	0.43	5.02	1.03			5.52	1.04			4.32	1.38			4.88	1.03		
High decile school	37	4.60	0.88			4.83	0.84			5.46	0.91			4.08	1.27			4.68	1.15		
Enrolment reason								0.51	0.60			0.26	0.77			0.38	0.68			0.22	0.80
Chemistry major	18	5.00	0.91	0.75	0.48	5.34	0.86			5.83	0.94			4.78	1.34			5.40	1.03		
Science support subject and interest	26	4.69	0.99			4.91	0.89			5.55	1.01			4.05	1.45			4.80	0.90		
Compulsory science course	29	4.65	1.04			4.96	0.93			5.22	1.04			3.89	1.08			4.64	1.27		

* statistically significant at $p<0.01$

[1] $\eta^2 = 0.11$

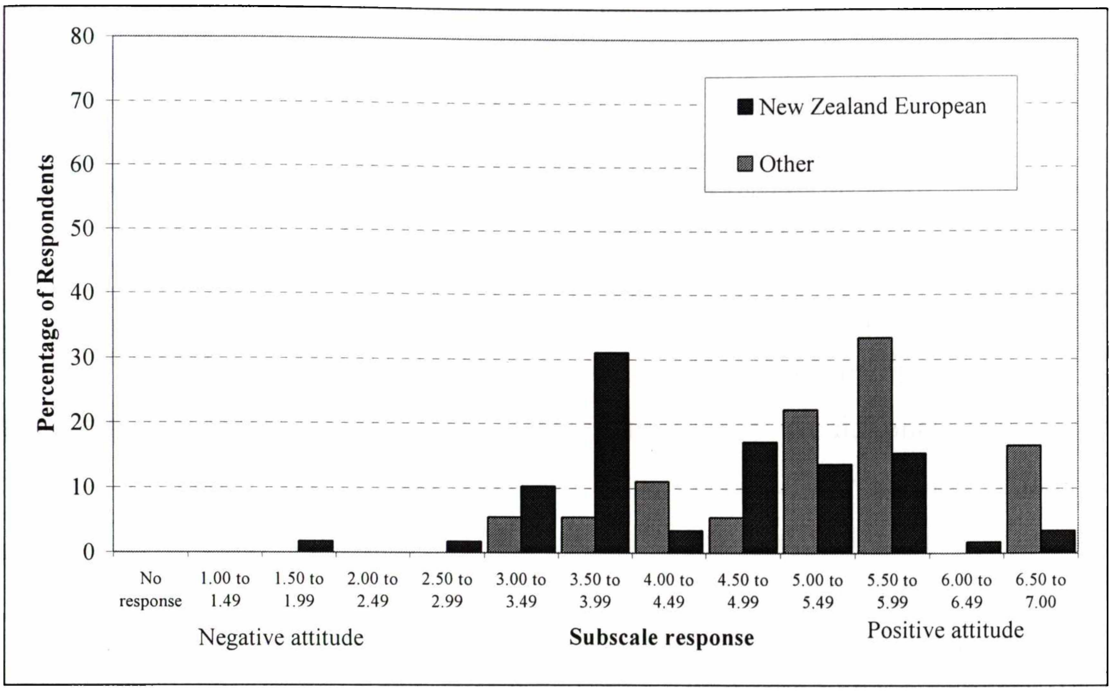

Figure 6.9

Graphical representation of the *career interest in chemistry* subscale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents who of New Zealand European ethnicity (n=58), compared to those of other ethnicities (n=19) - end of the second semester.

6.3.4 *Qualitative Findings for Attitude-Towards-Chemistry*

E_2: Explore student attitude-towards-chemistry

The interview questions relating specifically to attitude-towards-chemistry are presented in (Table 6.20). Data presented here examines the range of the responses given by the participants in all three interviews. Analysis of changes in responses are provided in Section 6.4.1 (p.178).

6.3.5 *Environmental Awareness of Chemists*

The interview participants' views about the environmental awareness of chemists gave some interesting insights into what the participants thought about both chemistry and chemists. A large proportion of the interview participants saw environmental awareness as part of being a chemist, with many participants assuming that chemists were routinely exposed to information about the environmental impact of chemicals. This, it seems, created the impression in the

Table 6.20

Interview protocol for attitude-towards-chemistry.

Start of the year/ End of first semester/ End of second semester
1. Do you agree or disagree with the statement 'chemists are environmentally aware'?
2. Do you think that chemistry research advances society?

interview participants' minds that chemists were inherently environmentally aware. In other words, the interview participant saw chemists as having knowledge of environmental issues and assumed they would automatically incorporate such knowledge into their own value systems. For example, Alan noted: "I think that chemists would be fairly learned people, and would have an awareness of what sort of impact they would have on the environment." Some interview participants also mentioned that some chemistry research was aimed at improving the environment, and they felt that chemists involved in this type of research would be environmentally aware. For example, Tabitha thought chemists were environmentally aware because "a lot of the research is to help the environment." Other interview participants thought that environmental awareness was dependent on an individual's personal values, and ascribed no particular values to chemists as a group. Others noted that some chemists were intent on their research goals, perhaps at the expense of considering environmental issues. For example, Felix said:

> It probably depends on the actual chemist, some of them are probably environmentally aware, some of them probably aren't. [It] depends on the individual ... I would think when some chemists are designing their research, then their priority is to complete that research.

Other participants believed that chemists in the past showed little consideration for the environment, but because of government regulations and environmental lobby groups, chemists in today's society have little choice but to be environmentally aware. For example, Neil said "back in the old days [chemists] didn't really care what they blew up, or what they destroyed," and Marcel noted that "if they are going to do something against the environment there will always be environmentalists that hold them up and make them take things into account."

A number of the participants thought that environmental awareness was not the responsibility of chemists, but rather the responsibility of engineers and industry who put into practice the results from chemistry research. For example, Robert said "pollution doesn't actually come from chemists. They've come up with it [i.e., chemistry knowledge], but it's really engineers that have applied it."

6.3.6 Attitude-Towards-Chemistry in Society

The interview participants were more positive about the role chemistry had in society with only one participant, Celia, believing that chemistry research exerted a negative influence on society. She commented: "Physicists built atomic weapons and chemists had to build the chemicals to put in the middle." Most interview participants quoted new materials and technology as being major advances in chemistry, although a significant number also mentioned medicine. Kevin said that chemistry advanced society in that "there has been advances to do with drugs for cancer. Also [chemistry has been used in] finding new polymers, alloys and structural materials." Other participants named a broader range of advances due to chemistry including "fuels" and "cosmetics." Other participants saw chemistry as advancing society in a more abstract manner, citing a gain in knowledge as a positive aspect to chemistry research. For example, Karen said "a lot of the things chemists find out helps us learn [about the world]." The male participants in particular felt that chemistry and chemistry research was so deeply incorporated into today's society that it could not be seen as anything but advantageous. For example, Gary said "chemistry has some basis in everything."

Some of the more academically-able interview participants identified instances where they had interacted with scientific material outside of formal classroom environments suggesting they held a leisure interest in science and chemistry. For example, when asked about how he became interested in chemistry Jack responded "basically I've just been interested in science and chemistry all my life, it's just been sort of a hobby as well for me."

6.3.7 Summary

The participants in this study overall had a positive attitude-towards-chemistry as indicated by all five subscales of the CAEQ for each of the three administrations, with the quantitative findings also supported by interview data (Table 6.21). The respondents were most positive about *attitude-towards-chemistry in society* – across all three administrations, whereas student *leisure interest in chemistry* was lower than for other attitude subscales. There were statistically significant differences between gender responses to the *attitude-toward-chemistry in society* scale at the start of the year, enrolment reason responses to the *required skills of chemists* at the end of the year and ethnicity responses to *career interest in chemistry* at the end of the second semester. However, none of these findings were repeated across semesters and only the ethnic differences in the *career interest in chemistry* subscale showed a sufficient effect size. This suggests that gender and other identity constructions have little influence on students' attitude-towards-chemistry, in this sample at least. Interview data suggests that the students hold mixed views about the environmental awareness of chemists, some seeing chemists as working to improve the environment, others seeing chemists as not considering the environment at all. A widespread and strongly held view was that chemistry research advances society, with participants citing a variety of examples of how this had occurred.

6.4 Influence of Learning Experiences on Attitude-Towards-Chemistry

1.vii	What influence, if any, does student attitude-towards-chemistry have on learning experiences?

Changes in student attitude-towards-chemistry were investigated using the CAEQ and these data again triangulated with interview data. The findings from the CAEQ are presented first, followed by a description of the findings from the qualitative data.

Table 6.21

Summary of findings from data on attitude-towards-chemistry.

Quantitative findings for attitude-towards-chemistry at the start of the year	
Attitude-towards-chemists, required skills of chemistry, attitude-towards-chemistry in society, leisure interest in chemistry and career interest in chemistry subscales	– Students exhibited positive attitudes as a whole
Differences between scales	– Attitude-towards-chemistry in society most positive – Leisure interest in chemistry least positive
Demographic differences	– Chemistry majors were more positive about the required skills of chemists than students for whom the course was a compulsory part of another programme
Quantitative findings for attitude-towards-chemistry at the end of the first semester	
Attitude-towards-chemists, required skills of chemistry, attitude-towards-chemistry in society, leisure interest in chemistry and career interest in chemistry subscales	– Students exhibited positive attitudes as a whole
Differences between scales	– Attitude-towards-chemistry in society most positive – Leisure interest in chemistry least positive
Demographic differences	– None
Quantitative findings for attitude-towards-chemistry at the end of the second semester	
Attitude-towards-chemists, required skills of chemistry, attitude-towards-chemistry in society, leisure interest in chemistry and career interest in chemistry subscales	– Students exhibited positive attitudes as a whole
Differences between scales	– Attitude-towards-chemistry in society most positive – Leisure interest in chemistry least positive
Demographic differences	– New Zealand European students have a more positive career interest in chemistry than other students
Qualitative findings	
Environmental awareness of chemists	– Intrinsic to what it means to be a chemist due to exposure to environmental and chemical information – Dependent on the individuals personal values – Lobby groups and governmental bodies mean that chemists have little choice but to be environmentally aware – Responsibility of industry and engineers who put chemical research into practice

Attitude-towards-chemistry in society	– Chemistry has had a positive influence on society through – New technologies – Medical advances – The gain of knowledge
Leisure interest in chemistry	– Gained from experiences outside of the classroom such as hobbies

6.4.1 Quantitative Findings for Changes in Attitude-Towards-Chemistry in Relation to First-Year Learning Experiences

> H_{13}: There is a relationship between student attitude-towards-chemistry and learning experiences

Changes in student attitude-towards-chemistry were investigated quantitatively in two ways. Repeated measures GLM was used to examine the differences in attitude-towards-chemistry in the three administrations of the instrument. Second, the subscale responses to the *attitude-towards-chemistry* subscales were correlated with the *learning experience* subscales.

Repeated measures GLM analysis for the attitude-towards-chemistry subscales from the three administrations of the CAEQ showed that the students' *attitude-towards-chemistry* remained stable throughout the year for all subscales. The relationship between individual student learning experiences and change in attitude-towards-chemistry were examined via Pearson's correlations (Table 6.22), which found no significant correlations between first semester learning experiences and changes in student attitude-towards-chemistry. This analysis did, however, identify a statistically significant correlation between changes in *career interest in chemistry* subscale from the first to second semester, and the *lecture learning experiences* and *practical learning experiences* subscales. This suggests that for the participants as a whole, there is little change in *career interest in chemistry*, but for those who did change, there is a correlation with lecture and laboratory learning experiences.

Table 6.22

Relationship between *learning experiences* subscales and changes in *attitude-towards-chemistry* subscales for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) based on Pearson's correlation

	End of first semester change in attitude between start of year and end of first semester (n=42)			**End of second semester change in attitude between end of first semester and end of second semester** (n=31)		
	Lecture	Tutorial	Practical	Lecture	Tutorial	Practical
Change in attitude subscale						
Attitude-towards-chemists	0.19	0.28	0.24	0.23	0.33	0.18
Required skills of chemists	0.24	0.30	0.28	0.10	0.05	0.14
Attitude-towards-chemistry in society	-0.06	0.10	0.16	0.20	0.18	0.26
Leisure interest in chemistry	-0.03	-0.01	0.05	0.10	0.04	-0.01
Career interest in chemistry	0.00	-0.01	0.16	0.49*	0.27	0.44*

**statistically significant at $p<0.01$

6.4.2 *Qualitative Findings for Changes in Attitude-Towards-Chemistry in Relation to First-Year Chemistry Learning Experiences*

The full interview protocol used to triangulate the quantitative data for the CAEQ is provided in Section 4.7 (p. 83). The questions relating specifically to students attitude-towards-chemistry are reproduced in Table 6.20 (p. 174), and the findings from the interviews are presented here.

The research findings from the CAEQ administrations suggest that student *attitude-towards-chemistry* did not change much during the academic year. However, the interview data suggests student responses and reasoning became more informed as the year progressed. In particular, the participants drew upon lecture material to illustrate their responses. For example, at the start of the year, Robert talked about chemistry advancing society in terms of well known multinational chemical corporations: "If you have a look at things like BP [i.e., British Petroleum] at the moment, they are doing a lot of research into cleaner petrols, cleaner burning petrols, that good for society." However, by the end of the year, Robert was much more thoughtful and articulate about the role chemistry might play in society:

> *Robert*: In the past there have been things like thalidomide which wasn't very good, but in general chemists are coming up with new things and new ways to create things.
> *Interviewer*: Can you give me an example of what you mean by that?
> *Robert*: I suppose different methods to help in industry. For example, the BHP [i.e., Broken Hill Proprietary] plant for materials and processing, we found out all the different ways the chemists were helping to preserve the environment.

The interview participants' responses were more thoughtful in nature after their university experiences and they made fewer assumptions, instead basing their views on actual tertiary learning experiences. For example, Patrick, an engineering student, changed from seeing environmental awareness of chemists as an historical problem to one of modern day engineers. At the start of the year Patrick, thought "maybe it's just industry, but I don't think really think until later stages [chemists] have really been that environmentally aware." However, by the end of the year, Patrick's attitude changed to seeing environmental impact of chemistry less of a responsibility of chemists, and more of engineers:

> One of the things that you think about [in engineering] is how the materials effect the environment around you. Like a big concrete slab, somewhere. How is that going to affect the wildlife around you? An engineer will come in and use that sort of material and decide how it is that going to effect [the environment]. That is [chemists], make a product to fit a solution, and then let someone else decide what implications are.

It is worthwhile to note, however, that participants' attitudes may have changed in response to content taught in another courses. Nonetheless, participants identified particular chemistry learning experiences. Jack, for example, specifically referred to laboratory class experiences that he felt reinforced his opinion that chemists are environmentally aware. At the start of the year Jack commented:

> You see a lot of chemists that don't really care about the environment, they just sort of dump effluent and wastes in the river, but then there are a

> lot of chemists that are working on ways to break chemicals down into more recyclable, more biodegradable products.

However after the first semester of tertiary chemistry, Jack's reasons for his opinion had changed to incorporate some of his own learning experiences.

> Some chemists are aware of the effects of what their research and tests are doing and they take precautions to ensure they are environmentally safe, like putting things in residue bottles[8] and not just pouring them down the drains. But then again there are the chemists that are just interested in the money and not about what happens to the environment.

6.4.3 Summary

In general there was little correlation between student *learning experiences* and changes in their *attitude-towards-chemistry* subscales for the CAEQ (Table 6.23). There were statistically significant correlations between the CAEQ *career interest in chemistry* subscale at the end of the second semester, and the *lecture learning experiences* subscale and *practical learning experiences* subscale. There were no statistically significant changes in student *attitude-towards-chemistry* for any of the subscales between the three administrations of the CAEQ. Interview data suggests that although the student attitude-towards-chemists and the environment and attitude-towards-chemistry in society did not change, they were more thoughtful and insightful about their beliefs, commonly linking their views to specific tertiary chemistry learning experiences.

6.5 Chemistry Self-Efficacy

1.v	What is student chemistry self-efficacy?
1.vi	What influence, if any, does student gender, ethnicity, socio-economic background and enrolment reason have on chemistry self-efficacy?

[8] In these laboratory classes, students are required to place waste solvents and other chemical wastes in labeled disposal containers

Table 6.23

Summary of findings from data on changes in attitude-towards-chemistry in relation to first-year learning experiences.

Quantitative findings for changes in attitude-towards-chemistry in relation to first-year learning experiences	
Attitude-towards-chemistry subscales	– No changes throughout year
Correlation of changes in attitude-towards-chemistry subscales and first-semester learning experiences subscales	– No statistically significant correlations
Correlation of changes in attitude-towards-chemistry subscales and second-semester learning experiences subscales	– Relationship between change in career interest in chemistry and lecture and practical learning experiences
Qualitative findings for changes in attitude-towards-chemistry in relation to first-year learning experiences	
– Students attitude-towards-chemistry became more informed citing lecture material from both chemistry and other disciplines when stating their beliefs	

Students' chemistry self-efficacy was investigated using the CAEQ and these data were again triangulated with interview data. The findings from the CAEQ are presented first, followed by a description of the findings from interview data.

Respondents were asked to provide a response to each item on the *chemistry self-efficacy* scale of the CAEQ using a 7-point semantic differential scale (7 representing positive self-efficacy, and 1 negative self-efficacy). Again estimated mean responses were computed for each subscale from the subscale response (mean response to all items in the subscale) for the relevant items. Summary statistical data were then calculated based on the estimated mean responses.

6.5.1 Quantitative Findings for Chemistry Self-Efficacy at the Start of the Year

E_3: Explore student chemistry self-efficacy

At the beginning of the year the students were slightly confident[9] about carrying out tasks involved in first-year chemistry, with an estimated mean response of 4.35 (Figure 6.10). There is a wide range in subscale responses indicating a

[9] Estimated means of greater than 4.0 have been interpreted as positive

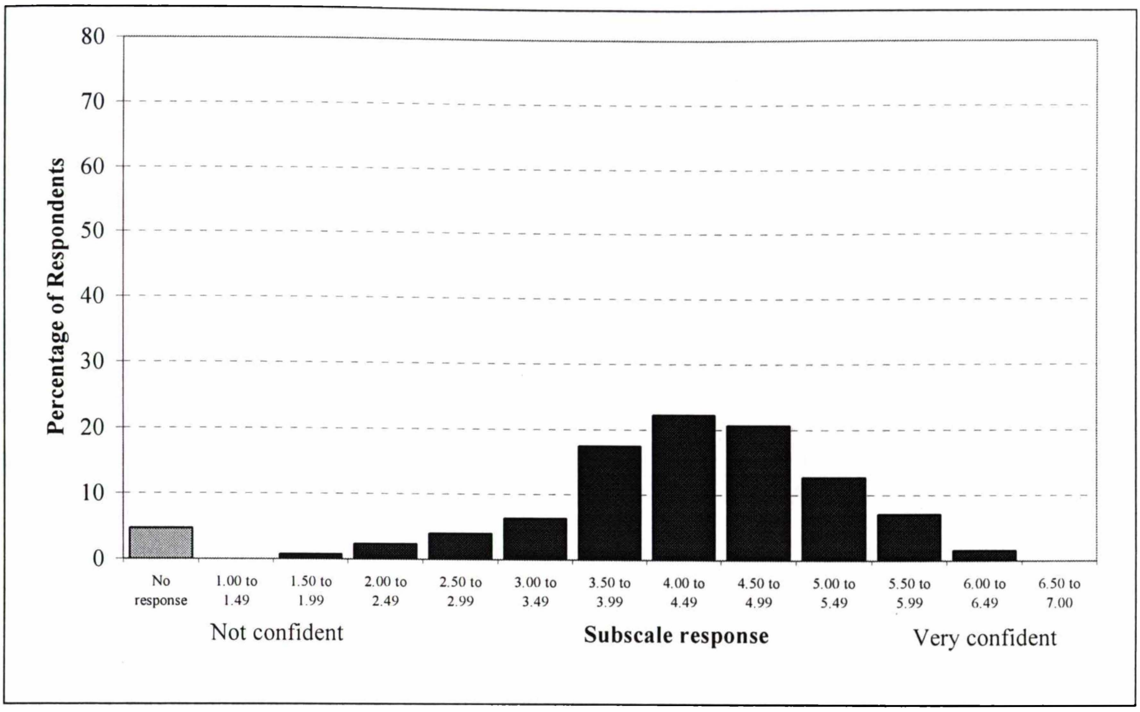

Figure 6.10

Graphical representation of the *chemistry self-efficacy* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) - start of the year (n=126).

variety of perceptions, with some students very confident and others very under-confident about studying first-year chemistry.

H_9:	Students of different gender have different chemistry self-efficacy
H_{10}:	Students of different ethnicity have different chemistry self-efficacy
H_{11}:	Students of different socio-economic background have different chemistry self-efficacy
H_{12}:	Students of who enrolled in the course for different reasons have different chemistry self-efficacy

Investigation using ANOVA for different demographic groups from the start of the year administration found statistically significant differences in *chemistry self-efficacy* between males and females, with males appearing to have a higher self-efficacy than females ($p<0.05$). Analysis of effect size (based on η^2 see, Table 6.24) suggests that this difference is likely be due to statistical variation, but closer examination of the spread of the data (Figure 6.11) shows that more males than females have 'very high' *chemistry self-efficacy* (see, in particular the range 5.50 to 5.99).

Table 6.24

Differences in the estimated mean responses to the *chemistry self-efficacy* scale for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents of different gender, ethnicity, decile rating of contributing school and enrolment reason from the administration at the start of the year (n=126).

	N	**Self-efficacy at start of the year** Mean	Std Dev.	F	p
Overall	126	4.35	0.89		
Gender				4.33[1]	0.04*
Male	4.51	0.87	0.9		
Female	4.18	0.87	0.9		
Ethnicity				3.36	0.07
New Zealand European	4.27	0.89	0.9		
Other	4.60	0.79	0.8		
Decile rating of contributing school				0.02	0.90
Low decile school	4.34	0.90	0.9		
High decile school	4.31	0.86	0.9		
Enrolment reason				3.64[2]	0.03*
Chemistry major	4.69	0.70	0.7		
Science support subject and interest	4.40	0.76	0.8		
Compulsory course	4.17	0.95	1.0		

* statistically significant at $p<0.05$
[1] $\eta^2 = 0.04$
[2] $\eta^2=0.06$

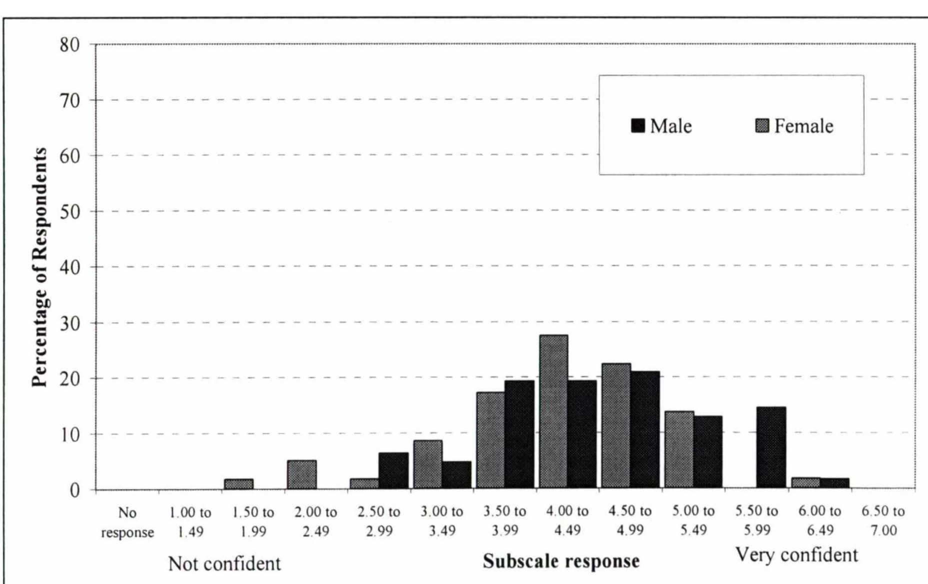

Figure 6.11

Graphical representation of the *chemistry self-efficacy* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for male (n=62) and female (n=58) - start of the year.

The ANOVA analysis along with post hoc analysis suggests that students that enrolled in first-year chemistry as a compulsory course have a lower *chemistry self-efficacy* than chemistry Table 6.25). Again the η^2 value is low, suggesting that this may be due to statistical variation rather than a real effect. Examination of the data shows that the mode of the responses from students enrolled in the course as a compulsory component of their programme was in the range 3.50 to 3.99 compared with 4.00 to 4.99 for chemistry majors (Figure 6.12).

6.5.2 Quantitative Findings for Chemistry Self-Efficacy at the End of the First Semester

E_3: Explore student chemistry self-efficacy

At the end of the first semester the participants' *chemistry self-efficacy* had increased very slightly with an estimated mean for the scale of 4.39 (cf. 4.35, earlier) (Figure 6.13). There are some interesting differences in the spread of the data (cf. Figure 6.10 and Figure 6.15) and the data at the end of the semester suggest that most students had high self-efficacy, although none had very high self-efficacy, in contrast with the results for the beginning of the semester. However, some caution is needed in interpreting this data as the non-response

Table 6.25

Post-hoc Scheffe analysis of the ANOVA analysis for the differences in the *chemistry self-efficacy* scale from the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) from respondents who were chemistry majors (n=28), enrolled in the course as a science support or interest course (n=41) and those for whom the course was a compulsory course of another degree (n=50) from the administration at the start of the year.

	Subsets (statistically significantly different at p<0.05)	
	1	2
Chemistry major	4.69	
Science support subject and interest	4.40	4.40
Compulsory course		4.17
p. (within subset)	0.32	0.48

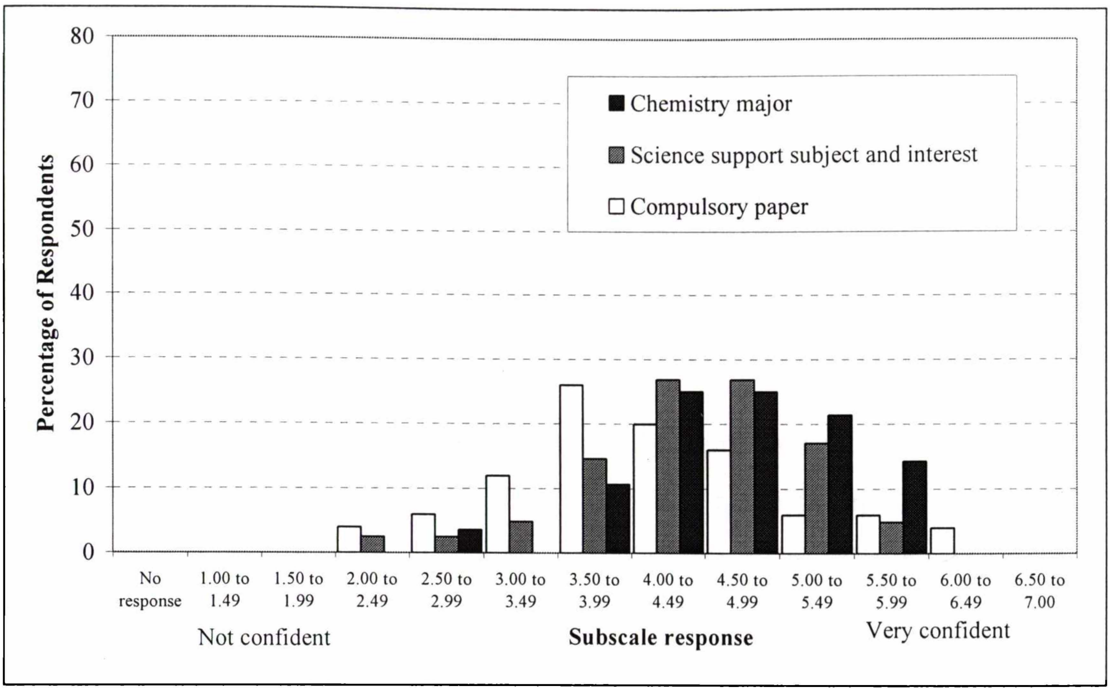

Figure 6.12

Graphical representation of the *chemistry self-efficacy* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents who were chemistry majors (n=28), enrolled in the course as a science support or interest course (n=41) and those for whom the course was a compulsory course of another degree (n=50) - start of the year.

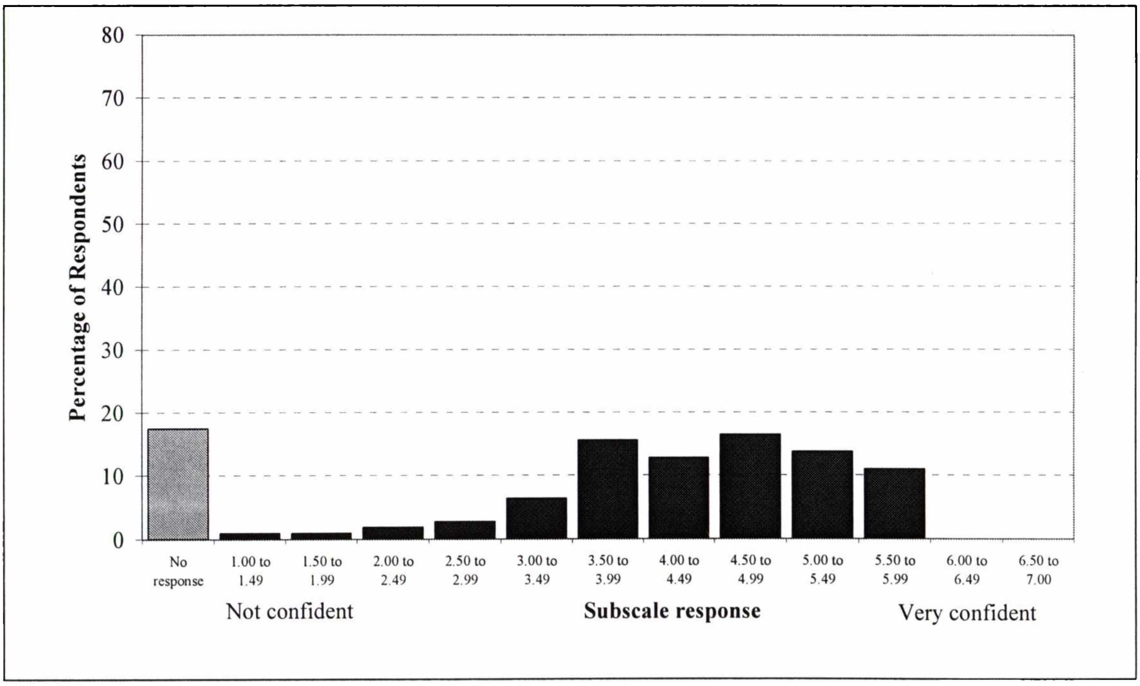

Figure 6.13

Graphical representation of the *chemistry self-efficacy* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) - end of the first semester (n=109).

was higher for the second administration (a non-response of 17.% cf. 4.8% for the first semester).

H_9:	Students of different gender have different chemistry self-efficacy
H_{10}:	Students of different ethnicity have different chemistry self-efficacy
H_{11}:	Students of different socio-economic background have different chemistry self-efficacy
H_{12}:	Students of who enrolled in the course for different reasons have different chemistry self-efficacy

As at the start of the year there was a statistically significant difference in male and female students *chemistry self-efficacy*, although again the η^2 value is low, suggesting that the size of the effect is small (Table 6.26). The mode (most common response) responses for males versus females show some interesting differences with the mode for female students' subscale response in the range 4.50 to 4.99 and the maximum subscale response in the range 5.00 to 5.49. For males the mode subscale response was in the range 5.00 to 5.49, with the maximum subscale response was in the range of 5.50 to 5.99 (Figure 6.14).

6.5.3 Quantitative Findings for Chemistry Self-Efficacy at the End of the Second Semester

E_3:	Explore student chemistry self-efficacy
H_9:	Students of different gender have different chemistry self-efficacy
H_{10}:	Students of different ethnicity have different chemistry self-efficacy
H_{11}:	Students of different socio-economic background have different chemistry self-efficacy
H_{12}:	Students of who enrolled in the course for different reasons have different chemistry self-efficacy

At the end of the second semester the estimated mean response for the self-efficacy scale was 4.67. The spread of the data shows that no students had a very low or very high *chemistry self-efficacy* (Figure 6.15). However, unlike the earlier administrations, there are no statistically significant differences based on gender.

Table 6.26

Differences in the estimated mean responses to the *chemistry self-efficacy* scale for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents of different gender, ethnicity, decile rating of contributing school and enrolment reason from the administration at the first semester (n=109).

	Self-Efficacy at Start of the Year			
	Mean	Std Dev.	F	p
Overall	4.39	1.00		
Gender			5.51[1]	0.02[1]
Male	4.62	1.07		
Female	4.07	0.82		
Ethnicity			0.05	0.83
New Zealand European	4.38	0.99		
Other	4.31	1.05		
Decile rating of contributing school			0.12	0.73
Low decile school	4.31	1.07		
High decile school	4.40	0.98		
Enrolment reason			1.11	0.34
Chemistry major	4.50	1.04		
Science support subject and interest	4.48	0.92		
Compulsory course	4.12	0.99		

* statistically significant at $p<0.05$

[1] $\eta^2 = 0.08$

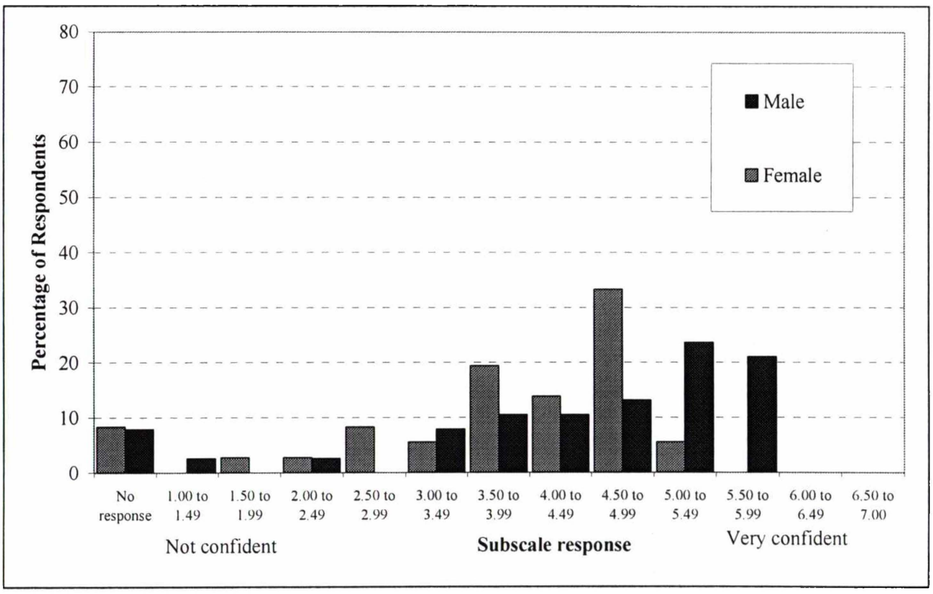

Figure 6.14

Graphical representation of the *chemistry self-efficacy* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for male (n=38) and female (n=36) respondents - end of the first semester.

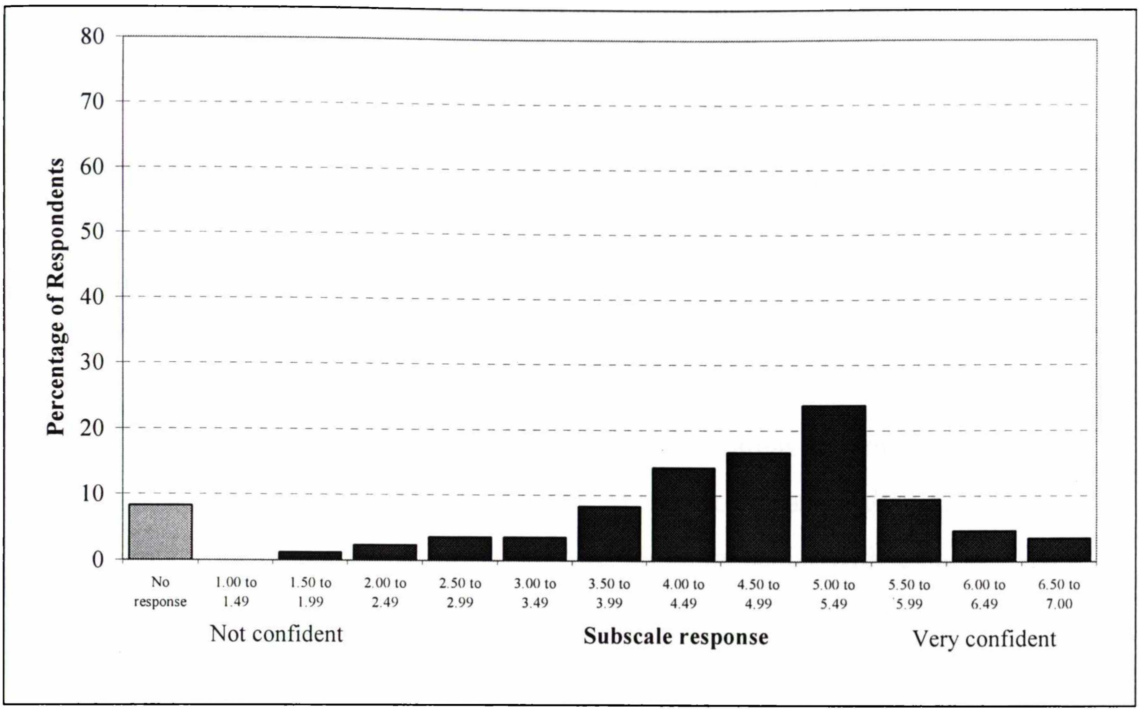

Figure 6.15

Graphical representation of the *chemistry self-efficacy* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) - end of the second semester (n=84).

6.5.4 Qualitative Findings for Chemistry Self-Efficacy

Participants in the interviews of the study were questioned about their self-efficacy about passing a chemistry course in all three interviews using the interview protocol in Table 6.27. Data presented here examines the range of the responses given by the participants in all three interviews. Analysis of changes in responses can be found in Section 6.6.2, (p. 194).

For most of the participants in all three stages, self-efficacy was related to prior learning experiences: males cited specific previous experiences, females were less specific. For example, at the start of the year Leanne said passing chemistry would be "not be very easy. I have to take a lot of concentration," whereas Felix suggested his concerns were related to "difficulty being able to understand [the maths], being able to work out the answers to things, calculations." Many of the participants referred to secondary school learning experiences as reasons for their perceptions of their abilities in chemistry. Some identified particular areas of chemistry that they found difficult at secondary school that they anticipated

Table 6.27

Interview protocol for chemistry self-efficacy.

Start of the year	
1.	How easy do you think you are going to find it to pass the first semester chemistry course?
End of first semester	
2.	How easy do you think you are going to find it to pass the second semester chemistry course?
End of second semester	
3.	How easy do you think you are going to find it to pass a second-year chemistry course?

would be problematic at the tertiary level. Specific areas of concern included mathematics, "I find the equations and stuff like that really hard," and assessment: "I always have a problem with stressing heaps with exams." Not surprisingly, the interview participants who found chemistry easy at secondary school anticipated that they would have fewer problems in studying tertiary chemistry. To illustrate Jack commented that first-year chemistry "so far seems to be mainly seventh form work [i.e., Year-13], seventh form work was pretty good for me. I found that quite easy, and with a bit of luck it will be sort of similar to that. Maybe a bit harder but I think it should be relatively good." Many of the participants believed their ability was related to the amount of effort that they put into studying the course content. For example, Eleanor felt that passing first-year chemistry would be "not easy at all, I think I will have to work hard, but I think I will work hard."

Interviewees that had been away from chemistry study for a significant period of time were concerned about the amount of memorisation required. However, after re-familiarising themselves with chemistry, their self-efficacy increased. For example, Alan who returned to chemistry study after five years in the work force, at the start of the year felt challenged:

> I think I'm going to find it a bit challenging at first. We had our first lab the other day and part of the first lab is to do a whole lot of revision questions and it's been five years since I've done chemistry. So it was a little bit daunting at first. I'm going to have to get back into looking in textbooks and stuff like that, so I think I might find it a little bit difficult at first. There looks like there's a lot of memorising involved in chemistry

> and I think it might be a bit interesting. If I don't work at it, I think I might find it hard.

However at the end of first semester Alan's self-efficacy had increased significantly:

> I got an A [i.e., grade]. I was a little bit worried at first because I haven't done this for so long so I though this is going to be a little bit hard. But I just put a bit of effort in, so it wasn't too bad. When I sat the exam it seemed so straightforward. The first few marks weren't the best, but towards the end I kind of got better, so I got good marks.

By the end of the year Alan did not anticipate any problems with second-year chemistry: "I'm not having any problems this year and I don't expect it to be so much harder next year that I'm all of a sudden going to have problems."

Achievement also influenced some of the participants' self-efficacy at the start of the year. The two direct entry students, who were generally more academically-able than other first-year students, had higher chemistry self-efficacy than their peers. In addition, Samantha - who was offered a place in the direct entry class but turned it down - also had high chemistry self-efficacy. It seems her self-efficacy was due to the fact that she was offered a place in the second-year chemistry course: "Well I got offered direct entry into the second-year course, so I think I should be alright." The relation between achievement and chemistry self-efficacy was not always so clear-cut, with, for example, with Kevin - a student who indicated that he did not score well in Year-13 chemistry and who was not anticipating scoring well in the first semester chemistry course - appearing to have high chemistry self-efficacy about some specific tasks required in his first laboratory first-year course. To illustrate consider, his comments about the accuracy required in titration experiments (±0.04 mL): "Something that we found out is that one drop of stuff from the burette is more than 0.04 mL." Such a statement is indicative of a high chemistry self-efficacy, and it seems that he believes that he knows more about this aspect of laboratory chemistry than those who designed the experiment. Kevin went on to explain that he felt his low grades in chemistry were due to lack of effort, rather than lack of ability: "I know that I haven't been working that hard this semester ... I would probably understand things if I worked harder."

6.5.5 Summary

In general, the responses to the chemistry self-efficacy subscale in the three administrations of the CAEQ imply that the students were confident about the tasks required of them in first-year chemistry (Table 6.28). Like the findings for student attitude-towards-chemistry, there were few differences in chemistry self-efficacy for the different demographic groups. Gender differences were observed at the start of the year and the end of the first semester with males being more efficacious. Although the effect size of this differences is not large, the consistency of this finding suggests that perception of ability in chemistry is different for male and female students. There also were statistically significant differences between chemistry majors and non-majors, with the former more efficacious at the start of the year. The main issues identified by interviewees included concerns about competency in mathematics, coping with assessment, and the memorisation of course content.

6.6 The Influence of Learning Experiences on Chemistry Self-Efficacy

1.viii	What influence, if any does student chemistry self-efficacy have on learning experiences?

The impact of students' tertiary learning experiences on their chemistry self-efficacy was investigated both quantitatively and qualitatively by considering changes in chemistry self-efficacy throughout the year. In the first instance, data from the CAEQ were examined to determine if changes in chemistry self-efficacy correlated with any of the students' learning experiences.

Table 6.28

Summary of findings from data on chemistry self-efficacy.

Quantitative findings for chemistry self-efficacy at start of the year	
Chemistry self-efficacy	– Students as a whole slightly confident about studying chemistry
Demographic data	– Males more confident than females – Students who enrolled in chemistry as a compulsory course less confident than chemistry majors
Quantitative findings for chemistry self-efficacy at the end of the first semester	
Chemistry self-efficacy	– Students as a whole slightly confident about studying chemistry
Demographic data	– Males more confident than females
Quantitative findings for chemistry self-efficacy at the end of the second semester	
Chemistry self-efficacy	– Students as a whole slightly confident about studying chemistry
Qualitative findings	

- Chemistry self-efficacy was related to prior learning experiences, with specific concerns made in relation to :
    - Mathematical ability
    - memorisation
- Males identified specific tasks that contributed to their self-efficacy beliefs whereas females were more general
- Perceptions of ability were related to the amount of effort put into studying
- Students who had been away from study for a significant period of time were concerned about memorisation, but their concerns dissipated throughout the year
- Prior achievement was attributed to high self-efficacy

6.6.1 *Quantitative Findings for Changes in Chemistry Self-efficacy in Relation to Learning Experiences*

H_{14}: There is a relationship between student chemistry self-efficacy and learning experiences

Changes in student chemistry self-efficacy were investigated quantitatively in two ways. First, repeated measure GLM method was used to examine the differences in the students' *chemistry self-efficacy* for the three administrations of the instrument. Second, the subscale responses to the *chemistry self-efficacy* subscales were correlated with the *learning experience* subscales.

Repeated measures GLM for the self-efficacy scale from the three administrations of the CAEQ suggests that *chemistry self-efficacy* remained stable throughout the year, with no statistically significant differences observed. Examination of the relationship between student learning experiences and change in self-efficacy using Pearson's correlation (Table 6.29) suggests that there is a

Table 6.29

Relationship between learning experiences subscales and changes in *chemistry self-efficacy* for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) based on Pearson's correlation

	End of First semester change in chemistry self-efficacy between start of year and end of first semester (n=42)			End of Second semester change in chemistry self-efficacy between end of first semester and end of second semester (n=31)		
	Lecture	Tutorial	Practical	Lecture	Tutorial	Practical
Change in chemistry self-efficacy subscale	0.32*	0.29	0.41*	0.45*	0.21	0.38*

* statistically significant at $p<0.05$

statistically significant correlation between student self-efficacy and lecture and laboratory learning experiences for both of the first and second semester courses. Hence it seems that although there is little change in chemistry self-efficacy for the participants as a whole, for those participants whose self-efficacy did change, this is influenced by their lecture and laboratory learning experiences.

6.6.2 Qualitative Findings for Changes in Chemistry Self-efficacy in Relation to Learning Experiences

Interview data were used to investigate what influence tertiary chemistry learning experiences exerted on students' chemistry self-efficacy. The questions relating specifically to chemistry self-efficacy are presented in Table 6.27 (p.190). Data presented here examines the change in the responses given by the participants in all three interviews.

For many of the interview participants, chemistry self-efficacy appeared to remain the same throughout the year. For example, Jack felt confident about passing the first semester chemistry course at the start of the year "[Year-13 chemistry] was pretty good for me, I found that quite easy, and with a bit of luck it will be sort of similar to that, maybe a bit harder." His perception of his own ability in chemistry remained similar at the end of the first semester course. He commented: "[The first semester course] was good, it wasn't too hard ... [The second semester course] would be pretty much the same I think, just different topics, different area of chemistry." Similarly, at the end of the year Jack believed he would not have any difficulties with second-year chemistry "as long as like I keep going to tutorials and doing the assignments and stuff it should be alright. It will probably be a bit harder than this year I guess."

Interview participants whose chemistry self-efficacy changed during the year cited specific learning experiences, effort and interest. For example, they related their chemistry self-efficacy to the amount of effort required, and the amount of effort they were prepared to expend, the later of which was subsequently related to their level of interest in the subject. So, for example, lack of enjoyment of lectures resulted in a decrease in student self-efficacy about achieving a passing grade for a given chemistry course. Patrick comments: "I just don't like that part of chemistry, and if I'm not enjoying it, then I will just go off on tangents and I won't keep up the effort." At the end of the first semester the interview participants felt that course structure influenced their perceptions of their ability to pass the course. For example, writing their own notes during lectures seemed to improve student chemistry self-efficacy, whereas speed of delivery of lecture material and a perception of a lack of approachability for some lecturers contributed to a decrease in chemistry self-efficacy. Felix, a student with low chemistry self-efficacy (as evidenced by his responses to the *chemistry self-efficacy* scale of the CAEQ and earlier interview comments) noted: "The lecturer wasn't the most approachable. He used to say, you should be able to solve this equation in a minute, and you are going, hang on, I don't know where we are."
Efficacious beliefs derived from laboratory classes were mixed, with some interview participants finding that the laboratory classes helped them pass and making statements that suggested that their chemistry self-efficacy had increased: Leanne commented: "Seeing that I could do it, that it was quite doable." In other cases unhappy experiences in the laboratory classes seemed to reduce chemistry self-efficacy with Patrick saying, "When it comes to lab work, well I've broken two pipettes in an hour and test tubes [laughs]. I'm a bit clumsy."

Interestingly, it seems that the tutorial classes exerted the greatest influence on interview participants with low chemistry self-efficacy, but apparently not for more able students - who typically did not attend tutorials. Lawrence comments: "I went to the first one [i.e., tutorial], but I don't really need to do the tutorials.

The work we did, it's all basic and I didn't really need any help with it." Interview participants who began the year with lower chemistry self-efficacy gave up attending tutorials as they grew in confidence. Alan, noted that by the end of the second semester, "things have kind of fallen a bit into place for me, so it has been a bit easier. I just didn't feel it necessary to go to the tutorials." However, for interview participants with concerns about a particular part of the course, the tutorials proved helpful - resulting in higher chemistry self-efficacy as the year progressed. Karen was selective in the tutorials she attending: "I didn't go to every single one because some of them I already know the stuff from last year so I though oh well, but the ones I did go to, I found really helpful."

6.6.3 Summary

Quantitative data from the CAEQ suggests that student chemistry self-efficacy does not increase as a result of student learning experiences overall, but revealed statistically significant correlations between changes in students' chemistry self-efficacy and their lecture and laboratory learning experiences (Table 6.30). The interview data suggests that the most important learning experiences were those that the students perceived would increase their chances of passing their courses. Specific experiences contributing to changes in chemistry self-efficacy included note taking in lectures, achieving good grades in internal assessment and good performance in laboratory classes. As the students' self-efficacy increased, they were less likely to attend tutorials.

6.7 Chapter Review

The findings reported here suggest that students come to university with particular beliefs and anxieties about tertiary level science study. However, most of the students overcame their concerns about tertiary level study relatively early in the first semester. For those that did not, a number of students dropped out of university study entirely. More specifically to chemistry, the students were overall positive about their learning experiences in their first-year chemistry courses. There is however, some disparity between the students' perceptions of their experiences in the different classrooms. That is, students were particularly

Table 6.30

Summary of findings from data on changes in chemistry self-efficacy in relation to first-year learning experiences.

Quantitative findings for changes in chemistry self-efficacy in relation to first-year learning experiences	
Chemistry self-efficacy subscales	– No changes throughout year
Correlation of changes in chemistry self-efficacy scale and first-semester learning experiences subscales	– Relationship between change in chemistry self-efficacy and lecture and practical learning experiences
Correlation of changes in chemistry self-efficacy scale and second-semester learning experiences subscales	– Relationship between change in chemistry self-efficacy and lecture and practical learning experiences

Qualitative findings for changes in chemistry self-efficacy in relation to first-year learning experiences

- For most participants chemistry self-efficacy remained stable throughout the year
- Changes in chemistry self-efficacy was related to learning experiences that involved the amount of effort that put into the course and the level of interest they had in the course
- Lecturers who trivialised the difficulty of a task impacted on students' chemistry self-efficacy
- Laboratories had little impact on chemistry self-efficacy
- Tutorials improved chemistry self-efficacy, although once the students became more confident they stopped attending

positive about their tutorial classes as they provide good preparation for tests and examinations. The students were less positive about their laboratory classes, with many citing over-emphasis on accuracy in titration experiments as a reason for this. This finding was in contrast with the students' views at the start of the year, where they were most positive about their impending laboratory classes. Other student experiences in the laboratory classes were positive, with students enjoying experiments involving the new equipment that they had anticipated at the start of the year. There were few differences in students' perceptions of their learning experiences between different demographic groups, although students who studied chemistry as a supporting subject to another science major were less positive about their learning experiences in their laboratory classes for the second semester course.

The majority of students held a positive attitude-towards-chemistry throughout the academic year, especially in reference to attitude-towards-chemistry in society. In fact they could cite a multitude of instances when chemistry research had improved society. The students were less interested in exploring chemistry in their leisure time. They also held mixed views about the chemists and the environment – with some thinking chemists are environmentally friendly, and others thinking chemists did not consider the environment at all. There were few differences observed in demographic parameters that were of sufficient size that were likely to be of interest, although New Zealand European students had a greater career interest in chemistry than students of other ethnicities at the end of the second semester.

In general there was little correlation between student *learning experiences* and changes in their *attitude-towards-chemistry.* There were statistically significant correlations between the CAEQ subscales *career interest in chemistry* at the end of the second semester, and the *lecture learning experiences* subscale and *practical learning experiences* subscales. There were no statistically significant changes in student *attitude-towards-chemistry* for any of the subscales between the three administrations of the CAEQ. Interview data suggests that although *student attitude-towards-chemists and the environment* and *attitude-towards-chemistry in society* did not change, they were more thoughtful and insightful about their beliefs, commonly linking their views to specific tertiary chemistry learning experiences.

Generally, the students were confident about the tasks required of them in first-year chemistry, with male students and chemistry majors particularly efficacious. The chemistry tasks that caused most concern for the interview participants were related to mathematical competence and the amount of memorisation required for course assessments. Although overall there were no statistically significant differences in the chemistry self-efficacy throughout the year, there was a relationship between learning experiences in lecture and laboratory classes, with student chemistry self-efficacy. The interview data suggests that positive assessment results influenced chemistry self-efficacy.

The relationship between learning experiences, attitude-towards-chemistry and chemistry self-efficacy, and attitude-towards-enrolling in second year chemistry is discussed in Chapter 9 (p. 253).

6.8 Chapter Summary

The chapter presented the first of the research findings for the study and examined the influence of student learning experiences on their attitude-towards-chemistry and chemistry self-efficacy. The chapter began with a sample description followed by details of student learning experiences and their attitude-towards-chemistry and influence of learning experiences on attitude-towards-chemistry. Next, the findings for students' chemistry self-efficacy and the influence of their learning experiences on their self-efficacy were explored. Chapter 7 which follows, presents research findings for research questions two to four, and focuses on students' attitude-towards-enrolling in chemistry, control beliefs about enrolling in chemistry, and their normative beliefs about enrolling in chemistry.

CHAPTER 7
RESEARCH FINDINGS: ATTITUDE-TOWARDS-ENROLLING IN CHEMISTRY, CONTROL BELIEFS ABOUT ENROLLING IN CHEMISTRY AND NORMATIVE BELIEFS ABOUT ENROLLING IN CHEMISTRY

In the previous chapter, Chapter 6, the findings for the first research question were presented. This chapter follows on from those findings, and presents the results for research questions two, three and four, namely:

2. What are student attitude-towards-enrolling in chemistry and what influence, if any, does student first-year learning experiences, attitude-towards-chemistry and chemistry self-efficacy have on student attitude-towards-enrolling in second-year chemistry?
    i. What is student attitude-toward-enrolling in second-year chemistry?
    ii. What influence, if any, does student first-year learning experiences have on attitude-towards-enrolling in second-year chemistry?
    iii. What influence, if any, does student attitude-towards-chemistry have on attitude-towards-enrolling in second-year chemistry?
    iv. What influence, if any, does student chemistry self-efficacy have on attitude-towards-enrolling in second-year chemistry?

3. Do students hold control beliefs about enrolling in second-year chemistry, if so what are they, and what influence, if any, do student first-year learning experiences, attitude-toward-chemistry and chemistry self-efficacy have on student perceived control over enrolling in second-year chemistry?
    i. Do students hold control beliefs about enrolling in second-year chemistry?
    ii. If students hold control beliefs about enrolling in second-year chemistry, what is student perceived control over enrolling in second-year chemistry?

iii. What influence, if any, does student first-year learning experiences have on perceived control over enrolling in second-year chemistry?

v. What influence, if any, does student attitude-towards-chemistry have on perceived control over enrolling in second-year chemistry?

iv. What influence, if any, does student chemistry self-efficacy have on perceived control over enrolling in second-year chemistry?

4. What are student perceptions of associates attitude-towards-chemistry and normative beliefs and what influence, if any, does student perception of associates attitudes-towards-chemistry have on subjective norm?
   i. What are student perceptions of associates attitude-towards-chemistry?
   ii. What is student subjective norm?
   iii. What influence, if any, does student perception of associates attitude-towards-chemistry have on subjective norm?

Student attitude-towards-enrolling in chemistry in their first-year courses based on interview data is analysed and presented first. This is followed by an examination of the influence that chemistry learning experiences, attitude-towards-chemistry and chemistry self-efficacy have on students' attitude-towards-enrolling in chemistry. Next are the results of the quantitative and qualitative findings about students' control beliefs about enrolling in second-year chemistry – again related to attitude-towards-chemistry, chemistry self-efficacy and chemistry learning experiences. Student perceptions of their associate's beliefs about enrolling in chemistry and attitude-towards-chemistry follow.

7.1 Attitude-Towards-Enrolling in Chemistry

2.i	What is student attitude-toward-enrolling in second-year chemistry?

E_4:	Explore student attitude-towards-enrolling in second-year chemistry

Student attitude-towards-enrolling in chemistry for both the first and second semester chemistry courses was investigated in interviews. Participants were probed at the start of the year, the end of the first semester, and again at the end of the second semester. The interview participants were asked about their reasons for enrolling in a first-year chemistry course, and what influenced their decision to study second-year chemistry. From the responses to these questions, the responses pertaining to attitude-towards-enrolling in chemistry were elucidated, and relevant follow up questions were asked in order to understand interview participants' attitudes about enrolling in chemistry.

There was strong commonality of views about enrolling in chemistry with most interview participants saying that they believed first-year chemistry would give them a good background for their studies in other science subjects, both in terms of content knowledge, and in skill acquisition. For example, Leanne said, "it kind of gives you a good grounding in a lot of things. You use a bit of maths, you use logical thinking, and also it gives you an understanding of things around you." Some interview participants were not sure of their overall education pathway and so they had enrolled in a range of science subjects – thinking that their first-year learning experiences would help clarify their thinking. Felix, for instance, was generally interested in computer science but was unsure as to what other science subjects to take in his undergraduate programme:

> In regards to the course, I'm not entirely sure what direction I want to follow. But I know I want to do computers and I want to do mathematics, so I've got some of that in my course but I also enjoy the sciences. I didn't really know what direction to take the sciences, so I've taken a range of them for now and I will have a better idea at the end of the semester and the end of the year what sciences I will want to take further.

Other interview participants felt that studying chemistry would be an extension of secondary school and thus they continued studying chemistry "because I've always done it." Others were more definite in their initial intentions. Consider Kerrie's (an intending chemistry major) attitude at the end of the year:

> It's just that I always planned to and I am still planning on taking chemistry as my major. This semester I haven't liked everything. I don't like the work that we are doing at the moment [in the second semester course] I find that a bit hard. I did like certain aspects of it, and I do think I will like organic as well.

It is interesting that she seemingly did not enjoy her first-year chemistry course much at all, but nonetheless planned on enrolling in a chemistry major.

7.1.1 The Influence of Chemistry Learning Experiences on Attitude-Towards-Enrolling in Chemistry

2.ii	What influence, if any, does student first-year learning experiences have on attitude-towards-enrolling in second-year chemistry?

H_{15}: There is a relationship between student first-year learning experiences and attitude-towards-enrolling in second-year chemistry

Some of the interview participants said that they enjoyed chemistry at secondary school and enrolled in chemistry at first-year because, as Eleanor put it, she "enjoyed it at school and so I thought I'd carry it on." Although the participants seldom identified specific first-year chemistry learning experiences as reasons for studying chemistry in the second semester or at second-year level, two of the interview participants who dropped out of chemistry said that their first-semester experiences influenced their decisions. Kevin, an intending chemistry major commented at the start of the year:

> I just don't like the lab work. I enjoy the lectures. I like all the material in them, but I don't like the actually having to do three hours lab each week. Maybe because I'm slower and I have to work a lot harder, but I just don't like that part of the course.

Lawrence, was planning to supplement his *Resource and Environmental Planning* (REP) specified programme with additional chemistry, instead he dropped chemistry at the end of the first semester: "I've kind of gone off [chemistry] a bit I suppose. It's just that we haven't done anything new. We have just done the same things for the last few years and it's kind of got a bit boring."

7.1.2 The Influence of Attitude-Towards-Chemistry on Attitude-Towards-Enrolling in Chemistry

2.iii	What influence, if any, does student attitude-towards-chemistry have on attitude-towards-enrolling in second-year chemistry?

H_{16}: There is a relationship between student attitude-towards-chemistry and attitude-towards-enrolling in second-year chemistry

The most popular reason for studying chemistry was that the students were "interested in chemistry." However, the reasons for such interest were not well articulated, as seen in Kirsten's comments:

Interviewer:	So what is the major reason that you want to be a chemistry major?
Kirsten:	I just like it, I enjoy chemistry
Interviewer:	What is it about it that you like?
Kirsten:	I don't know, I just find it interesting.

Male students who expressed leisure interest in chemistry said that they were interested in studying chemistry to learn more about the nature of the world. Kevin, an intending chemistry major came to chemistry study with an interest in pyrotechnics, and went on to say that he was interested in chemistry because:

> It's just knowing how things [work]. Like you've got bleach at home, it's knowing how the elements are bonded and what it takes to break them apart. Like if you put two chemicals together, they may or may not bond, and it's just knowing what that happens and why it doesn't.

Other interview participants, also predominantly male, also were interested in the nature of the world, and chose chemistry over other sciences because they believed that chemistry was more focussed on the 'what' and 'how' of science compared with other science subjects. For example, Patrick wanted to study chemistry because "at the end of the day the fundamental science is chemistry. [Physics and biology] sort of follow it, I think, and you need knowledge in chemistry, or at least basic confidence in it."

7.1.3 The Influence of Chemistry Self-Efficacy on Student Attitude-Towards-Enrolling in Chemistry

2.iv	What influence, if any, does student chemistry self-efficacy have on attitude-towards-enrolling in second-year chemistry?

H_{17}: There is a relationship between student chemistry self-efficacy and attitude-towards-enrolling in second-year chemistry

Chemistry self-efficacy also influenced interview participants' intentions to carry on studying chemistry with many interview participants relating enrolment choices to good academic performance. Comments such as: "I got good grades in it," were common reasons given for reason to study chemistry at tertiary level. The interview participants also cited this reason at the end of year as being a factor in their decision as to whether or not they undertook second-year chemistry. Many of the interview participants found the second semester course more difficult than the first semester course, meaning that they thought second-year chemistry would be considerably more difficult. The interview participants thus became apprehensive about studying second-year chemistry. Kerrie comments:

> I don't know how hard second-year chemistry is going to be. I would say there is a huge jump from second-year to first-year. I found first-year okay, like I got through it, but some parts of it I found difficult, like

organic. If there's going to be a huge jump from that, I'm thinking maybe I won't do so well.

7.1.4 Summary

A summary of the key findings from this section are presented in Table 7.1. The students identified a number of beliefs that contributed to their attitude-towards-enrolling in second-year chemistry, including those derived from learning experiences, attitude-towards-chemistry and chemistry self-efficacy.

7.2 Control Beliefs About Enrolling in Chemistry

3.i	Do students hold control beliefs about enrolling in second-year chemistry?
3.ii	If students hold control beliefs about enrolling in second-year chemistry, what is student perceived control over enrolling in second-year chemistry?
3.iii	What influence, if any, does student first-year learning experiences have on perceived control over enrolling in second-year chemistry?
3.iv	What influence, if any, does student attitude-towards-chemistry have on perceived control over enrolling in second-year chemistry?

H_{18}:	Students hold control beliefs about enrolling in second-year chemistry
E_5:	Explore student perceived control over enrolling in second-year chemistry

Student control beliefs about enrolling in chemistry were investigated quantitatively and qualitatively using interviews and data gleaned from the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) instrument. The quantitative data are presented first, looking at differences across subscales for all administrations of the CAEQ. Comparisons are made between those students who chose to enrol in either of the two chemistry courses (choice students), and those for whom the courses were compulsory (compulsory students). The description of the quantitative findings is then followed by the interview data.

All administrations of the CAEQ were examined using ANOVA across all subscales, looking at differences between choice and compulsory students (Table 7.2). Statistically significant differences were further examined on the basis of effect size (η^2) and by examination of the spread of data using histograms.

Table 7.1

Summary of findings from data on student attitude-towards-enrolling in chemistry.

Student attitude-toward-enrolling in chemistry	
Attitude-towards-enrolling in chemistry	– Good background for their studies in other science subjects – Enrolled in a range of science subjects to help decide what subject to major in – Studied chemistry at university because they studied chemistry at secondary school
Learning experiences and attitude-towards-enrolling in chemistry	– Enjoyed chemistry at school – Did not want to study chemistry at second year level because of poor experiences in laboratories
Attitude-towards-chemistry and attitude-towards-enrolling in chemistry	– Interested in studying chemistry including with particular reference to understanding the nature of the world
Chemistry self-efficacy and student attitude-towards-enrolling in chemistry	– Achievement in chemistry encouraged the students to study it at higher levels – Students were concerned about the increased difficulty in chemistry at second year level

H_{19}: There is a relationship between student first-year learning experiences and perceived control over enrolling in second-year chemistry
H_{20}: There is a relationship between student attitude-towards-chemistry and perceived control over enrolling in second-year chemistry
H_{21}: There is a relationship between student chemistry self-efficacy and perceived control over enrolling in second-year chemistry

Interestingly, there were few statistically significant differences in estimated mean responses observed for choice and compulsory students. The only subscales showing statistically significant differences between these two cohorts were *required skills of chemists*, *career interest in chemistry,* and *chemistry self-efficacy* at the start of the year, and *practical learning experiences* at the end of the year

These data suggest that students who chose to study chemistry were more positive in attitude about *required skills of chemists* than those for who chemistry was compulsory (Figure 7.1). However, the η^2 value is low suggesting that effect size is probably small. Examination of the spread of the data confirms the small effect in that the statistically significant difference seems to be due to the fact that a higher proportion of students who enrolled in chemistry as a compulsory course had negative attitudes (19% and 6% for compulsory and choice students respectively). Furthermore, students who chose to study chemistry were more

Table 7.2

Differences between the estimated mean responses between those students who choose to enrol in chemistry and those for whom first-year chemistry is compulsory for all subscales of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for all three administrations.

	Choice Students		**Compulsory Students**				
	Mean	Std. Dev.	Mean	Std. Dev.	F	p	η^2
Start of year							
N	69		50				
Attitude-towards-chemists	4.65	0.81	4.49	1.08	0.82	0.37	0.01
Required skills of chemists	5.24	0.79	4.89	0.90	5.03	0.03*	0.04
Attitude-towards-chemistry in society	5.76	0.77	5.43	0.97	4.01	0.05	0.03
Leisure interest in chemistry	4.44	1.36	3.98	1.33	3.40	0.07	0.03
Career interest in chemistry	5.11	0.77	4.74	1.07	4.64	0.03*	0.04
Chemistry self-efficacy	4.52	0.75	4.17	0.95	5.17	0.02*	0.04
End of first semester							
N	42		26				
Lecture chemistry learning experiences	3.54	0.49	3.40	0.62	0.97	0.33	0.01
Tutorial chemistry learning experiences	3.84	0.53	3.75	0.60	0.37	0.54	0.01
Practical chemistry learning experiences	3.59	0.58	3.36	0.50	2.87	0.09	0.04
Attitude-towards-chemists	4.62	0.86	4.49	0.88	0.39	0.53	0.01
Required skills of chemists	5.09	0.98	4.82	0.99	1.12	0.29	0.02
Attitude-towards-chemistry in society	5.65	0.97	5.41	1.02	0.90	0.35	0.01
Leisure interest in chemistry	4.31	1.36	3.66	1.36	3.60	0.06	0.05
Career interest in chemistry	5.06	0.84	4.83	1.18	0.81	0.37	0.01
Chemistry self-efficacy	4.49	0.97	4.12	0.99	2.25	0.14	0.03
End of second semester							
N	30		18				
Lecture chemistry learning experiences	3.66	0.46	3.52	0.61	1.10	0.30	0.02
Tutorial chemistry learning experiences	3.75	0.77	3.89	0.59	0.60	0.44	0.01
Practical chemistry learning experiences	3.50	0.50	3.78	0.55	5.26	0.02*	0.07
Attitude-towards-chemists	4.73	0.93	4.56	1.14	0.49	0.49	0.01
Required skills of chemists	4.91	0.93	5.07	0.96	0.46	0.50	0.01
Attitude-towards-chemistry in society	5.42	0.96	5.51	1.01	0.15	0.70	0.00
Leisure interest in chemistry	4.19	1.30	4.25	1.30	0.04	0.85	0.00
Career interest in chemistry	4.75	0.98	4.74	1.18	0.00	0.98	0.00
Chemistry self-efficacy	4.82	0.87	4.48	1.68	1.15	0.29	0.02

*statistically significant at $p<0.05$

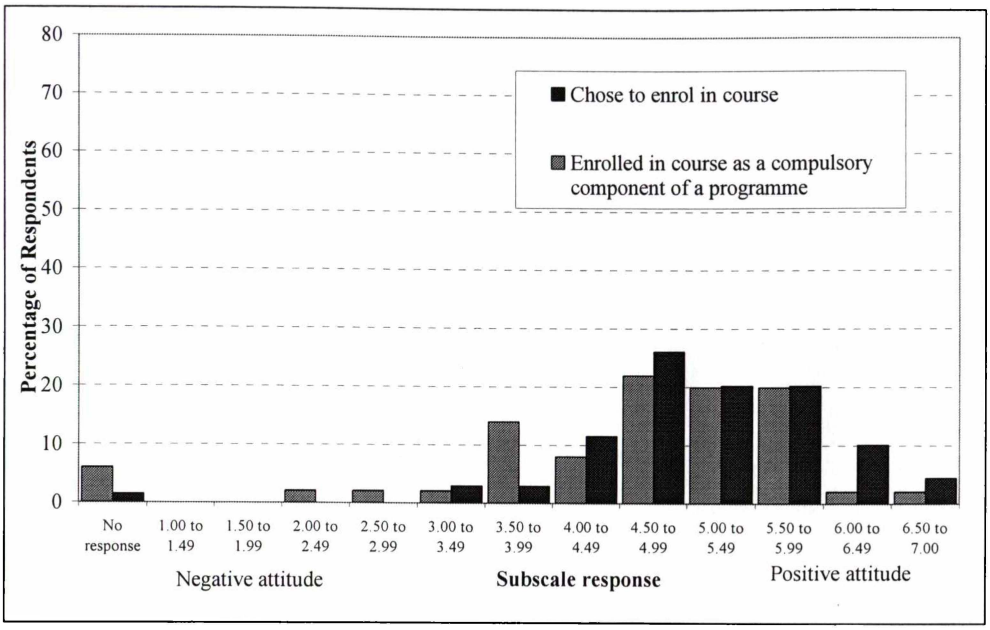

Figure 7.1

Graphical representation of the *required skills of chemists* subscale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents who chose to enrol in the first semester course (n=69) and those for whom the course was a compulsory course of another degree (n=50) - start of the year.

likely to have a very positive attitude with 14% providing estimated mean responses of above 6.00 compared with 6% for compulsory students.

Data from the *career interest in chemistry* subscale at the start of the year suggests that students who choose to study chemistry have more of a career interest in chemistry than those for whom chemistry is a compulsory course. However, again η^2 values suggest that this result is due to statistical variation. Analysis of the spread of the data (Figure 7.2) indicates that whilst those who chose to study chemistry are likely to have a moderately positive career interest in chemistry, those who did not chose to enrol in the first-year were more likely to have a negative career interest in chemistry.

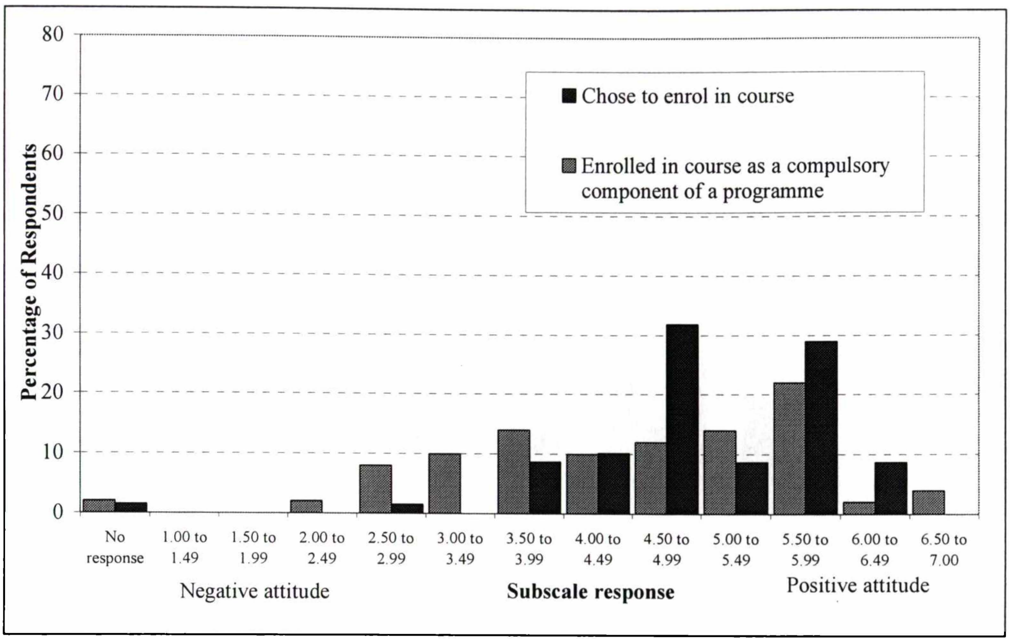

Figure 7.2

Graphical representation of the *career interest in chemistry* subscale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents who chose to enrol in the first semester course (n=69) and those for whom the course was a compulsory course of another degree (n=50) - start of the year.

The statistically significant differences in the estimated mean responses for the *chemistry self-efficacy* scale between the compulsory students and choice students have a low η^2 value. This suggests that the effect size is small. Examination of the spread of the data shows that students who enrol in the first semester chemistry course as a compulsory subject have a slightly lower mode (most common response) subscale response (3.50 to 3.99) than those students who chose to enrol in the course (4.00 to 4.99) (Figure 7.3). These findings are consistent with those in Chapter 6 (Section 6.5.1, p. 182) where chemistry majors chemistry were found to be more efficacious at the start of the year than students who enrol in chemistry as a compulsory course.

At end of second semester the data suggest that compulsory students were more positive about their laboratory class experiences with statistically significant differences seen in estimated mean response for the *practical learning experience* subscale. However, again a low η^2 (η^2 =0.07) value suggests that this is due to statistical variation. Examination of the data shows there is only a slight difference in the mode subscale response for the two groups with those that chose

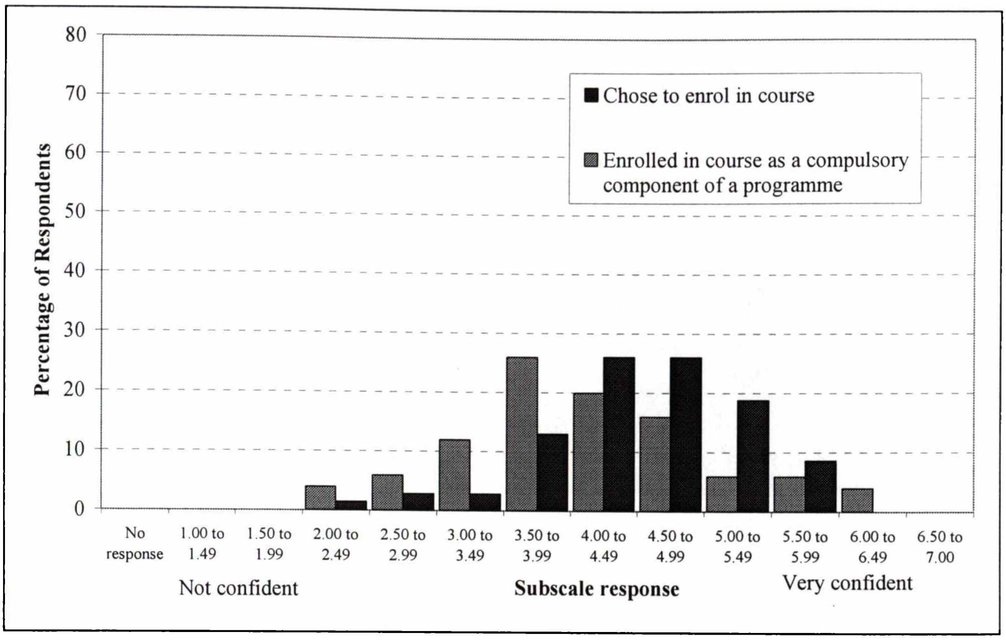

Figure 7.3

Graphical representation of the *chemistry self-efficacy* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents who chose to enrol in the first semester course (n=69) and those for whom the course was a compulsory course of another degree (n=50) - start of the year.

to enrol in the course having a mode of between 3.50 to 3.99, compared to 3.00 to 3.49 for those for whom the course is compulsory (Figure 7.4).

Interview participants' control beliefs were probed during interviews using open-ended prompt questions such as: "If the first semester chemistry course was not compulsory would you consider enrolling in it anyway?" The interviews showed that most interview participants felt they had little control over their enrolments. For example, the engineering interview participants (all of whom were male) were enrolled in fully-prescribed degree programmes for which they had no choice of enrolment. Marcel typifies this situation, commenting: "I just wanted to do engineering and it's part of the course." When questioned as to whether they would study chemistry if it were not compulsory, the engineering interview participants said they would, because they believed it was relevant to their

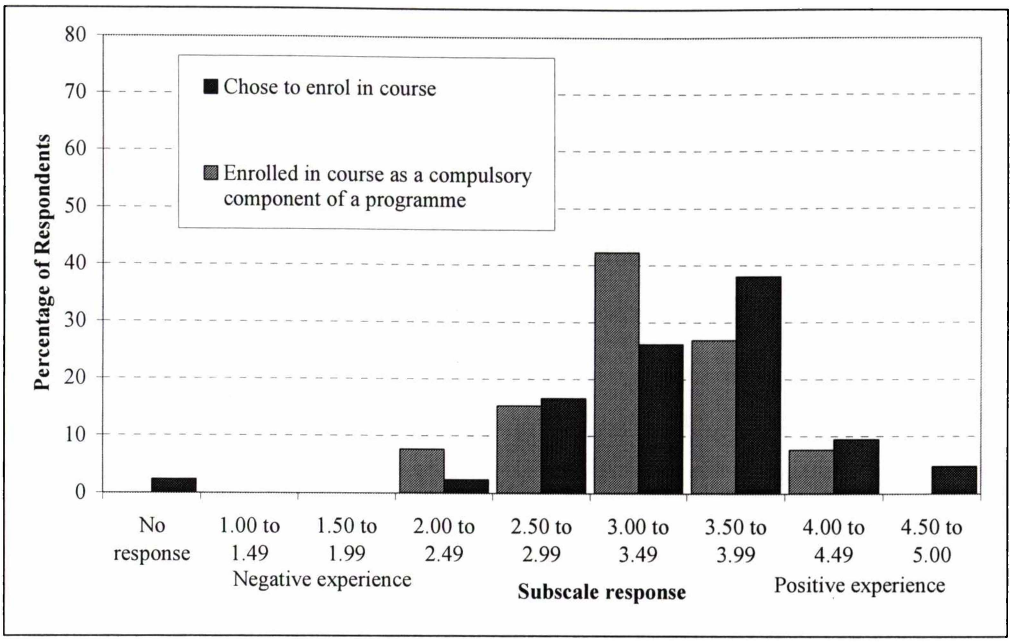

Figure 7.4

Graphical representation of the *practical learning experiences* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents who chose to enrol in the second semester course (n=44) and those for whom the course was a compulsory course of another degree (n=29) - end of the second semester.

engineering degree. What this means is that these interview participants do have an interest in studying chemistry, but only because they see it as related entirely to their overall interest, in this case, engineering. Jack's comments are illuminating:

> Basically because whenever you sort of think materials and processing engineering there's obviously going to be the need for chemical knowledge in there somewhere, working with different sorts of materials, organic and inorganic, stuff like that.

A similar situation exists for other degree programmes that had compulsory first-year chemistry (or for which it was highly recommended). For example Karen said "I'm doing animal behaviour so it [i.e., chemistry] was part of my course." Unlike the engineering interview participants these interview participants (who were predominantly female and enrolled in biology-related disciplines) made less reference to perceptions of relevance of chemistry to their programmes, and were more ambivalent about studying first-year chemistry given a choice. So Karen wanted to do chemistry anyway because "I like chemistry," however, Celia only studied chemistry because she had to chose between chemistry and calculus, and felt she was unlikely to pass the calculus course. Her comments suggest that she could not really relate to the course content, nor see how it would be relevant to her specified programme in marine science:

> I know I don't have a great chance at passing it and it doesn't interest me. It doesn't make me want to come to class to know I've got chemistry. It just doesn't make me want to get up in the morning, sitting in a lecture for an hour, listening to someone go on about [chemistry]. It's funny how they can get really excited and you can't, how a = b and if you change to c to b, it doesn't make any sense to me, and because it doesn't make any sense I don't like it.

7.2.1 Summary

The main control belief held by the students was related to the course being a compulsory element of their degree programme (Table 7.3). Students for whom the course was compulsory had less positive attitudes about the required skills of chemists and career interest in chemistry at the start of the year. They were also less confident about studying chemistry at the start of the year. Interestingly, students for whom the course was compulsory were more positive about their practical learning experiences in the second semester course.

7.3 The Influence of Associates' Beliefs on Normative Beliefs

4.i	What are student perceptions of associates attitude-towards-chemistry?
4.ii	What is student subjective norm?

In this section the influence of social norms on interview participants' attitude-towards-chemistry, chemistry self-efficacy, chemistry learning experiences and normative beliefs about studying chemistry are described. The influence of

Table 7.3

Summary of findings from data on student control beliefs about enrolling in second-year chemistry.

Student control beliefs about enrolling in second-year chemistry	
Control beliefs about enrolling in second-year chemistry	– Students enrolled in courses that chemistry was compulsory felt they had little control over the decision to enrol in second-year chemistry – Some students for whom chemistry was compulsory would choose to study it anyway, whereas others would not
Learning experiences and control beliefs about enrolling in second-year chemistry	– Students for whom chemistry was a compulsory subject were more positive about their laboratory classes at the end of the second semester
Attitude-towards-chemistry and control beliefs about enrolling in second-year chemistry	– Students who chose to study chemistry were more positive about the required skills of chemists at the start of the year – Students who chose to study chemistry have more of a career interest in chemistry at the start of the year
Chemistry self-efficacy and control beliefs about enrolling in second-year chemistry	– Students who chose to study chemistry were more confident about studying chemistry at the start of the year

social interactions with significant individuals in interview participants' lives was investigated using data gleaned from administrations of the CAEQ and interviews.

In all three administrations of the CAEQ the participants were asked if they had any associates (friends or relatives) who they though of as scientists. Interestingly, there were no statistically significant differences for any of the subscales from any of the administrations between the students who had associates in a science field, and those that did not. This suggests that social experiences of science students (i.e., interactions with scientific associates) had limited influence on their attitude-towards-chemistry, chemistry self-efficacy and chemistry learning experiences.

Student perceptions of beliefs of peers, parents, mentors, and the media portrayal of chemistry, were investigated in order to understand what influence everyday social attitudes about chemistry might make on enrolment choice. The main tool used here were interviews, and participants were probed about three components of chemistry, namely the chemistry profession, personality traits of chemists and values of chemists (Table 7.4).

E_6: Explore student perceptions of associates attitude-towards-chemistry

7.3.1 Perceptions of Peer Beliefs About Chemistry

An interesting outcome of the interviews was that despite a multitude of careers available to chemistry graduates, the interview participants felt that their peers identified chemistry occupations with images, rather than professions. In particular, the participants felt that their peers very much subscribed to the image of a person in a laboratory environment, working with chemicals and wearing a white laboratory coat. Alan, a first-year biochemistry student comments: "They would be probably see chemists as people who wear white coats, work in a laboratory, and play with chemicals all day." Some interview participants did

Table 7.4

Interview protocol used to probe the influence of associates' beliefs on student enrolment choices

Peers

1. What do you think your friends think a person who works as a chemist does?
2. What do you think your friends think the personality traits of a chemist are?
3. Do you think your friends think that chemists consider the effect has on humanity when they design their research?
4. Do you think your friends think you should study (the first semester/second semester/a second-year) chemistry course?

Parents

5. What do you think your parents/guardians think a person who works as a chemist does?
6. What do you think your parents/guardians think the personality traits of a chemist are?
7. Do you think your parents/guardians think that chemists consider the effect has on humanity when they design their research?
8. Do you think your parents/guardian think you should study (the first semester/second semester/a second-year) chemistry course?

Mentor

9. Do you have someone you consider to be a mentor?
10. What do you think your mentor thinks a person who works as a chemist does?
11. What do you think your mentor thinks the personality traits of a chemist are?
12. Do you think your mentor thinks that chemists consider the effect has on humanity when they design their research?
1. Do you think your mentor thinks you should study (the first semester/second semester/a second-year) chemistry course?

Media

13. How do you think the media portrays what a person who works as a chemist does?
14. How do you think the medial portrays what the personality traits of a chemist are?
15. Do you think the media portrays chemists as considering the effect has on humanity when they design their research?

extend this to the stereotypical image of chemistry, viz., boiling beakers and test tubes. Kerrie, a chemistry major, said her friends would think of chemists in terms of "someone in a white coat mixing things in test tubes with little science glasses on." A few interview participants thought that their friends would think of chemistry being involved in dramatic things like bomb making, explosives or pyrotechnics. Gary, another chemistry major, assessed his friends' opinions of chemists as "probably crazy people, making bombs and stuff, and mix up concoctions and things like that." Those interview participants that believed their friends could name specific professions, specified research and lecturing – probably as a result of their university experiences. Robert, a chemistry major, concluded his friends would see chemistry occupations as "probably just research most of them, [they would think] a few jobs involve repetitive sample analysis." Other interview participants supposed their friends would not distinguish between chemistry and pharmacy. Grace, taking first-year chemistry as part of a university bridging course, believed that her friends would see a chemist as "a person who works in a pharmacy. Not very many [of my friends] are science people so I suppose that would be the first thing that would come to mind." In contrast Celia, a marine science student, felt that her friends would associate chemistry with "all these experiments on mice and stuff, [people] wearing their white lab coats, and big horned rimmed glasses."

None of the interview participants thought that their friends would see chemists as normal people. In particular, the interview participants believed their friends thought that chemists must be highly intelligent. Jack thought his friends would describe chemists as "really smart, an intellectual type person, someone who really knows their stuff." Chemistry majors generally felt their friends would subscribe to the "mad scientist" stereotypical image of chemists. Many mentioned "eccentric", "crazy" and "different" as words that their friends would use to describe chemists. Kevin, a chemistry major, said his friends would describe chemists as a "mad scientist," going on to say that he thought "they would probably get the mad scientist idea from me because of my opinion of fireworks," and that "they would probably get a lot of this off the TV and movies." Some interview participants - especially chemistry majors - thought their friends would think of chemists as analytical people and as "nerds," being both unsociable and boring. Kerrie, a chemistry major, saw her friends opinion of the personality traits of chemists as "nerdy, boring, kind of absorbed in the subject of chemistry, not very sociable, that type of thing."

Most of the participants felt their friends would see chemists to be rather insular about chemistry, believing that chemists would not consider the effect of their chemistry research on people, either because they would get carried away with their work and not think of their consequences or, because they would not consider the effect of their results to be their responsibility. Robert summarised his friends' view of chemists considering the effects of their research:

> Not until they've found something out, then they think about it, but when you are researching in chemistry you don't even know what you are going to be doing. You don't know what you are going to find out, let alone think of people and what it's going to do to them.

Some of the chemistry majors thought that their friends would appreciate the positive impacts chemistry might have, for example, in medicine or in environmental chemistry. For example, Kevin thought his friends would think that chemists consider the effect on humans when designing their research because "there always seems to be lots of safety things put in place, like by the government. I think they would probably have to consider what's happening in order to do research, and since they do research that's supposed to be helping people, like new drugs. Then I think [they would think] chemists do consider people."

Few of the interview participants could give specific illustrations of when their friends would judge chemists as not taking into account the effect on people. Rather, most of the examples cited related to the biological sciences, and the interview participants often cited issues like genetic engineering. Grace, for example said: "I suppose [they would think] it depends on what the research is. Like for some things it would be like oh my God they're testing this on animals." Hence the participants' perceived their peers' as being generally negative about the extent to which chemists consider the effect on people when they design their research.

7.3.2 Perceptions of Parental Beliefs About Chemistry

The interview participants felt that their parents, like their peers, would identify chemists and chemistry with working in a laboratory environment, using chemicals in test tubes, and wearing white coats. Karen, a non-major, thought that her parents "would think of test tubes and doing reactions and chemicals and things like that." Confusion between chemistry and pharmacy again surfaced, although the interview participants felt their parents would have a more comprehensive view of the range of occupations open to chemists. Specific occupations mentioned included industrial chemistry, medical research and fieldwork, along with lecturing and research. Alan commented that his parents' views would be more informed than his peers: "A lot more broader than that. You know chemists are involved in a lot of areas through production, pharmaceutical science, or wine making."

The students thought that their parents also would perceive chemists to be intelligent, with chemistry majors in particular, thinking that their parents would see chemists as hard-working. Leanne, a biochemistry major, said her parents "would probably think of one as being quite intellectual and not all that in touch with reality." Some of the interview participants thought their parents believed chemists to be serious people and again highly unsociable. Eleanor said: "They would say chemists would be hard-working, with no social life. Somebody who is independent, and someone who can go out there and find out about something." A few interview participants thought their parents would see chemists as normal people. Patrick, for example, thought his parents were "pretty realistic I expect. They would think chemists are just normal people who do normal things and just have a different job from everybody else."

The interview participants felt their parents would have had more experience about the effect chemistry has, on society. This led the student to think that their parents would have a broader view as to what influence – good and bad – could exert on society. Celia believed her parents would know more about the effect chemistry has on people based on "the fact that they've had lots of interaction with chemists, so they know a lot more about what they [i.e., chemists] do than we do." Some of the interview participants thought that their parents would perceive considering the effects of chemistry research as the responsibility of the people who put the research into practice, rather than the chemistry researchers themselves. Patrick comments:

> The perception that chemists sort of given an assignment and work towards a goal of the most efficient things. [chemists would think] I'm not sure how this product is going to be used, I'm not sure how this product is going to effect people, that's much more of engineer thing, and what the engineer does with that product.

However, the bulk of the interview participants thought that their parents would think that chemists do consider the effect of chemistry on people, mainly because the parents had observed some of the positive outcomes of chemistry research. Kevin, a chemistry major, thought his mother would "know about a lot of things that are put in place in research, all the drugs and stuff that's the main thing I can think of. So I think she would think that they do consider the effects."

7.3.3 Perceptions of Mentor Beliefs About Chemistry

The interview participants felt that their mentors would have similar attitude-towards-chemistry and chemists as their parents, but also felt that the mentors would likely be more tolerant. Not all participants identified a mentor, of those that did; the majority identified a person involved in science. So, some interview participants had chemistry teachers as mentors, whilst others, considered relatives or friends who worked in a science-related field, including engineering, and veterinary science, to be mentors. Kevin, a first-year chemistry student, an avowed pyrotechnics enthusiast, identified his mentor as "my uncle. After my father died, my uncle who was also a chemist taught me quite a few of the fireworksy things." Other participants had more unusual mentors, with inventors from history and "the Bible," all seen as mentors, in that they influenced the students' behaviour. Nathan, a student enrolled in a Bachelor of Technology degree saw a mentor differently to most of the participants:

> I don't know, I sort of try of learn from everyone, I mean I look at the Bible and it has a lot of scientific foundations in it, and the fact that it is basically a complete code in Hebrew from the start to the end, it's quite amazing seeing how our computers haven't yet been powerful enough to break it properly. So things like that stoke me out, and I can get stoked out about something else that someone is teaching me whoever it is whether it is a little child or the oldest of oldies.

As with their parents, the interview participants thought that their mentors would think of chemistry in terms of the tasks involved in chemistry, especially laboratory work and experiments. Kerrie thought her mentor (a chemistry graduate) would "see what he does in the labs and working on experiments. He just sees himself in his own lab working with his colleagues"

The interview participants felt their mentors had a good understanding of the variety of occupations available to chemists including environmental, synthetic and industrial chemistry - as well as research and lecturing. Patrick, a engineering major whose mentor was a science teacher, thought his mentor would think a chemistry job would involve "a bit of work in the laboratory of course, but also researching and a bit more out in the factory, a broader view [than my parents or peers]. For example, carbon dating, electrolysis, that sort of thing."

The interview participants though that their mentors would see the personality traits of chemists in positive terms, unlike their peers and parents - probably a reflection of scientific background of almost all of the participants' mentors. Descriptors used by the interview participants included "passionate," "social," "adventurous," and "intellectual." Kerrie - a chemistry major – thought that her mentor:

> Probably thinks of his own personality traits and the people around him. I would say that a chemist wouldn't be boring, unsociable, that [he or she] would be adventurous kind of. They don't mind taking risks, well he doesn't mind taking risk. I would say sociable rather than unsociable, and still, always wanting to get things right and that though.

In addition, some of the interview participants thought their mentors would see chemists to be hard-working. Robert, believed his mentor would think chemists are "pretty hard working," because "he is."

Because most of the student's mentors came from a science-related background, the interview participants thought their mentors thought chemists would consider the effect of chemistry on people. The mentors also would believe this is a trait common for all scientists. Eleanor, a marine science major (whose mentor was a chemistry teacher), commented: "He's also a farmer so whatever he does as chemistry obviously has an effect on land. So as he works on the land he must, he must consider what he's doing."

7.3.4 Perceptions of the Media Portrayal of Chemistry

The interviews showed that the participants believed many of the stereotypes about chemistry were based on media portrayals. In the minds of the interview participants, chemistry occupations are portrayed in terms of chemistry images such as "working in a lab," "wearing white coats," and "using chemicals." Alan, a biochemist, believed "you don't really see that much about scientists on TV. Normally when the media does portray it, it's the same scenario. It's a person in a white coat, working in a laboratory doing some form of research." The stereotypical images of bubbling samples and test tubes were also identified as images used by the media to portray chemistry. Eleanor, a chemistry student comments: "Well you rarely find a chemist on TV. Usually they have a lab coat there's a few test tubes in the background under a Bunsen burner boiling things like that." Many of the interview participants saw the portrayal of medical research and environmental issues as a way in which chemistry features. Kevin, a chemistry major, stated "the main way chemists are portrayed is media as developing [medicinal] drugs."

The interview participants felt that the "geek" stereotype as well as the perception that chemists are intelligent was media based. Celia believed the media portrayed chemists as "geeks [laughs]. They look intellectual, but they still look like the high school geek that everyone picks on." Most of the participants also saw the media as portraying chemists as boring, unsociable people. Leanne, a biochemist, concluded "[Chemists] from movies and things are boring. They spend all day in the laboratory. [The type of] person who doesn't have any other life."

The interview participants were on the whole were disparaging about the media portrayal of science, believing that the media only produces a one-sided argument, that which makes for a sensational story. To this end, they suggested the media portrayal of the values of chemists depended on which view would give the best story. Leanne, a biochemist major, judged "the media would prefer to think that chemists don't [consider people] as this gives them a better story line to go with the controversial kind of things." Chemistry majors felt the media portrayed chemists as focussed on their results, with little regard for what impact their profession might have on society. Kerrie, a chemistry major, formed the impression that the media "thinks that chemists want to get the right result and do things and so they achieve the right results and don't really consider the things around them." The participants identified a number of negative images that they felt the media attributed to chemistry; including nuclear disasters, chemical spills, inappropriate use of insecticides, side-effects of drugs, and biological sciences issues such as genetic engineering and human cloning. Leanne felt that media would automatically associate chemistry with negative images or issues: "Nuclear power, how you always hear the bad things, but never the good things. I mean I don't know much about that, but you never hear anything good, and there probably is." The participants thought that the media did portray chemist in a positive aspect occasionally. Robert, a chemistry major, said: "The last time I heard about was the chemists that came up with conducting plastics. They don't get reported about unless they do something good, like get a Nobel prize."

However, this maybe due to the extensive media coverage at the time, of one of the winners of the 2000 Nobel Prize for chemistry, Alan McDiarmid, who was a New Zealander.

7.3.5 Subjective Norm

E_7: Explore student subjective norm

The participants felt their peers for the most part were supportive of their career and educational choices. Laurence (doing a resources and environmental planning programme) felt that "whatever I want to do is fine with them [his friends]." Others, likewise, thought their friends did not really care what courses they took. Samantha, a chemistry and law double-major found her friends supportive of her chemistry study: "They don't really worry about what I study." Others felt their friends did not understand why they would want to take chemistry, because they did not like it themselves, or that they found it hard. Leanne, a biochemistry student, comments:

> Some of my friends don't like chemistry and don't understand it. I don't think they object to me studying it, however, they do make it known that they think it's a waste of time. But that's not saying or telling me that I'm stupid, it's just that they wouldn't do it

Several of the interview participants said their friends were also enrolled in chemistry courses, and number of participants were encouraged to take chemistry by their peers. Grace (doing first-year chemistry as part of a university bridging course) concluded her friends thought she should take chemistry because "I've got a few friends who are studying chemistry and biology."

The vast majority of the participants felt that their parents were supportive in their educational choices generally, whatever they chose to study. Jack, for example (an engineering student), said his parents "have been really supportive in this sort of thing. They've never pushed me into anything I don't want to do. They've just sort of let me go." Some of the interview participants thought that their parents were happy just as long they were studying something. Gary, a chemistry major, said "I don't think my family really minds, as long as I'm doing something. It's better than being a bum, and not doing anything at all." A few parents encouraged the participants to do chemistry because they felt chemistry was a good skill to have, or because they thought their child was good at it. Karen, an animal behaviour student, summarised her parents attitude as: "My mum and dad wanted me to [take chemistry] because they know I'm good at it."

The fact that a large number of interview participants' mentors came from a chemistry or science background was reflected in the participants' normative beliefs about mentors. Most of the interview participants said that their mentors believed they should take chemistry, because the mentors were themselves were chemists or scientists. Robert, a chemistry major whose mentor was a chemistry teacher, said he believed his mentor would think he should study chemistry "because he's a chemistry guy, so he wouldn't say no to it. I would assume he would want me to take it." Others indicated their mentors, like their parents, were supportive in whatever they did. Celia thought her mentor "would understand [why I don't want to take further chemistry courses], he always knew that chemistry wasn't really my thing anyway."

7.3.6 The Relationship Between Associates Beliefs and Subjective Norm

> H_{22}: There is a relationship between student perceptions of associates attitude-towards-chemistry and subjective norm

Despite the plethora of attitudes that the students believe their associates hold, there is little evidence to suggest a direct relationship between students' perceptions of their associates' attitude-towards-chemistry and students' normative beliefs. This is due to the nature of the students' normative beliefs. That is, as students' predominantly felt their associates were supportive of their choices, independent of what those choices were. Consequently, it appears that the perception of support is more salient in determining normative beliefs than any negative or positive attitude-towards-chemistry.

7.3.7 Summary

A summary of the findings from this section is presented in Table 7.5. The findings suggest that the students' mentors have the most positive attitude-towards-chemistry and their peers the least positive. Furthermore the students were scathing about the media portrayal of chemistry. Almost all associates were supportive of the students' enrolment choices, and there was little relationship between the students' perceptions of associates' attitude-towards-chemistry and their normative beliefs.

7.4 Chapter Review

The chapter examined the beliefs students had about studying both first and second-year level chemistry. The findings suggest that these students' hold a variety of beliefs about studying chemistry at university level, many of which are attitudinal. For example, some students believe first-year chemistry study will be a good background to other sciences. Similarly, others think it is important to study a range of science subjects at first-year level. Other students thought that continuing on in a subject is important, mentioning they would consider studying chemistry at first and second-year level because they studied chemistry at secondary school. Learning experiences had two major influences, first some students mentioned secondary school experiences that led them to first-year chemistry. Second, first-year chemistry experiences in some cases resulted in negative beliefs about enrolling in chemistry. That is, some students disliked aspects of first-year chemistry, particularly the practical classes, resulting in them reconsidering as to whether they would study chemistry at second-year level. Other attitudinal beliefs about studying chemistry, both at the first and second year level include factors pertaining to student attitude-towards chemistry. For example, some students indicated leisure interest in chemistry, and others an interest in how chemistry applied to the nature of the world. These interests were more often held by male interview participants. Students also held attitudinal beliefs about studying chemistry at second-year level that were related to their chemistry self-efficacy beliefs. Students specifically mentioned achievement in assessment as a belief contributing to their decisions. However, a number of

Table 7.5

Summary of findings from data on student perceptions of their associates' attitude-towards-chemistry and subjective norm.

Student perceptions of associates' attitude-towards-chemistry		
Peers	–	Profession: Images in laboratories, explosives, pyrotechnics, with research and teaching specific professions mentioned
	–	People: Intelligent people, mad scientists and nerds
	–	Values: Insular with work, get carried away with their research, medicine, and environmental chemistry
Parents	–	Profession: Again laboratory images, with some mention of pharmacy, industrial chemistry and research
	–	People: intelligent, hard-working, serious
	–	Values: broader understanding as seen positive impacts of chemistry on society, believe responsibility is that of those that put chemistry into practice rather than the scientists
Mentors	–	Mentors are typically in science industries, although some more unusual such as the bible and historical inventors
	–	Profession: more informed, environmental, industrial
	–	People: positive terms including intelligent and hardworking
	–	Values: Would consider the effects of their research on people
Media	–	Profession: images of laboratories, medical research, environmental research
	–	People: geeks and intellectuals
	–	Values: Sensationalised, results orientated, negative images.
Student subjective norm		
Peers	–	Generally supportive of what ever student chooses to do
	–	Some question why student would want to study chemistry
	–	Other encourage student to study chemistry as they are also studying chemistry
Parents	–	Supportive of what student chooses to do
	–	Some encourage to study chemistry as they believe the student is good at it
Mentors	–	Encourage student to study chemistry
Relationship between perceptions of associates' attitude-towards-chemistry and subjective norm		
	–	Very little

students also believed that chemistry study was only going to become more difficult at second-year level.

Students also held some control beliefs about studying chemistry at tertiary level – related to the compulsory nature of chemistry in some degree programmes. Surprisingly, there were no statistically significant differences (that also exhibited a sufficient effect size) between those students who chose to study chemistry and those for whom it was compulsory, for any of the subscales of the CAEQ in any administration of the instrument. Some of the students for whom first-year and, in some cases, second-year chemistry were compulsory, noted they were interested in studying chemistry insofar as it related to their degree. Others did not wish to study chemistry at all.

The students held a variety of beliefs about what their associates thought of chemistry. However, their were no statistically significant differences observed between those students who had associates in a science field and those that did not for any of the subscales in all three administrations of the CAEQ. The interview participants were questioned on their perception of their parents, peers and mentors beliefs about chemistry, and on the media portrayal of chemistry. The students saw their peers as considering science in terms of occupations, rather than professions, such as, for example, forensic scientists. They also thought that their peers would subscribe to a number of stereotypes including 'mad scientist' and intelligent - or in a more negative terminology 'nerd'. The students also though their peers would think that chemists would get carried away with their work and not think of the consequences, although a number also mentioned their friends would know examples where chemistry had contributed positively to society. The students perceived their parents would be more informed than their peers and named a number of professions that they thought their parents would associate with chemists, although there was some confusion with pharmacy. They also framed their responses in a more positive terminology stating their parents would think chemists were intelligent and serious, rather than 'geeks'. They thought their parents would have a good conception of how chemistry influenced society, both in terms of positive and negative events. The students perceived their mentors, many of whom were involved in a science related occupation, as having similar views to their parents. That is, they saw their mentors as perceiving chemistry positions in terms of occupation such as laboratory work, but also in terms of position titles including researching and production line work. . Again they perceived their mentors' views to be less reliant on stereotype than their peers or parents. In fact, they often thought their mentors would describe chemists in a very positive frame, and would consider society when carrying out research. The students typically believed the media resorted to stereotypes when portraying chemistry, although noted that chemistry was discussed in terms of medical and environmental issues. They thought the media used the 'geek' stereotype to present chemists, and believed that the media portrayed chemistry, and all other issues, in terms of the most sensational story-line. In fact, the students named a number of negative images that the media associated with chemists.

Generally the students felt their associates were supportive of their educational choices, independent of what they were. Some thought their friends would encourage them to take chemistry as they themselves were studying it, whilst others thought their friends did not understand why they would want to take it. Generally, the students perceived their parents to be more supportive of their choices, especially if they thought they had ability in it. There was a perception that their parents would be happy with what they chose to do, as long as they chose to do something academic. Similarly, the students thought their mentors would be supportive of the choices, and, as many of their mentors were involved in a science field, the students believed they would encourage them to study chemistry.

The findings for attitude-towards-enrolling in second-year chemistry, perceived behavioural control and subjective norm are discussed in Chapter 9, Section 9.2, p. 260.

7.5 Chapter Summary

This chapter presented the results about antecedents of student enrolment intentions; namely, attitude-towards-enrolling in chemistry, control beliefs about enrolling in chemistry, and normative beliefs about enrolling in chemistry. The next chapter focuses on actual student enrolment choices. It discusses how chemistry learning experiences, attitude-towards-chemistry and chemistry self-efficacy correlate with enrolment choice. Additionally, the strength of each the antecedents describe above influences on enrolment choice are discussed.

CHAPTER 8
RESEARCH FINDINGS: THE INFLUENCE OF ATTITUDE-TOWARDS-ENROLLING IN SECOND-YEAR CHEMISTRY, PERCEIVED CONTROL OVER ENROLLING IN SECOND-YEAR CHEMISTRY AND SUBJECTIVE NORM ON ENROLMENT INTENTIONS

This chapter follows on from Chapters 6 and 7 and presents the research findings for research question five, namely:

5. What influence, if any, does student attitude-towards-enrolling in second-year chemistry, perceived control over enrolling in second-year chemistry, and subjective norm, have on intentions to enrol in second-year chemistry?
   i. What are student intentions to enrol in second-year chemistry?
   ii. What influence, if any, does student attitude-towards-enrolling in second-year chemistry have on intentions to enrol in second-year chemistry?
   iii. What influence, if any, does student perceived control over enrolling in second-year chemistry have on intentions to enrol in second-year chemistry?
   iv. What influence, if any, does student subjective norm, have on intentions to enrol in second-year chemistry?

The research findings presented here are based on based on both quantitative and qualitative data. The findings are related to those presented in Chapter 7. However, the findings in Chapters 7 and 8 are distinct in that the findings in Chapter 7 are concerned with identifying the beliefs that students hold about enrolling in chemistry, whereas the findings presented in this chapter are concerned with identifying the beliefs that *actually influenced* their enrolment intentions.

The chapter begins with the findings for student enrolment intentions followed by the influence of learning experiences, attitude-towards-chemistry and chemistry self-efficacy - mediated through attitude-towards-enrolling in chemistry - on second-year enrolment intentions. Next a description of perceived behavioural control influences on student enrolment intentions is described, and this is followed by the influence of subjective norm on enrolment intentions.

8.1 Enrolment Intentions for Second-Year Chemistry

5.i	What are student intentions to enrol in second-year chemistry?

E_8: Explore student intentions to enrol in second year chemistry

The student's second-year chemistry enrolment intentions were examined in a number of ways. First, the first two administrations of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) included questions about student enrolment intentions; specifically, they were asked if they intended to enrol in the second semester chemistry course (i.e., *Chemical Change & Organic Compounds*). Respondents were also asked, in all three administrations of the instrument, whether or not they intended enrolling in any of the second-year chemistry courses. In addition, interview participants were questioned about their intentions to enrol in the second semester chemistry course at the start of the year and end of the first semester, and if they intended to enrol in any second-year chemistry in all three interviews. Enrolment intentions about the second semester chemistry course also were elucidated as this course is a prerequisite for all but one[11] of the second-year chemistry courses; hence if students do not enrol in this course they cannot continue on into second-year chemistry.

At the start of the year, 88.8% of the respondents who completed the CAEQ were planning on enrolling in the second semester chemistry course; however, by the end of the first semester this dropped to 78.0% (Table 8.1). Likewise, at the start of the year 78.9% of the respondents were planning on enrolling in a second-year chemistry course, and by the end of the first semester this dropped to 70.3%. By

[11] An interdisciplinary geochemistry course

Table 8.1

Second semester chemistry and second-year chemistry enrolment intentions of respondents to the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) from all three administrations of the instrument

	N	**Intending to enrol** (% of respondents who answered this question)	**Intending to not enrol** (% of respondents who answered this questions)
Second semester chemistry enrolment intentions			
Start of year	116	88.8	11.2
End of first semester	82	78.0	22.0
Second-year chemistry enrolment intentions			
Start of year	114	78.9	21.1
End of first semester	74	70.3	29.7
End of second semester	69	79.7	20.3

the end of the second semester chemistry course, the proportion of the remaining students who were planning on taking second-year chemistry was 79.7%. This suggests that students who were not planning on taking a second-year chemistry course dropped primarily at the end of the first semester. This finding is borne out when examining the data in more detail.

Of the students enrolled in the first semester chemistry course 50 answered the question about their intentions to enrol in the second semester chemistry course. The data (Figure 8.1) suggests that some students who had intended to enrol in the second semester chemistry course at the start of the year, changed their mind at the end of the first semester (12% of all respondents). These students will have dropped the second semester chemistry course instead taking other second semester courses, such as, for example, environmental science. However, none of the respondents that indicated at the start of the year that they were not going to enrol in the second semester had changed their intentions by the end of the first semester. Thus it seems that whilst students drop the second semester course, there is not a corresponding cohort of students who pick up the course.

This trend is repeated in the data on second-year chemistry enrolment intentions (Figure 8.2). By examining the enrolment intentions of the 34 respondents who supplied data on their enrolment intentions in all three administrations of the CAEQ, it is observed that at the start of the year 85% (29) of the students

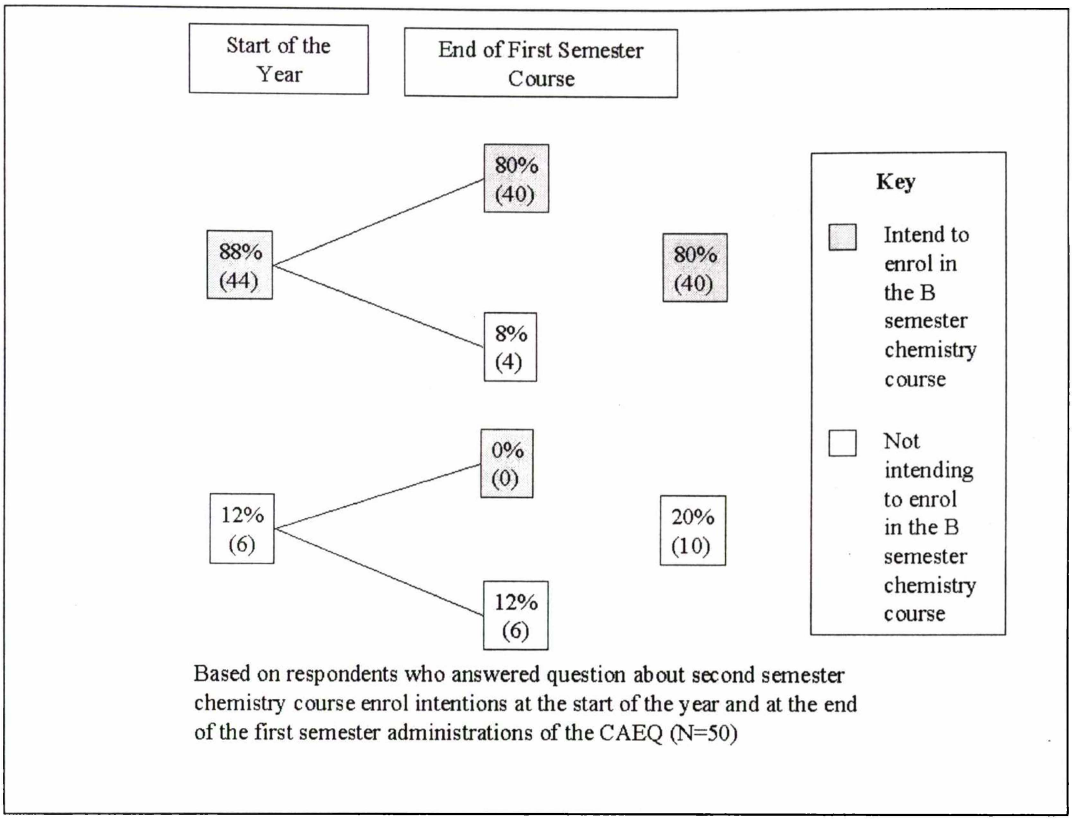

Figure 8.1

Intention to enrol in the second semester chemistry course for students who answered the enrolment intentions questions in the start of the year and end of the first semester administration of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ).

enrolled in the first semester course were intending to enrol in a second-year chemistry course. However, by the end of the semester only 68% (23) of the respondents were intending to enrol in a second-year course. This is because 18% (6) of the respondents dropped the second semester course at this stage. Furthermore another 6% (2) of all respondents decide not to take a second-year chemistry course at the end of the second semester. Overall, this suggests that over a quarter of the students who intend to enrol in second-year chemistry at the start of the year change their mind at some stage of their first-year studies. Again none of the students that did not intend to enrol in a second-year chemistry course at the start of the year, changed their mind at any stage of the first-year chemistry courses.

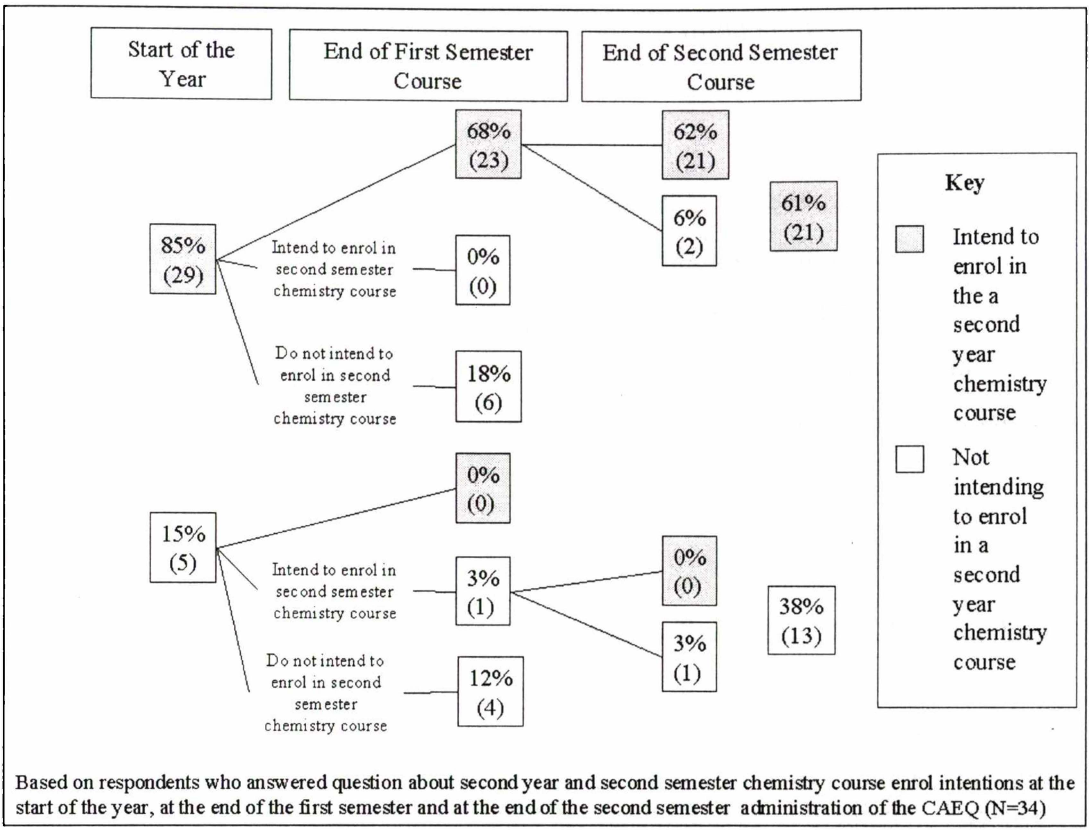

Figure 8.2

Intention to enrol in a second-year chemistry course for students who answered the enrolment intentions questions in the start of the year, the end of the first semester and end of the second semester administration of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ).

The qualitative data supports the quantitative findings reported above. Of the 14 participants that did not drop out of the study, 12 planned to enrol in the second semester chemistry course at the start of the year. However, at the end of the first semester course, only eight of the interview participants were planning on enrolling in the second semester course, with one, Felix, considering on enrolling in it in the subsequent academic year. That is, three of the participants, Leanne, Kevin and Laurence, all dropped chemistry at this stage, with Leanne dropping out of university study entirely. The one participant, Karen, who stated at the start of the year that she was not going to enrol in the second semester course, had not changed her mind by the end of the first semester. Of the remaining nine interview participants, all of whom at the start of the year and the end of the first semester intended to enrol in a second-year chemistry course, eight stated at the end of the second semester that they did still intend to enrol in second-year chemistry. Only, one student, Jack had changed his mind at this stage.

8.1.1 Summary

Therefore these data suggest that whilst some students change their intentions and fail to enrol in either the second semester or a second-year chemistry course, there is not a corresponding group of students who pick up either option at any stage (Table 8.2). Furthermore, most students appear to change their minds at the end of the first semester course, suggesting that this is the crucial stage in students' decision making.

8.2 The Influence of Attitude-Towards-Enrolling in Second-Year Chemistry on Enrolment Intentions

> 5.ii What influence, if any, does student attitude-towards-enrolling in second-year chemistry have on intentions to enrol in second-year chemistry?

> H_{23}: There is a relationship between student attitude-towards-enrolling in second-year chemistry and intentions to enrol in second-year chemistry

The estimated mean responses for all subscales of the CAEQ of those students intending to enrol and intending to not enrol in second semester and second-year chemistry were examined for all three administrations of the instrument. Data analyses were carried out using ANOVA and by examination of effect size (i.e., η^2 data). Some caution is needed in interpreting these data as in a number of cases there were less than 30 respondents indicating that they did not intend to enrol in either the second semester chemistry course or a second-year chemistry course. Hence, the extent to which these results can be generalised to the whole population is limited.

8.2.1 Learning Experiences

At the end of the first semester the respondents were asked about their intentions to enrol in both the second semester chemistry course and a second-year

Table 8.2

Summary of findings from data on students' enrolment intentions.

Intention to enrol in the second-semester course	
Survey findings	– Around one fifth of students drop chemistry after the first-semester course, half of whom were originally planning on taking it at the start of the year – Two thirds of the students were not planning on taking a second-year chemistry course by the end of the second semester, compared to over 80% at the start of the year. Most students changed their minds at the end of the first semester
Interview findings	– Five of the 14 interview participants dropped chemistry after the first semester – three of whom were planning on doing the second semester course at the start of the year – Only one of the remaining interview participants changed their minds about studying chemistry at second-year level after the second semester course.

chemistry course. Interestingly, it seems that there is no statistically significant correlation between enrolment intentions and learning experiences.

8.2.2 Attitude-Towards-Chemistry

Comparison of the estimate mean responses for the *attitude-towards-chemistry* subscales by ANOVA and effect size analysis reveal no statistically significant differences between students intending to enrol and not intending to enrol in the second semester chemistry course at the start of the year or at the end of the first semester.

There are however, statistically significant differences in the estimated mean responses for respondents intending to enrol and intending not to enrol in a second-year chemistry course for some of the subscales (Table 8.3). For example, at the start of the year there are statistically significant differences ($p<0.05$) for all *attitude-towards-chemistry* subscales, other than *leisure interest in chemistry*. In addition, there were statistically significant differences ($p<0.05$), for the two cohorts of students for the *attitude-towards-chemists*, *required skills of chemists* and *attitude-towards-chemistry in society* subscales at the end of the first semester and for the *attitude-towards-chemists*, *leisure interest in chemistry* and *career interest in chemistry* subscales at the end of the second semester. However, the η^2 values suggest that effect size is small for all but the *career*

Table 8.3

Differences in the estimated mean responses to the *attitude-towards-chemistry* subscales of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents who intended to enrol and intended not to enrol in a second year chemistry course.

Subscale	**Intending to enrol in a second-year chemistry course**		**Not intending to enrol in a second-year chemistry course**		**ANOVA and effect size**		
	Mean	Std. Dev.	Mean	Std. Dev.	F	p	η^2
Start of the year							
N	89		21				
Attitude-towards-chemists	4.67	0.87	4.17	1.08	4.93	0.03*	0.04
Required skills of chemists	5.20	0.87	4.76	0.74	4.66	0.03*	0.04
Attitude-towards-chemistry in society	5.74	0.86	5.25	0.86	5.48	0.02*	0.05
Leisure interest in chemistry	4.32	1.40	4.15	1.21	0.28	0.60	0.00
Career interest in chemistry	5.11	0.86	4.31	0.96	13.99	0.00*	0.11
End of the first semester							
N	53		22				
Attitude-towards-chemists	4.67	0.82	4.15	1.00	5.32	0.02*	0.07
Required skills of chemists	5.11	1.10	4.54	0.72	5.11	0.03*	0.07
Attitude-towards-chemistry in society	5.78	0.97	5.28	0.95	4.17	0.04*	0.05
Leisure interest in chemistry	4.19	1.29	3.91	1.58	0.64	0.43	0.01
Career interest in chemistry	5.14	0.93	4.67	1.13	3.46	0.07	0.05
End of the second semester							
N	55		14				
Attitude-towards-chemists	4.79	0.95	4.19	0.99	4.32	0.04*	0.06
Required skills of chemists	5.03	0.96	4.51	0.82	3.36	0.07	0.05
Attitude-towards-chemistry in society	5.60	0.99	5.25	0.97	1.44	0.23	0.02
Leisure interest in chemistry	4.28	1.29	3.48	1.17	4.40	0.04*	0.06
Career interest in chemistry	4.97	1.02	4.14	0.97	7.52	0.01*	0.10

interest in chemistry subscale at the start of the year and the end of the second semester. This is borne out by examination of graphical representations of the data (Figure 8.3 & 8.4). In both instances there are clearly more cases from students intending to enrol with an estimated mean greater than 4.00 for the *career interest in chemistry* subscale.

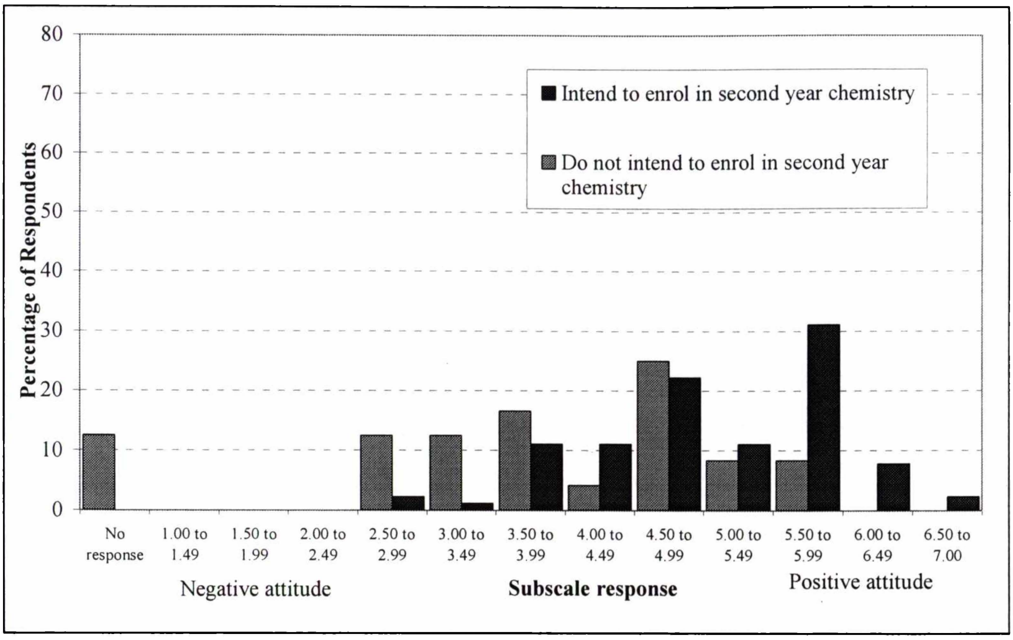

Figure 8.3

Graphical representation of the *career interest in chemistry* subscale of *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents who intend to enrol (n=90) in a second year course and those students who intend not to enrol (n=24) in a second-year course - start of the year.

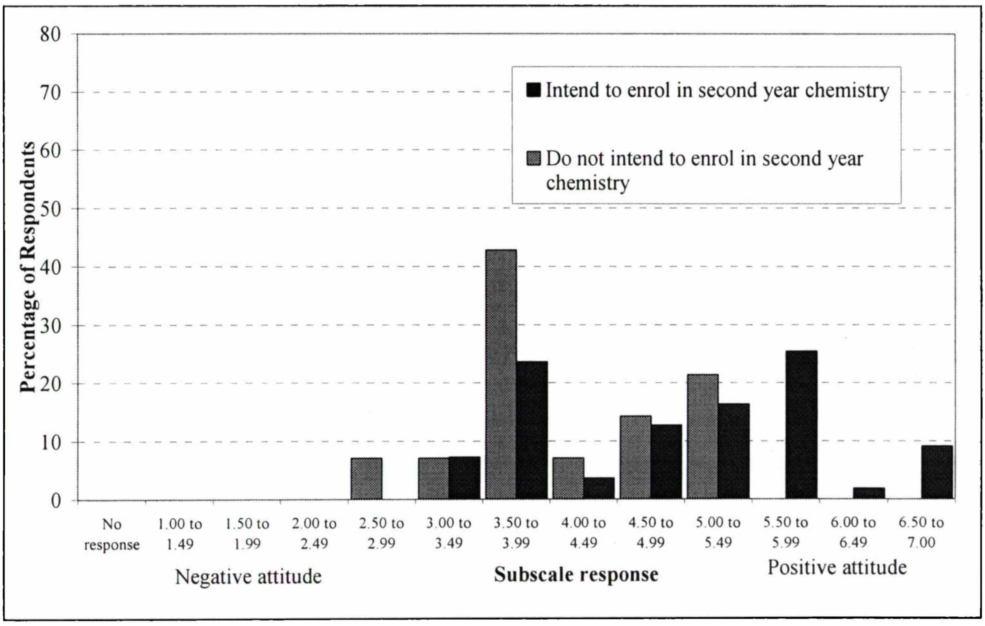

Figure 8.4

Graphical representation of the *career interest in chemistry* subscale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ for those students intend to enrol (n=55) in a second-year course and those students who intend not to enrol (n=14) in a second-year course - end of the second semester.

8.2.3 Chemistry Self-efficacy

Investigation of the data using ANOVA for the *chemistry self-efficacy* scale shows no statistically significant difference in the estimated mean responses between those students intending to enrol in the second semester chemistry course and those that do not at the start of the year (Table 8.4). A statistically significant difference ($p<0.05$) was observed in the estimated mean responses to the *chemistry self-efficacy* scale between respondents intending to enrol and not intending to enrol in the second semester chemistry was observed at the end of the first semester. The η^2 value of less than 0.10 suggests that the effect size, however, is small.

There were statistically significant differences in *chemistry self-efficacy* between respondents intending to enrol and not intending to enrol in a second-year chemistry course in all three administrations ($p<0.05$) (Table 8.5). The η^2 analysis suggests that a real effect size is observed for only the end of the first semester administration only ($\eta^2 = 0.17$). However, the replication of this statistically significant difference suggest that self-efficacy may influence students enrolment intentions.

Examination of graphical representations of data spread suggests that students intending to enrol in second-year chemistry at the end of the first semester are more likely to be very confident about chemistry tasks compared with those that do not intend to enrol in chemistry (Figure 8.5). That is, 48% of those students intending to enrol in second year chemistry have a subscale response greater than 5.00 compared to only 7% of those students not intending to enrol in second year chemistry.

The qualitative data support the quantitative findings from the CAEQ. At the start of the year students were asked what was the major influence on their decision to enrol in first-year chemistry. This question was repeated for the other two interviews (i.e., at the end of first semester and at the end of the year) but in these latter interviews they were asked about their enrolment intentions for the second semester and second-year chemistry courses. The research findings

Table 8.4

Differences in the estimated mean responses to the *chemistry self-efficacy* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents who intended to enrol (start of the year n=89, end of first semester n=53) and intended *not* to enrol (start of the year n=21, end of first semester n=22) in the second semester chemistry course.

Subscale	**Intending to enrol in the second semester chemistry course**		**Not intending to enrol in the second semester chemistry course**		**ANOVA and effect size**		
	Mean	Std. Dev.	Mean	Std. Dev.	F	p	η^2
Start of the year	4.39	0.88	4.13	1.03	1.60	0.32	0.01
End of the first semester	4.54	0.85	4.00	1.21	4.62	0.04*	0.06

Table 8.5

Differences in the estimated mean responses to the *chemistry self-efficacy* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents who intended to enrol (start of the year n=89, end of first semester n=53, end of second semester n=55) and intended not to enrol (start of the year n=21, end of first semester n=22, end of second semester n=14) in a second year chemistry course.

Subscale	**Intending to enrol in the second semester chemistry course**		**Not intending to enrol in the second semester chemistry course**		**ANOVA and effect size**		
	Mean	Std.Dev	Mean	Std.Dev	F	p	η^2
Start of the year	4.47	0.87	3.99	0.82	5.98	0.02	0.05
End of the first semester	4.73	0.74	3.92	1.06	14.33	0.00	0.17
End of the second semester	4.82	0.90	3.94	1.91	6.23	0.02	0.09

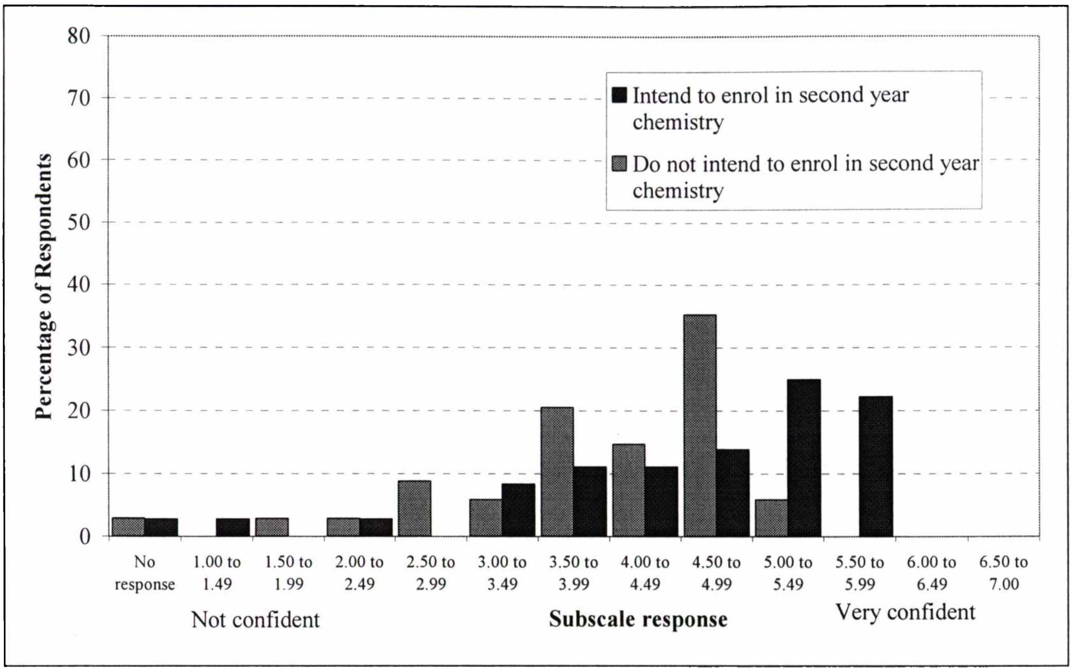

Figure 8.5

Graphical representation of the *chemistry self-efficacy* scale of *Chemistry Attitudes and Experiences Questionnaire* (CAEQ). for those respondent who intend to enrol (n=53) in a second year course and those respondents who intend not to enrol (n=22) in a second-year course - end of the first semester.

presented in Chapter 7 (p. 200) looked at what factors exert *some* influence on students' enrolment intentions throughout the year; here these findings are brought together in order to identify major influential factors with respect to students' attitude-towards-enrolling in second-year chemistry, and how these factors *actually* influenced their decision to enrol.

The interviews revealed diverse reasons for choosing to study or not to study second-year chemistry. Although first-year learning experiences were not in general influential, for two participants, Kevin and Lawrence, first-year chemistry learning experiences led them to decide against enrolling in the second semester chemistry course, and this alone precluded them from studying second-year chemistry. Both students intended to enrol in the second semester course at the start of the year, and Kevin was intending to complete a major in chemistry.

Lawrence was initially interested in continuing on in chemistry because he found it interesting.

> *Lawrence*: Probably because it's all right to do, it has got some interesting things about it.
> *Interviewer*: What is it about chemistry that you think is interesting?
> *Lawrence*: Probably the fact that chemistry is the basis of a lot of other sciences, it helps you understand other sciences, the knowledge of chemistry.

At the start of the year, Kevin was interested in a particular field of chemistry.

> *Kevin*: I've always like fireworks, pyrotechnics, that sort of things, that's part of chemistry [I like] and my father was a chemist. [I would] also like to learn better formulas to make all different fireworks and that's pretty much why I took it, and it's my preferred subject, along with computer science.

By the end of the first semester Lawrence had changed his mind: "I've kind of gone off it a bit I suppose just that we haven't done anything new, we have just done the same things for the last few years and it's kind of got a bit boring," and Kevin gave up chemistry entirely: "I just don't like the lab work, I enjoy the lectures I like all the material in them, but I don't like the actually having to do three hours lab each week." Interestingly, both of these students came from atypical entrance backgrounds with Kevin intending to do a double major in chemistry and computing, and Lawrence a degree in *Resources and Environmental Planning* (REP), a multi-disciplinary programme more popular with students with a background in the social sciences.

It seems that attitude-towards-chemistry has little influence on students' second-year enrolment intentions. Although some of the students indicated leisure interest in chemistry as a reason for studying chemistry at the start of the year, the reasons for studying chemistry at the end of the second semester were related to interest in chemistry per se and, particularly, in studying chemistry at the tertiary level. By far the most common reason given for studying second-year chemistry was an interest in the subject. Typically these students had decided to become chemistry majors whilst they were at high school, as is exemplified in Robert's comments at the start of the year.

Robert: I enjoy it, that's the main factor … I just like the concepts, I think it's logical, it's kind of very easy to understand, everything about it, how can you say it, is interesting, everything's laid out, it all make sense it all goes together, and it's kind of exciting thinking about the interactions between molecules and atoms.

Whilst the intending majors were keen to continue in chemistry, at some stage most expressed some disillusionment with their chemistry learning experiences as seen in Kirsten's comments during her interview at the end of the first semester.

Kirsten: I just really enjoy chemistry
Interviewer: What did you think of the first semester course that you did [in Kirsten's case the second-year analytical chemistry course]?
Kirsten: I thought it was kind of boring.
Interviewer: What was it about it that you thought was boring?
Kirsten: I don't know, it was different to the kind of stuff we normally did when we were at school, it was more machines and how they worked. I thought the labs were fun; it was just the lectures that were boring.

However, despite a number of 'negative' experiences the students remained resolute in their decision to continue as chemistry majors. It seems these experience did not undermine the students' interest in chemistry, as Kerrie put it at the end of the second semester, "I like the subject it seems pretty interesting, I got good grades in it."

Kerrie's comments above point to another influential factor in students' enrolment intentions - chemistry self-efficacy. Chemistry self-efficacy, and its' relationship with achievement and interest appear to have a great deal of impact on students' enrolment intentions. For example, Karen, completing Waikato's animal behaviour programme, said at the start of the year that she enrolled in chemistry because "I took it [i.e., chemistry] in seventh form [i.e., Year-13] and I really liked it and I did quite well in chemistry in sixth form [Year-12] I nearly got a one[12], yeah I just like it overall." By the end of the year she was considering enrolling as for a major in chemistry because "I like chemistry, so I am just tossing up whether to do chemistry or biology." For some participants, however, a decrease in chemistry self-efficacy caused them to drop chemistry. Leanne, who dropped out of university during the first semester, suggested that she would not study chemistry again if she returned to university because "it was a while since I'd done any chemistry and thought I would be okay about doing it, but it was a bit harder than I thought."

8.2.4 Summary

The findings on the importance of attitude-towards-enrolling in second-year chemistry are presented in Table 8.6. These findings suggest that one of the most important factors that impact upon students' enrolment intentions is self-efficacy. However, attitude-towards-chemistry and chemistry learning experiences do impact upon some students' enrolment intentions.

8.3 The Influence of Perceived Behavioural Control on Enrolment Intentions

> 5.iii What influence, if any, does student perceived control over enrolling in second-year chemistry have on intentions to enrol in second-year chemistry?

> H_{24}: There is a relationship between student perceived control over enrolling in second-year chemistry and intentions to enrol in second-year chemistry

The influence of perceived behavioural control on student enrolment intentions was examined in two ways. First, the enrolment intentions of students who studied first-year chemistry as a compulsory course for other degree programmes

[12] In New Zealand Year-12 or sixth form students are graded from 1 to 9, with 1 being the highest grade achievable and 9 the lowest.

Table 8.6

Summary of findings from data on attitude-towards-enrolling in second-year chemistry as an antecedent of students' enrolment intentions.

Attitude-towards-enrolling in second-year chemistry	
Intention to enrol in the second semester chemistry course – survey findings	– No relationship between learning experiences and students' enrolment intentions – No relationship between attitude-towards-chemistry and students' intention to enrol in the second semester course – There was no statistically significant difference in chemistry self-efficacy between those students who were intending to enrol in the second semester chemistry course and those that were not at the start of the year, but there was by the end of the first semester.
Intention to enrol in a second-year chemistry course - survey findings	– No relationship between learning experiences and students' enrolment intentions – At the start of the year and the end of the first semester students who were intending to enrol in a second-year chemistry course had more a more positive attitude-towards-chemistry than those that were not intending to enrol in the second-year course for all subscales except the *leisure interest in chemistry* subscale in both administrations, and the *career interest in chemistry* subscale at the end of the first semester – Only the *leisure interest in chemistry* and *career interest in chemistry* subscales indicated a more positive attitude-towards-chemistry for students who were intending to enrol in a second-year course at the end of the second semester – Students who were planning on enrolling in a second-year chemistry course were more confident about studying chemistry in all three administrations of the CAEQ.
Interview findings	– Two of the students dropped chemistry after the first semester after negative experiences in the laboratory classes. – Some students chose to study chemistry because of an interest in the chemistry discipline – Other students chose to continue to studying chemistry because of an interest in the discipline, despite negative learning experiences – Students who perceived they were capable in chemistry wanted to go on and study it at second-year level

were compared with those students that chose to enrol in first-year chemistry. Second, the interview data were analysed looking for an understanding about student control beliefs that exerted a major the influence on their second-year enrolment intentions. The proportion of students intending to enrol in second-year chemistry was examined by determining if a given student had enrolled in first-year chemistry by choice, or as a compulsory course. Intention to enrol in the second semester course was examined graphically (Figure 8.6), and this revealed that students enrolled in the first semester chemistry as a course by choice were more likely to intend to enrol in second semester chemistry, compared with those who enrolled in first semester chemistry as a compulsory

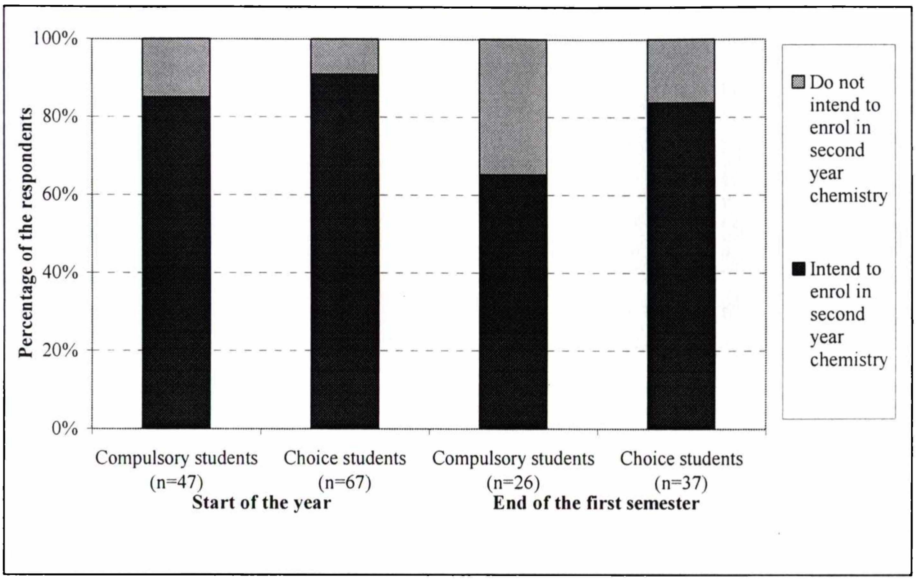

Figure 8.6

Graphical representation of those students who are studying chemistry as a compulsory course by intentions to enrol in second semester chemistry course. Based on data collected in the first two administrations of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ).

course - although this difference is not statistically significant (χ^2 = 0.964, p=0.33). After the first semester, the proportion of those intending to enrol in second-year chemistry stayed about the same for the students doing chemistry by choice, however, for those doing it as a compulsory subject, a greater proportion did not intend to enrol at this time. Again, the difference in the proportion of students intending to study the second semester course between choice and compulsory students is not statistically significant (χ^2 = 2.850, p=0.09).

A similar trend is evident at the end of the year with the proportion of those intending to enrol in second-year chemistry dropping slightly at the end of the first semester for the students doing chemistry by choice, and a larger drop seen for those doing it as a compulsory subject (Figure 8.7). The differences in proportions of students intending to enrol in a second-semester course are only statistically significant at the end of the second-semester (χ^2 = 4.036, p=0.04). Note that specified programmes in which the two first-year courses are compulsory, also have a compulsory second-year course. Hence the proportion

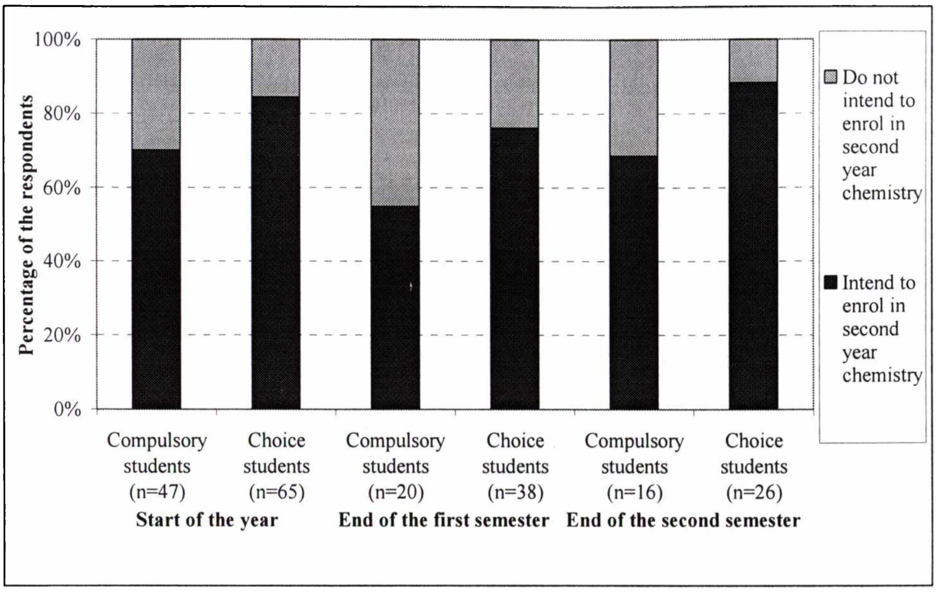

Figure 8.7

Graphical representation of the proportion of those students who are studying chemistry as a compulsory course by intentions to enrol in second-year chemistry, based on data collected in all three administrations of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ).

of compulsory students who intend at the end of the second semester to study chemistry at second-year level increases.

The interview data are consistent with the quantitative findings and data gathered focused on a question that asked students what was the major influence in their decision to enrol in a given chemistry course (first semester, second semester, second-year, depending on the timing of the interview). The engineering students are typical of students doing chemistry as a compulsory subject; these students were strongly focused on a specific educational and career path and, without exception, were studying chemistry because they had to. As pointed out in Chapter 7, they did have an interest in chemistry, but if chemistry was not specified in their highly constrained degree programme, then they would not have studied it. For example, at the start of the year Jack said: "I've just been interested in science and chemistry all my life, it's just been sort of a hobby as well for me. I've been taking science, physics, chemistry, biology, at high school," but by the end of the second semester he observed that he probably would not be studying chemistry at second-year: "I had a look at the [next years] semester timetable and I don't think there is any chemistry in there."

For one other participant, Celia, perceived behavioural control had a big impact on her enrolment intentions. Celia was enrolled in a degree programme that required her to study either first-year calculus, or first-year chemistry, neither of which she wanted to study. Her decision to study chemistry was in fact more to do with her desire to avoid studying calculus.

> *Celia*: It was a fill-in subject. I didn't really know anything about so I just took it.
>
> *Interviewer*: What made you decide to do chemistry as your fill in subject?
>
> *Celia*: I didn't want to do calculus.

At the end of the first semester she indicated that she would not study chemistry at tertiary level again: "I hate chemistry. I don't understand it, it just doesn't interest me." That is, Celia only studied first-year chemistry as it was a compulsory part of her degree. Once she was no longer required to study it, she dropped chemistry entirely. Therefore her control beliefs encouraged her to take the first semester chemistry course, but once she no longer held these beliefs, she no longer studies chemistry.

8.3.1 Summary

Some of the students had very defined career aspirations which meant that they studied chemistry solely as a means to obtaining their goals (Table 8.7). Consequently, these students would study chemistry if it was a compulsory part of their course, but in same cases would not if it was not part of their degree programme.

8.4 The Influence of Subjective Norm on Enrolment Intentions

5.iv	What influence, if any, does student subjective norm, have on intentions to enrol in second-year chemistry?

H_{25}: There is a relationship between student subjective norm and intentions to enrol in second-year chemistry

Table 8.7

Summary of findings from data on perceived control over enrolling in second-year chemistry as an antecedent of students' enrolment intentions.

Perceived control over enrolling in second-year chemistry		
Survey findings	–	No relationship between choosing to study chemistry and students' intentions to enrol in the second semester course
	–	At the end of the second semester students who chose to enrol in first-year chemistry were more likely to intend to enrol in second-year chemistry
Interview findings	–	Students who did chemistry as a compulsory element of another degree course were very focussed on career and educational aspirations and consequently would study chemistry if they thought it would help reach their desired goals. In one case this meant a student studied first-year chemistry despite having very little interest in the discipline.

The influence of subjective norm on student enrolment intentions was investigated by analysis of CAEQ and interview data. First, was a comparison of the enrolment intentions for students with associates employed in a science field to see if there were differences with students who had no such associates. Second, the interview data were examined carefully for statements indicating which normative beliefs were the major influence on student second-year enrolment intentions.

Analysis of the data from the CAEQ suggests that at the start of the year there was little difference in enrolment intentions for students with associates in a science field and those without (Figure 8.8). That is, those students with associates in a science field were equally likely to enrol in the second semester course, as those without associates in a science field. However, by the end of the first semester, the proportion of students intending to enrol in second semester chemistry course had decreased for students without science associates in a science field. However, at the end of the first-semester the difference in the proportion of students intending to enrol in the second semester chemistry course between those who had associates and those that did not was not statistically significant (χ^2 = 1.469, p=0.23). Interestingly, students with associates in a science field are consistently more likely to intend to enrol in second-year chemistry (Figure 8.9). For example, in all three administrations of the CAEQ,

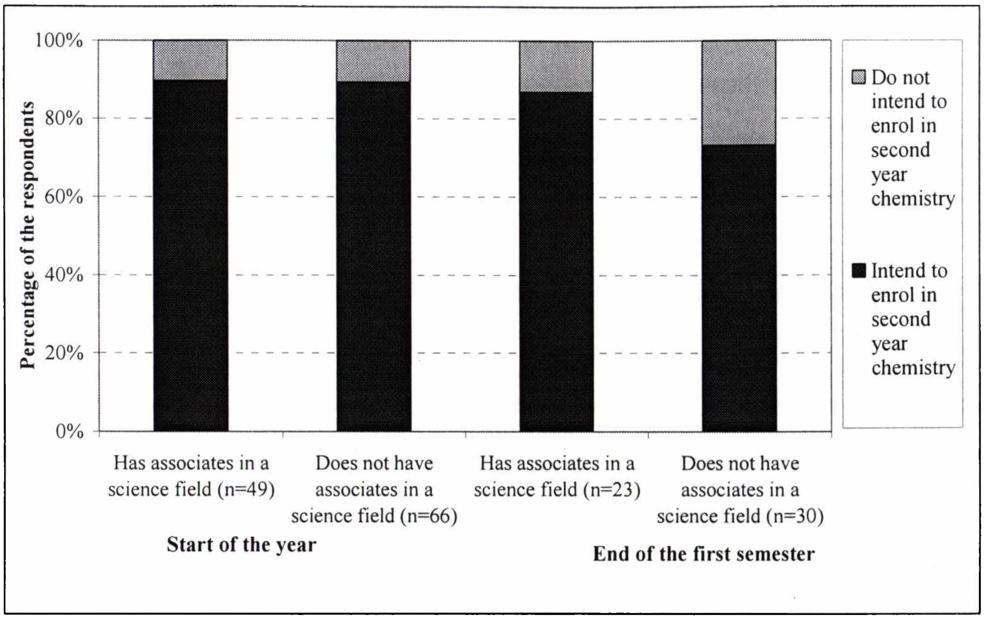

Figure 8.8

Graphical representation of the proportion of those students who have, and do not have, associates in a science field by intentions to enrol in second semester chemistry course, based on data collected in the first two administrations of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ).

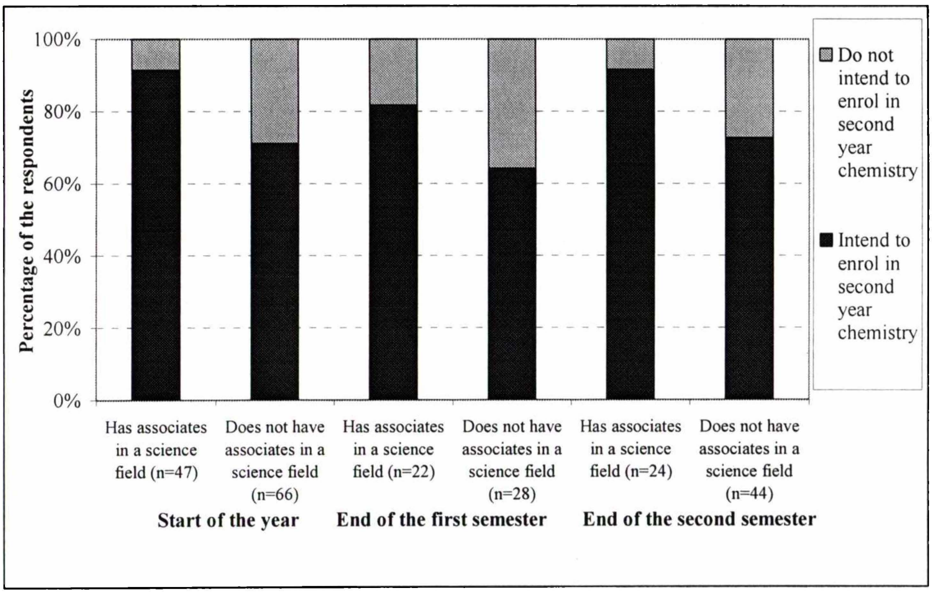

Figure 8.9

Graphical representation of the proportion of those students who have associates in a science field by intentions to enrol in second-year chemistry, based on data collected in all three administrations of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ).

those students who identified themselves as having associates in a science field were more likely to intend to study second-year chemistry. However, the proportions at the start of the year were the only that were statistically significantly different ($\chi^2 = 6.963$, p=0.01).

The interview data suggests that subjective norm had little impact on student enrolment intentions; rather attitudinal beliefs and control beliefs were salient. However, normative beliefs were influential for one student, Eleanor. At the start of the year Eleanor explained why she enrolled in chemistry: "I think anything basic is really made up of science and chemistry and biology and so by putting them both together it will give me a basis of everything really." However, by the end of the first semester she was considering enrolling in the second semester chemistry course because of her experiences with a particular chemistry staff member: ""Well I don't know if I really want to [study second semester chemistry], but I'm going to because [a chemistry staff member] told me to." Eleanor pointed out that she had decided to study chemistry rather than French (a subject she was actually more interested in) because of parental influence: "Mum and Dad would want me to take another course like chemistry if I didn't [enrol in the second semester chemistry course]. They wouldn't want me to take anything like French that would muck me around [in terms of my programme of study]. I suggested it and they said no."

8.4.1 Summary

The findings of the impact of subjective norm are presented in Table 8.8. These findings suggest whilst there is very little direct impact of subjective norm on students enrolment intentions, that less overt socialisation factors may impact on students' enrolment behaviour as students with associates in a science field were more likely to intend to study chemistry at second-year level.

8.5 Chapter Review

The research findings reported in this chapter suggest that whilst students dropped out of chemistry at some stage of their first-year of chemistry study,

Table 8.8

Summary of findings from data on subjective norm as an antecedent of students' enrolment intentions.

Subjective norm		
Survey findings	–	No relationship between choosing to study chemistry and students' intentions to enrol in the second semester course
	–	Students who had associates in a science field were consistently more likely to intend to enrol in a second-year chemistry course.
Interview findings	–	Although most interview participants did not identify subjective norm as impacting on their enrolment intentions one student chose to study chemistry based on her discussions with her parents who were funding here university study.

predominantly at the end of the first semester, students do not chose to pick up chemistry. There was no direct relationship between learning experiences and students' enrolment intentions from the data collected in the end of the first and second semester administrations of the CAEQ. However, students who chose to enrol in second year chemistry have a more positive career interest in chemistry at the end of the second semester. Additionally, there appears to be a relationship between chemistry self-efficacy and intention to enrol in second-year chemistry. The interviews revealed that students dropped out of chemistry due to negative learning experiences, particularly in laboratory classes. Students chose to enrol in second-year chemistry because of their interest in the subject, even if they did not have positive learning experiences in their first-year of tertiary level study. The findings from the interviews are consistent with the relationship between chemistry self-efficacy and enrolment intentions with students who perceived they had achieved in their first year stating this as a reason for studying at second-year level.

Students who enrolled in first-year chemistry as a compulsory part of another degree programme were less likely to enrol in both the second semester or a second year chemistry course. For these students, even if they had enjoyed chemistry, control beliefs were the major influential factors in their enrolment intentions, and they typically did not intend to enrol in second-year chemistry.

For the most part normative beliefs had little influence on enrolment intentions. However, there was a relationship between having a associate in a science field and intending to enrol in second-year chemistry. This suggests that although students do not make an overt connection between their educational interests and their associates in these fields, students choices are probably influenced by their social interactions indirectly.

The findings from this research question will be discussed in more detail in Chapter 9, Section 9.3, p. 265).

8.6 Chapter Summary

This chapter presented the results on the salient influences on students enrolment intentions It began by discussing how enrolment intentions are influenced by students attitude towards enrolling in chemistry, followed by a discussion on how students' control beliefs influenced their enrolment intentions. Finally, the influence of students' subjective norm on enrolment intentions was discussed,. The next chapter, Chapter 9, discusses the conclusions from this study and some implications of the results. Additionally, some of the limitations of the study are discussed and ideas for future work in this area are presented.

CHAPTER 9
DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

The purpose of this chapter, Chapter 9, is to discuss the research findings presented in Chapters 6 – 8 in terms of relevant literature, and to draw some conclusions from the findings. This chapter begins with a discussion of the research findings for each of the five research questions. Following on from this is a number of recommendations are made based upon the conclusions from this research. Next is a discussion on the limitations of the research, followed by some ideas for future research. This chapter ends with some concluding thoughts.

9.1 Learning Experiences and their Influence on Attitude-Towards-Chemistry and Chemistry Self-Efficacy

1	What are student first-year chemistry learning experiences, attitude-towards-chemistry and chemistry self-efficacy, how does student background influence these and what influence, if any does student first-year chemistry learning experiences have on attitude-towards-chemistry and chemistry self-efficacy?

The structure of the first-year chemistry courses at the tertiary institution involved in this study is similar to that in other universities world-wide (Fensham 1992; Zoller, 1990). Students are taught chemistry theory in lectures, with lecture material complemented by laboratory classes intended to provide students with an opportunity to gain 'hands on' experience in laboratory chemistry. Regular tutorial classes are provided and these are intended to allow students clarify lecture material and to provide a mechanism for self-evaluation by the use of problem sheets that mimic topic tests and examinations. The research findings reported here suggest that the participants see the three learning experiences to be very different in nature, and that they serve different purposes to high school learning experiences. In this section learning experiences and the influence these experiences have on student attitude-towards-chemistry and chemistry self-efficacy are discussed in relation to the science education literature.

9.1.1 First-Year Chemistry Learning Experiences

The lecture classroom environment was of concern for many of the students. In particular, the students were worried that they might not possess the requisite study skills anticipated difficulty in completing assignments, and in mathematical manipulation. This result is consistent with other research - particularly for other countries for which university entry is based on external summative examinations (White et al. 1995). Mature students were apprehensive about their tertiary studies: previous research involving mature students, suggests that this is likely to lead to a high attrition rate for first-year science courses (Fensham, 1992; Wilson, Ackerman & Malave, 2000). This latter fear was borne out in the present work with a significant number of first-year students (both mature and new entrants) dropping out after the first semester.

Interestingly, despite some initial concerns, the students reported positive first-year learning experiences - in contrast with other research (e.g., Boo, 1998; Hesse & Anderson, 1992). The quantitative data suggests that the students had no particular preference for a given course. However, the qualitative data identified some topics within these courses that were popular with the students and others were that were unpopular. As it turns out, the most popular topic (organic chemistry) and the least popular topic (physical chemistry) both are presented in the second semester course. Furthermore, the students' views about inorganic chemistry and aqueous chemistry (taught in the first semester course) varied with some liking aqueous chemistry because it was familiar, and others disliking the heavy mathematical component of these topics. It is somewhat surprising that some of the students liked aqueous chemistry given that equilibria (part of the aqueous chemistry component of the course) has been reported to be very unpopular in other studies (e.g., Huddle & Pillay, 1996; Quilez-Pardo & Solaz-Portoles, 1995). Another interesting finding was that some of the direct entry students did not enjoy the lecture content for the second-year course - mostly because it was so different to their secondary school chemistry study. This is an important finding for the institution involved in this study since direct entry into the second-year is seen as a useful recruitment tool intended to encourage more academically able students to pursue a major in chemistry.

The students made a number of useful suggestions of ways in which they believed their chemistry courses could be improved. First, they did not like lecturers to provide them with full, detailed, lecture notes: this, they reported, inhibited them from engaging with the subject and made the lectures seem rather dry and pointless. The students did not like taking extensive lecture notes either; for example, copying notes verbatim from the blackboard or from overhead transparencies (Laws, 1996; Mulligan & Kirkpatrick, 2000). The best form of lecture notes, according to the students, consists of 'skeleton notes' containing the main points, that require the students to add additional material based on the lecture presentation and in-class discussions. The students also liked lecture material to be contextualised, using relevant real-world examples that were familiar to them. This latter finding is consistent with the findings of Ebenezer and Zoller (1993) and Manzanal, Barreiro and Jiménez (1999) who found relevant contextual examples to be effective in enhancing student interest in chemistry. Other suggestions about the lecture component of the course included increased use of visual aids: a finding reported to be effective at other tertiary institutions (Deschsri, Jones & Heikkinen, 1997).

At the start of the year the students were looking forward to their laboratory classes. Although they still enjoyed the classes, the students were less positive in attitude-towards-the laboratory component of their courses after their experiences in the first and second semester courses. This result is somewhat concerning and contradicts other research, which found that students reported the laboratory classes to be the most enjoyable aspects of their chemistry study (Bennet et al., 2001; Piburn, 1993). The qualitative data in the present work was useful in identifying reasons for this apparent anomaly. In general the students did not like the high emphasis placed on titrations - particularly what they saw as an overemphasis on accuracy and precision. The students enjoyed experiments that allowed them to use new equipment. It seems this latter aspect is particularly influential in that the most popular experiment involved titrations, but also allowed students to use new equipment and the staff running this experiment placed less emphasis on accuracy and precision. An interesting finding was the two direct entry students were less than positive about their laboratory classes. It seems these classes, which are often demonstrator-led rather than student-led, were not popular with the students, due to the reduction of 'hands on' experience for the students. Thus, when students have less 'contact' with experiments they tend to enjoy the classes less (as found in previous studies, see, e.g., Fensham, 1992).

The students made few suggestions for the improvement of the laboratory classes. The main suggestions were that the laboratory manual needed a better introduction to the experiment and that introductory laboratory talks would be beneficial as would time set aside for laboratory questions in tutorials. Although laboratory talks do occur in these classes, they are typically informal as the students turn up, and have no set structure. It appears that students would prefer a more formal approach to these talks. Students also wanted more guidance on how to present their data in the write-up of their laboratory classes. These findings are similar to those of other studies that found students engage better in laboratory classes when they are better prepared (Rollnick et al., 2001).

The students were most positive about their learning experiences in their tutorial classes as reported elsewhere (Bennet et al., 2001; Mulligan & Kirkpartick, 2000). Interestingly, this positive feeling only occurred for the first semester tutorial classes. Interview data suggests that this probably occurred because the students stopped attending tutorial classes in the second semester, when they found that they could cope with lecture material without help. Tutorial learning experiences were seen in a positive light because the students found them useful in preparation for topic tests and examinations. However, as reported previously, tutorial sheets that contain mainly algorithmic problems are seen as being less useful because students cannot see what relevance such problems have to lecture material (Mason, Shell & Crawley, 1997; Voska & Heikkinen, 2000). It appears the majority of students see the tutorials as a positive learning experience, not because of the opportunity to ask questions, but because of their relationship of the material presented in tutorials to examination and test questions (Hobden, 2001; Jackman, Mollenberg & Brabson, 1990).

Lecturing style, staff-to-student ratios in the laboratories, and in some cases staff attitude-towards-students, were identified as important factors in all three learning environments: indeed negative learning experiences were commonly attributed to such issues. Some lecturers were deemed unapproachable, and in some cases students felt that there were too few laboratory demonstrators. Other interpersonal issues reported included a perception that some tutors 'picked on' target students in tutorials (see, Tobin & Gallagher, 1987). This is of concern, given that interpersonal relationships between students and teachers have been found to be highly influential in formation of student attitude-towards-science for both practical and theory (Ebenezer & Zoller, 1993; Van Keulen, Mulder, Goedhar & Verdonk, 1995).

It was interesting to note that the students felt academics and course tutors could not be expected to modify teaching styles to suit student needs. Although the students made some suggestions that a more learner-centred method of instruction would be better, for the most part any discussion on teaching style was within a context of a teacher-centred method of instruction. It is unclear, whether this is because, as reported previously, that tertiary students are content with teacher-centred methods of instruction (Coll, Taylor & Fisher 2002; Mulligan & Kirkpatrick, 2000), or if students do not consider different methods of teaching possible in the tertiary environment.

9.1.2 Attitude-Towards-Chemistry

The students' attitude-towards-chemistry was mostly positive. In all three administrations of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) student *attitude-towards-chemists* and *required skills of chemists* were positive, suggesting that the stereotypes of chemist such as the 'mad scientist' stereotype identified in other studies is not particularly prevalent for this group of students (Billingsley, 2000; Jones, Howe & Rua, 2000). The majority of the students felt chemists were environmentally aware although a few did not. Other students saw environmental issues to be the responsibility of the end users of chemistry, rather than of chemists, and recognised that much chemistry research was centred on improving the environment (Dawson & O'Conner, 1991).

It is encouraging to note that the students were very positive about the role of chemistry in society. This is in contrast with general public views, and seems to suggest that chemistry students have a better understanding of the value of chemistry and the contributions chemistry has made to society (Levinson et al., 2000). As in previous studies, there were some differences based on gender (Jones, Howe & Rua, 2000), with males more likely to be positive about the role of chemistry in society (particularly at the start of the year).

As might be expected, the students were positive about their career interest in chemistry, but surprisingly were less positive about leisure interest in chemistry. This difference suggests that the students are interested in chemistry-related careers but are not particularly interested in chemistry-related activities outside of formal learning environments. However, some of the more academically able students described the incidents in which they had been involved in chemistry-related activities during leisure time, suggesting that at least some students have a leisure interest in chemistry.

It is interesting to note that there were few differences in student attitude-towards-chemistry across demographic groups. This suggests that gender differences reported in the past (e.g., Baker, 1985) are no longer present, as found in recent research (Piburn, 1993). Schibeci's (1984) proposition that ethnicity differences are due to socio-economic reasons is not borne out in the present work, as there were no significant differences based on decile ratings of schools. This finding is consistent with more recent research at primary school level, where socio-economic status appeared to have little effect on pupils attitude-towards-science (Tymms, 1997).

There was little relationship observed between student learning experiences and changes in their attitude-towards-chemistry, with the only changes observed being for career interest in chemistry with statistically significant correlation's found between second semester lecture and laboratory learning experiences. However, students were more thoughtful about reasons for the attitudes they held by the end of the year with some recounting specific chemistry (and other science) learning experiences.

9.1.3 Chemistry Self-Efficacy

Overall student chemistry self-efficacy was high, with all three administrations of the CAEQ suggesting that the respondents were reasonably confident about the tasks they anticipated conducting in first-year chemistry. However, as reported elsewhere, there were statistically significant differences in chemistry self-efficacy between cohorts of students, with chemistry majors having greater self-efficacy at the start of the year than non-majors (Bodner et al., 2001; Koballa, 1990). By the end of the semesters these differences disappeared, suggesting that the students' first-year learning experiences influenced their chemistry self-efficacy. Issues noted to influence chemistry self-efficacy were low self-efficacy with respect to mathematical competence, although, surprisingly, the influence was not as strong as reported elsewhere (Betz & Hackett, 1983; Lent, Larkin & Brown, 1984). The major concerns with respect to chemistry self-efficacy appeared to be to do with concerns about assessment and the need for memorisation of large amounts of chemistry content.

There were some differences in chemistry self-efficacy due to gender and past achievement. Differences between males and females decreased as the students studied chemistry – in accordance with previous research for self-efficacy for the physical sciences (Andre et al., 1999; Yang et al., 2001). It appears that for the present work that males' concerns are focused on a specific aspect of chemistry, (mathematics in chemistry, laboratory practice, etc.) whereas females have lower chemistry self-efficacy overall. As might be expected, there is a relationship between chemistry self-efficacy and previous achievement in chemistry. Self-efficacy was related to students' prior achievement in tests and examinations.

This is seen to be cyclic, arising as a function of motivation to achieve, with students with high self-efficacy becoming more motivated to achieve and consequently achieving and thereby improving their self-efficacy (Lent, Larkin & Brown, 1984; Rowe, 1988; Williams, 1994).

Students' learning experiences appear to influence their chemistry self-efficacy and there were statistically significant correlations between changes in chemistry self-efficacy and lecture and laboratory learning experiences. It seems that learning experiences influence self-efficacy by influencing student interest in a course which they related to perceptions of the effort required to achieve a passing grade for the course. Experiences that contributed to this include note taking in lectures, performance in earlier chemistry courses, and obtaining expected results for laboratory classes for certain experiments. Tutorial experiences, did not appear to influence chemistry self-efficacy; rather it appears that as students' self-efficacy increased, they perceived little need to attend tutorials.

9.2 Attitude-towards-Enrolling in Chemistry, Control Beliefs About Enrolling in Chemistry and Normative Beliefs About Enrolling in Chemistry

As discussed in Chapter 3, the theoretical framework for this thesis identified three main antecedents of enrolment choices; student attitude-towards-enrolling in chemistry, control beliefs about enrolling in chemistry, and student normative beliefs about enrolling in chemistry. The influence of each of these antecedents are now discussed in turn in relation to the literature.

9.2.1 Attitude-Towards-Enrolling in Chemistry

2	What are student attitude-towards-enrolling in chemistry and what influence, if any, does student first-year learning experiences, attitude-towards-chemistry and chemistry self-efficacy have on student attitude-towards-enrolling in second-year chemistry?

There is a variety of reasons why students enrol, or do not enrol, in science or science-related courses reported in the literature (Lips, 1992; Robertson, 2000; Woolnough et al., 1997). However, in this work the students identified with only a few reasons. Most students enrolled in first-year chemistry because they felt they required some chemistry knowledge to undertake study in other science subjects. They also felt that the first-year chemistry courses would help them to decide what other courses they might do in later years. This finding is similar to other reports in the literature which has found that students become increasingly career-motivated as they get older, and as a consequence, course choices represent a response to underlying career aspirations (Koballa, 1988a; Joseph & Joseph 1998; 2000). In this study, students' secondary school experiences were very influential on attitude-towards-enrolling in chemistry. This occurred via a number of contributing factors; enjoyment of chemistry at school, a sense of continuation of previous studies, interest in the subject, and past achievement in chemistry or related subjects. This is in line with Robertson's (2000) study of first-year Scottish bioscience students in which 75% of students reported being influenced by their secondary school experiences. Some of the students in the present work were specific about what interested them about studying science. Things identified included learning more about nature and 'what' and 'how' things worked. Such reasons suggest that the participants held a positive attitude-towards-science. It is interesting to note that, as reported elsewhere, males reported more leisure interest in chemistry (Jones, Howe & Rua, 2000; Sullins et al., 1995). However, unlike previous research, the perception of social skills of scientists had little influence on student decisions about studying chemistry (Cronin & Roger, 1999). Chemistry self-efficacy beliefs also were mentioned in this work, with students thinking that chemistry was likely to become more difficult as they moved on to more advanced study.

9.2.2 Control Beliefs about Enrolling in Chemistry

3	Do students hold control beliefs about enrolling in second-year chemistry, if so what are they, and what influence, if any, do student first-year learning experiences, attitude-toward-chemistry and chemistry self-efficacy have on student perceived control over enrolling in second-year chemistry?

It seems that the major barrier in choice about study chemistry is organisational rather than affective. That is, a significant proportion of students enrolled in the first and second semester chemistry courses, simply because they felt that it was compulsory and required for their degree programme. Such students typically had low career interest in chemistry at the start of the year, although this did increase as the year went on. This is consistent with previous research that found students enrolment choices are primarily related to vocational factors (Koballa, 1988b). For example, in this work, the main influence for engineering majors was that in order to become engineer, they had to do some chemistry.

Hence, because chemistry is a compulsory component of the degree programme for many participants, other affective barriers to studying chemistry were less influential. Other studies suggest that a fear of failing chemistry inhibits students from enrolling in chemistry (see, e.g., Crawley & Black, 1992). It is possible that this fear influenced at least some of the students in the present work; since those students for whom chemistry was compulsory, had lower chemistry self-efficacy at the start of the year, than other students. Interestingly, these differences in chemistry self-efficacy had disappeared by the end of the year. The students who enrolled in chemistry as a compulsory component of a programme were more positive about their second semester chemistry learning laboratory experiences, and it seems that the apprehensions that these student's harboured at the start of the year were allayed somewhat by their tertiary level chemistry experiences.

9.2.3 Perceptions of Associates' Attitude-Towards-Chemistry and Subjective Norm

4	What are student perceptions of associates attitude-towards-chemistry and normative beliefs and what influence, if any, does student perception of associates attitudes-towards-chemistry have on subjective norm?

There were few differences in student attitude-towards-chemistry, chemistry self-efficacy and chemistry learning experiences between students who defined themselves as having associates that were involved in the scientific industry, and those that did not. This is perhaps not surprising given that parental involvement in student attitude-towards-science decreases as students mature, and peer links have always been tenuous (Jones & Young, 1995; Crawley & Black, 1992; Ray, 1991). Despite this, the students in the present work held clear, specific, beliefs about their associates' attitude-towards-chemistry.

There were several common themes found across all of the students' associates, and their views of media portrayals; all seeing chemistry professions in terms of chemistry images, particularly engaged in laboratory work, experiments and wearing white coats. Some students saw at least one of their associates' thinking chemists are intelligent, hard-working and analytical people.

There appears to be a strong relationship between student perceptions of peer attitude, and the manner in which the media portrays chemists. For example, both peers and the media were seen to identify chemistry occupations as environmental or medical-based, both viewed as a positive portrayal of chemistry by the media. A number of participants themselves related chemistry to media portrayals of issues in the biological sciences, including genetic engineering and human cloning, as did their peers. The participants perceived that their peers' attitude-towards-the values of chemists also correlated with the media portrayal of chemistry, which they perceived as suggesting that chemists care only about their results, and not about the effect of their results. This is consistent with previous research which suggests that the public and students' image of science is influenced by exposure to 'mad scientist' images through television and comic books, with students generally having a negative perception of chemists (Cross & Price, 1999; Fensham, 1999; Schibeci, 1986). Encouragingly, none of the participants involved in this study perceived their peers as attributing scientists as any particular gender, which is consistent with some recent findings at the secondary school level (Dawson & O'Connor, 1991).

The students considered that their parents and mentors to be more positive about chemistry than their peers. The former groups were seen to think of a greater variety of chemistry occupations, and were more cognisant of the role chemistry plays in industry. Given that the participants were all interested in chemistry to some extent (as evidenced by them enrolling in first-year chemistry), this is consistent with previous research that suggests that the home environment has some influence on student attitude-towards-science (George & Kaplan, 1997; Schibeci, 1989; Woolnough, 1994). The students did see their parents holding some misunderstanding about chemistry occupations, with some thinking that their parents would see chemistry in terms of pharmacy (in New Zealand pharmacy is a different occupation and requires a different, specific, professional qualifications). Some of the students did not see their parents as envisaging chemists as analytical people, rather they saw them as thinking of chemists as conforming to the nerd stereotype. Parents were seen to be more aware of the positive aspects of chemistry, but also were seen as considering research as the responsibility of the people putting it into practice, rather than the researchers themselves.

The students' mentors were predominantly involved in a science industry. This is different to other studies in which high school students with a programme of study intended to lead to science at university were found to rank science and mathematics teachers lowest on a scale normative referents (Myeong & Crawley, 1993). The students felt their mentors would see chemists as studious people, having similar personality traits to the nerd stereotype identified by parents, but presented in a more positive manner. Several of the students felt their mentors would see chemists as outgoing people, possibly a reflection of the fact that most of the mentors were in science occupations. Finally, the students believed their mentors would consider ethical behaviour in science as part of their own personality. Consequently, the students believed that their mentors would think that the rest of the science profession would behave in a similar manner.

In general the participants felt that their parents, peers and mentors were supportive of their enrolment choices. Although some of the students felt that their peers would not understand why they would want to study chemistry, in most cases where they believed an associate to hold any beliefs about studying chemistry it was for positive reasons such as ability in chemistry. As reported previously, peers were often supportive as they were also studying chemistry (Gogolin & Swartz, 1992; Talton & Simpson, 1985). Mentors were seen as supportive because of similar interests, and to a lesser extent, like parents, were seen as supportive of any academic or vocational choices.

9.3 The Influence of Attitude-Towards-Enrolling in Second-Year Chemistry, Perceived Control over Enrolling in Second-Year Chemistry and Subjective Norm on Enrolment Choices

5	What influence, if any, does student attitude-towards-enrolling in second-year chemistry, perceived control over enrolling in second-year chemistry, and subjective norm, have on intentions to enrol in second-year chemistry?

The research findings reported here suggest that student enrolment intentions with respect to second-year chemistry change throughout the year. There is a significant proportion of students who at some stage of their first-year change to intending to not enrol in second-year chemistry. In particular there is a high attrition rate of students at the end of the first semester chemistry course. Additionally, whilst students change their intentions to not enrol in chemistry, there is not a corresponding group of students that change their intentions to enrol in chemistry.

Although it appears that learning experiences are not the only influence on student enrolment choices, learning experiences were cited by some students who changed their intentions to not enrol in second-year chemistry. The influence of attitude-towards-chemistry is widespread. However only *career interest in chemistry* that has an observable difference between the students who intended to enrol in a second-year chemistry course and those that do not. This suggests that, as found previously, students are vocationally orientated in their educational choices (Dawson & O'Conner, 1991; Lapan & Shaughnessy, 1996). As found in secondary schools there is a relationship between chemistry self-efficacy, achievement and enrolment intentions (Dawson & O'Conner, 1991; Koballa, 1990). However, as previous research has shown the predominant reason for studying chemistry, was interest in studying chemistry (Crawley & Black, 1992; Stokking, 2000).

Students who enrol in first-year chemistry as a compulsory course are less likely to intend to enrol in either the second semester chemistry course or a second-year chemistry course. There are two types of students within this group, namely, engineering majors and science specified programme students, who have differing reasons for not pursuing chemistry beyond the first-year. As reported previously, engineering students appear to be interested in studying chemistry but are focussed on their degree paths, whereas science specified programme students may not be interested in chemistry due to a lack of interest in the subject (Bodner, et al. 2001).

Although, as reported previously in the literature, subjective norm appears to be less influence on student enrolment intentions than either attitude-towards-enrolling in chemistry or perceived behavioural control; students are more likely to enrol in second-year chemistry if they have associates that are scientists (Butler, 1999; Ray, 1991). Although in most cases students do not appear to be directly influenced by subjective norm the influences are not necessarily overt, with a long-term exposure to science through friends and family likely to be an influence on enrolment intentions.

9.4 Methodological Considerations

Before examining the conclusions and recommendations from this inquiry I would like to draw attention to some methodological considerations – especially in terms of the *Modified Theory of Planned Behaviour* (MTPB) and the quantitative elements in this research.

9.4.1 The Modified Theory of Planned Behaviour

The MTPB was a useful tool in developing and examining the research questions. There was at least one instance where a relationship existed between the antecedents of enrolment intentions, namely attitude-towards-enrolling in second-year chemistry, perceived behavioural control and subjective norm and enrolment intentions. In most cases the modifications made were appropriate. Learning experiences, attitude-towards-chemistry and chemistry self-efficacy all had some impact on attitude-towards-enrolling in chemistry and learning experiences had some impact upon attitude-towards chemistry and chemistry self-efficacy. The validity of assuming a relationship between associates' attitude-towards-chemistry and subjective norm, was more tenuous, but still apparent. Consequently, the MTPB was an appropriate means for examining students' enrolment intentions and ultimately choices, and would be useful in guiding future research in this area.

9.4.2 Quantitative Research

The quality of quantitative research has become quite a contentious issue amongst practitioners of social science and education research – with a clear divide between those whose interests are primarily qualitative and those who include quantitative methods in their research practice. The more qualitatively orientated researchers have been known to describe quantitative methods as 'positivistic' and lacking in validity (see, e.g., Ebye & Schmidt, 2001). Yet, I believe that the quantitative component within in this inquiry has shown that quantitative research can inform naturalistic inquiry and produce valid findings.

The quantitative and qualitative elements of this research has effectively complemented each other. For example, the MTPB, a framework derived from quantitative methods, has provided a clear focus for the research, and has been exhaustive in its description of the research questions. Additionally, many of the findings from the interviews have explained findings from the administrations of the CAEQ.

The validity of the quantitative elements was exhaustively examined. Much of the rigor in this work can be attributed to the use of Trochim's (1999) comprehensive framework for construct validity. The use of effect size data has also been invaluable in looking for 'real' differences in data. The understanding of construct validity and the awareness of limitation in statistical analysis, especially methods involving statistically significant differences has made what I believe a very strong statement about ways of maximising validity in quantitative research.

In summary, I suggest that this research has provided a clear example of how quantitative research can be used is naturalistic inquiry and produce valid findings.

9.4.3 Qualitative Findings

One of the key elements of the MTPB is the emphasis on salience – it is not what beliefs a student holds, but the beliefs that contribute towards enrolment intentions that are relevant to the research problem. One of the consequences of the salient approach to research interviews and reporting of findings is the drawing of conclusions from one specific report. Although the interview data cannot be generalised to the class as a whole (this is a recognised weakness of this method) the experiences of the individual student are important. The fact that the salient beliefs maybe at time contradictory suggest that there is not one easy solution to enrolment issues in chemistry at the tertiary level.

9.5 Conclusions and Recommendations

One of the key findings from this research is that the reasons cited by students for their enrolment choices are considerably varied. Consequently, there is no single recommendation that will improve enrolment numbers across the board. Indeed in some cases change in practice which may result in an increased educational interest from particular types of students may result in a decreased interest in another. Therefore it is up to the reader to decide which recommendation and conclusions would be most appropriate for their educational context.

As stated in Chapter 3, (Section, 3.2.4, p. 47) the author subscribes to a social constructivist view of learning and teaching. As such I believe that the social constructs of the students should be taken into account when teachers plan their lessons. However, if one seeks to effect changes to pedagogy, the beliefs of the people involved in the educational context must be taken into account. Many of the findings of this thesis suggest that, as reported elsewhere, a transmissive style of teaching generate some negative feelings about learning undergraduate chemistry. However, it seems unlikely that the research in this thesis is sufficient to effect a complete change in ideology for the science academic staff that seemingly hold beliefs different to those of my own. Rather, these teachers and scientists would likely rebel against, rather than conform to, a new way of thinking. With this in mind, I have produced a series of recommendations from this research that involve modifying codes of practice, that requires changes to tertiary chemistry teachers' metaphysical beliefs.

The recommendations are structured under the four objectives of research question five. Although research questions one to four explored the different types of beliefs that lead students to make the educational choices that they do, research question five was key to understanding students' enrolment intentions. In fact the structure of the research questions means that research questions one to four all inform the objectives of research question five. For example, research questions one and two, which examine learning experiences, attitude-towards-chemistry, chemistry self-efficacy and attitude-towards-enrolling in second-year chemistry inform with objective two of research question five: *What influence, if* *any, does student attitude-towards-enrolling in second-year chemistry have on intentions to enrol in second-year chemistry?* Similarly, research questions three and four, which examine perceived behavioural control and subjective norm, inform objectives three and four of research question five: *Do students hold control beliefs about enrolling in second-year chemistry, if so what are they, and what influence, if any, do student first-year learning experiences, attitude-toward-chemistry and chemistry self-efficacy have on student perceived control over enrolling in second-year chemistry?;* and *What are student perceptions of associates attitude-towards-chemistry and normative beliefs and what influence, if any, does student perception of associates attitudes-towards-chemistry have on subjective norm?* Therefore, the following conclusions and recommendations are made from findings from all research questions, but are focussed around research question five: *What influence, if any, does student attitude-towards-enrolling in second-year chemistry, perceived control over enrolling in second-year chemistry, and subjective norm, have on intentions to enrol in second-year chemistry?*

5.i	What are student intentions to enrol in second-year chemistry?

The research reported here uncovered some reasons why students choose to discontinue their chemistry study. The students in this study changed their enrolment intentions throughout the first-year of their chemistry study, with some students discontinuing university study entirely, others discontinuing chemistry at the end of their first semester, and others at the end of the second semester. One of the major findings of this study is that whilst students drop out of chemistry at some stage of their first-year, there is no corresponding group of students that change their minds and choose to study chemistry. Therefore for the department involved in this research, and indeed for other comparable departments facing similar challenges, a twofold approach to recruiting students is proposed. First, students should be discouraged from dropping second-year chemistry from their degree programme, and second, students should be encouraged to enrol in second-year chemistry, particularly at the end of the first-semester course. I detail below a number of specific measures that the research in this thesis suggests will help chemistry departments to realise these recommendations.

5.ii	What influence, if any, does student attitude-towards-enrolling in second-year chemistry have on intentions to enrol in second-year chemistry?

9.5.1 First Year Tertiary Experiences

The research reported here confirms studies in other disciplines (both science and non-science), and found that an appreciable proportion of students drop out of university study entirely during their first semester at university (McInnis, 2001). This suggests that students need to be better prepared for university study in all disciplines, including chemistry. This could be achieved in a number of ways; first, tertiary institutions and appropriate schools of study could offer summer school and first-semester courses that focus on ensuring prospective students have adequate content knowledge - as many of 'foundation level' courses do - but also have the study skills needed to succeed in a tertiary learning environment. Second, there is a case for the inclusion of study skills in the senior secondary school curriculum, especially for those students who are intending to carry out university study. In New Zealand, the introduction of the *National Certificate of Educational Achievement* (NCEA) framework at secondary school level (Black, 2001), which aims to better prepare both vocationally and academically orientated students for their career and employment goals, could readily incorporate a 'study skills' component in the curriculum. As previous researchers have suggested the introduction of such courses at both secondary and tertiary level may reduce the dropout rate for students in other university courses (White et al., 1995).

9.5.2 Improving First-Year Chemistry Learning Experiences

It appears from this study that some of the learning experiences in first-year chemistry are not particularly encouraging for students, especially for students from atypical chemistry backgrounds (e.g. computer science majors). Enrolment retention could be improved by examining teaching practices for all components first-year chemistry. The study shows that lecture classes would benefit from the use of 'skeleton' notes, rather than a complete set of notes or large amounts of photocopied material. This appears to appeal to both academically able and less able students because it allows them to listen to the lecturer, without feeling that they can 'tune out' because it all they need is already provided for them. Lecture material could be made more interesting by the use of relevant examples and better use of visual aids. Such activities would introduce more variety into lectures and would be particularly useful for less popular components of the course, as in, for example, basic physical chemistry that academics see as useful and necessary, and students do not.

Laboratory classes should be designed so that the students focus on the concepts behind their laboratory work rather than trying to achieve unrealistic 'high' standards of accuracy and precision, especially for experiments involving titrations. Such experiments need not be discarded, but they can be readily improved and made more appealing by making the experiment itself more relevant and interesting, and by allowing students to use new or novel equipment. This study showed, for example, that experiments that included the use of ion exchange chromatography were popular, and such tools should be exploited and be used in conjunction with less popular techniques such as titrations. Laboratory classes would also be more enjoyable for students if they are provided with a clear introduction to the class before beginning work and by a quick sum up or conclusion talk at the end of the class.

The students in this study reported that the tutorials were the most valuable of the three learning environments they experienced, and these classes should be targeted in action seeking to improve student retention. Tutorials would benefit from dedicated discussion of laboratory and lecture classes. Ideally the same tutors should be used throughout the academic year, so that students develop an enduring relationship with at least one staff member of the chemistry department. Tutors could also be present in student's laboratory classes, as this will enable students to have a communality of experience with at least one member of staff and can provide a chemistry 'mentor' for the student. This deeper personal relationship with their tutor, would likely improve attendance of the students at tutorials - which in turn should result in an increased academic performance.

Like many traditional science classes at tertiary level (Laws, 1996) assessment in the courses studied in this research is based mostly on algorithmic type questions. The literature suggests that academics often erroneously assume that if students can answer such questions, then they understand the underlying fundamental concepts (Hobden, 2001).

Coll, Taylor and Fisher (2002) found that tertiary students expect to encounter similar learning experiences at university to what they experienced at high school. Such an observation was also borne out in the present study. The chemistry lecturers of the future will be drawn from a pool of students like those that participated in this study. As pointed out at the beginning of this chapter, it is likely to be problematic to change the metaphysics and pedagogies of current tertiary chemistry teachers, however, if we expose current students to some different teaching approaches - however modest - this would at least expose the teachers of tomorrow's chemistry students to greater diversity in teaching style.

9.5.3 Improving Attitude-Towards-Enrolling in Chemistry

A fascinating finding from this study is that the students (not just intending chemistry majors) held predominantly positive attitude-towards-chemistry, particularly about the role of chemistry in society, in contrast with misrepresentation and sometimes outright antagonism to the profession from the mass media. Although the study showed that such attitudes have little direct impact on enrolment intentions, a large proportion of chemistry students are vocationally-orientated with career interests in chemistry influencing enrolment choices. As vocationally-orientated students make their decisions at the secondary school level, these results suggests that promotional material targeted at secondary school students needs to include information about the variety of chemistry-related vocations available to students.

The study suggests that chemistry self-efficacy is related to enrolment intention through achievement and motivation, with students who achieve higher grades in chemistry being more efficacious and more motivated to study and consequently more likely to achieve. Therefore, early achievement in first-year chemistry can lead to increased enrolment retention by means of enhanced self-efficacy towards chemistry. Non-chemists, who are typically are less efficacious, would likely benefit most. Furthermore, student chemistry self-efficacy is influenced by laboratory and lecture learning experiences suggesting that early assessment tools need to comprise material from both lectures and laboratory classes, and be set at such a level that the majority of students receive positive feedback This is not to say that the course content should be 'dumbed down' but that positive early assessment experiences can increase student perceptions of their chemistry ability and thus make them feel that studying further chemistry is feasible. For example, a simple laboratory-based test in which students put into practice laboratory techniques learnt in the first few weeks of laboratory classes as well as incorporating rudimentary theoretical material from lectures. The assessment exercises can then increase in demand without undermining student self-efficacy because this work found that students already perceive chemistry as increasing in difficulty during their first-year chemistry courses.

Students bring their own perceptions about chemistry and their ability in chemistry to first-year chemistry study. This study has shown that these perceptions formed at high school are in many cases a major influence on student second-year enrolment choices. If students are interested in chemistry before they come to university, they are more likely to continue on to study advanced tertiary chemistry. Hence, another useful strategy would be for university staff to help secondary school students develop an interest in chemistry before embarking on tertiary study. This could be achieved via promotional events such as summer school type activities for academically able students, chemistry quizzes and the like, that stimulate interest in chemistry. Other useful strategies include using young academics and recent chemistry graduates to enthuse students by describing exciting new leading–edge chemistry research and vocational opportunities.

5.iii	What influence, if any, does student perceived control over enrolling in second-year chemistry have on intentions to enrol in second-year chemistry?

9.5.4 Utilising Control Beliefs about Enrolling in Second-Year Chemistry

The tertiary institution involved in this study also has a pool of potential chemistry majors in their current first-year enrolment. To maximise enrolments a recruitment campaign could target students who take chemistry in specified programmes - or as a supporting subject. There is seemingly little point in targeting students like engineering students whose specified programmes have few options, such individuals are less likely to be persuaded to another degree programme compared with non-chemistry science majors (see, Bodner, et al., 2002). There are three non-chemistry science majors worthy of attention; biological science majors, particularly those in biochemistry programmes, Earth sciences majors, and materials and process or technology majors. All of three cohorts would benefit from additional chemistry knowledge and expertise and thus could be persuaded more readily than say mathematics or physics majors. Some attention to degree or specified programme regulations may be required to increase options. Clearly such students who have a legitimate interest in chemistry may be convinced to study more chemistry if their learning experiences in chemistry are more positive.

5.iv	What influence, if any, does student subjective norm, have on intentions to enrol in second-year chemistry?

9.5.5 The Role of Normative Beliefs about Enrolling in Second-Year Chemistry

The study suggests that socialisation factors are not particularly influential in student chemistry enrolment decisions. However, it seems that students who had more interaction with scientists are more likely to study second-year chemistry. This is probably due to increased awareness about chemistry and support for chemistry learning that other students not associated with scientist are not exposed to. The department in this study could utilise such positive student experiences with scientists by, for example, implementing a tutoring or mentoring programme. Such a programme currently exists in the School of study for Maori students (i.e., indigenous New Zealanders) and has been reported to be popular and successful in recruiting and retaining students (Zegwaard, Paku & Coll, 2002).

9.6 Limitations of the Research

The research inquiry reported in this thesis, like any research undertaking, has some limitations (Shulman, 1998). It is appropriate at this point for the author to reflect upon what limitations were present in the study and to consider what impact these limitations may have had on the trustworthiness of the inquiry.

First, the study was only carried out in one institution. Such an approach of necessity limits the transferability of the research findings and conclusions. The university involved in this study is situated in a rural setting with an enrolment of around 12,000 students, and a modest sized chemistry department (a fulltime equivalent of 12 academic staff). As a result, there were limited responses for some of the subscales in the various administrations of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ). This suggests that caution is required in interpretation of such statistical data. This point became evident in the comparison of the quantitative data in the pilot study and main study, which while producing similar trends overall revealed some differences (e.g., to items in the chemistry self-efficacy scale). If other researchers wish to use the CAEQ in their own learning contexts, revalidation would be necessary. The participants in this study were mostly of one ethnic group (describing themselves as New Zealand European). The transferability of these findings to other ethnic groups is unknown.

Second, some ethical issues limited the investigation of student learning experiences. For instance, the author was careful to protect the rights of the academics involved in this study, and attempted at all times to ensure that no academic could be identified in either the quantitative or qualitative components of the work. As a consequence, questions about student perceptions of their learning experiences for each of the chemistry courses were independent of the individual lecturer. In other words the students described their overall impression of lecturing style, rather than commenting or assessing the lecturing styles of individual lecturers. This might mean that reports of student experiences or views of individual staff 'cancelled each other out' resulting in a tendency for the estimated mean responses for CAEQ items to be in the middle of the Likert scale. A second issue relating to ethical concerns is the timing of the administration of the CAEQ and the interviews. These were timed so as to avoid added stress for the students buy choosing times of low workload. So for example, the administration at the end of the first semester and the final administration at the end of the year occurred *towards* the end of the semesters in question rather than right at the end, when the students would have finished the course. A number of other activities occurred after these administrations. Members of academic staff often recruit students to the second semester and second-year chemistry course toward the end of the semesters, the impact of these recruitment drives is thus not measured by the CAEQ or some of the interviews.

Third, the main focus of this inquiry was to examine student learning experiences in chemistry classes and to ascertain what influence these experiences exerted on subsequent enrolment intentions. This is a relatively narrow focus and the study did not investigate student learning experiences in other disciplines such as courses in the biological sciences or Earth sciences. The influence of learning experiences in these disciplines of student chemistry enrolment choices remains unknown.

9.7 Suggestions for Future Research

The research reported in the thesis has provided some insights into students' chemistry learning experiences and resulted in a number of recommendations described above. If such recommendations were followed then an evaluation study that reported on the implementation and effectiveness of these suggestions would be of value and interest. For example, the tutor/mentor programme involving consistency of academic staff in tutorials and laboratory classes has been suggested as a way to provide socialisation with scientists for students who do not have a social background in science. The development and implementation of such a programme would be informed by research prior to implementation.

Second, research on secondary school students' enrolment choices and the influence of these choices on student tertiary level enrolment choices should be ongoing and the effectiveness of university and secondary school programmes should be investigated.

Finally, this research has revealed that a large number of students are unsure about their enrolment choices at the start of their university careers. Further work in researching how undecided students decide on a particular educational path will provide valuable insight into why students choose, for example, biology over chemistry.

9.8 Concluding Thoughts

At the start of this thesis I quoted John Nash, a Nobel Prize winner in the field of economics and a brilliant mathematics scholar who did not continue to study chemistry because of his experiences in undergraduate chemistry classrooms:

> *It was not a matter of how well one could think ... but of how well one could handle a pipette and perform* [a] *titration in the laboratory.*

At the end of this thesis I offer another quote from another gifted scholar, Pierre Berthelot (1827-1907). Berthelot made significant contributions to an area of chemistry that many undergraduates students find problematic, thermodynamics, and coined two terms that haunt many first-year chemistry students: *exothermic* and *endothermic*. Berthelot wrote:

> *Chemistry creates its' subject. This creative ability, similar to that of art, essentially distinguishes chemistry among the natural sciences.*

These two great scholars clearly had very different experiences when studying undergraduate chemistry, and it seems that these experiences made a significant impact on their enrolment and career choices. Whilst one might argue that chemistry's loss of Nash, was economics and mathematics gain, it is regrettable that this loss seems to have occurred for inappropriate reasons - namely undesirable chemistry learning experiences - rather than as a result of free choice. I leave this as a thought to all academic staff involved in the teaching of undergraduate chemistry: Which of the quotations above would you wish your students to relate to most?

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APPENDIX A
FIRST-YEAR CHEMISTRY AT THE UNIVERSITY OF WAIKATO

The purpose of this appendix is to give an overview of the content of the two first year courses *Chemical Concepts* and *Chemical Change & Organic Compounds*. Additionally, a brief description of the direct entry course *Analytical Chemistry & Instrumental Techniques* is presented.

A.1 First Semester Course - Chemical Concepts

A.1.1 General Structure

The first semester course, *Chemical Concepts*, covers two components of chemistry theory: aqueous chemistry and inorganic chemistry. This is presented in 36 lecture classes and 12 laboratory classes. The textbook for this course is Chang, R.(1998). Chemistry (6^{th} Ed.). McGraw Hill: New York. The course is assessed by two topic tests (each worth 7% of the students final grade), the laboratory write up (19% of the students final grade) and a final examination (67% of the students final grade).

A.1.2 Aqueous Chemistry

In the first six weeks of the lecture course, students are introduced to aqueous chemistry. There are four key concepts taught in this section of the course; balancing chemical equations, principles of equilibria, solubility and pH. In the first few lectures of the course students are taught how to balance chemical equations. This material is part of the Year –12 and 13 secondary chemistry curriculum, and hence the purpose of these lectures is to help the students 'catch up'. The major aim of the aqueous chemistry lectures is to convey the principles of equilibrium including equilibrium constants and their relationship to concentration. As specific examples, material is presented on solubility and solubility constants as well as pH. Included in the lecture material on pH is the relationship between of pH with acid and bases properties. Additionally, pH curves and buffer solutions are covered. These concepts are typically tested by algorithmic mathematical questions in the first topic test and the end of the year examination.

A.1.3 Inorganic Chemistry

The second half of the course introduces students to inorganic chemistry and bonding theory. The derivation of quantum numbers is presented and the concept of an *orbital* introduced. Valence bond theory also is taught and related to the Periodic Table. Additionally, material is presented on the trends in the Periodic Table, and ideas such as electron configurations and oxidation states are introduced. The material in this part of the course is examined in the second topic test and the final examination. Assessment questions are less quantitative than those from the first half of the course, with students asked to write essays and paragraphs with diagrams to explain concepts.

A.1.4 Laboratory Course

The laboratory course is taught over 12 three hour classes, and taught material is predominantly related to aqueous chemistry. Students are given a laboratory manual at the start of the semester which contains all the details of the experiments as well as tables of data that they need throughout the course. This laboratory class is staffed by a laboratory supervisor, a laboratory technician and a number of graduate student demonstrators.

The first laboratory class provides an introduction to chemistry experimentation. Students are asked to complete simple exercises in pipetting and titrating techniques as well as learning how to describe their observations, through a series of test tube reactions. For the following three laboratories the students are asked to prepare a standard solution which they then titrate against an unknown solution to determine its' concentration. Once they have standardised the unknown solution accurately they then are given another unknown to titrate and finally they asked to perform a back titration. The subsequent experiments focus on teaching students other components of chemistry including solubility and solubility constants, recrystalisaton techniques, pH and pH meter titrations, and redox chemistry, which also included a number of titrations. The final set of experiments involves synthetic inorganic chemistry where the students make a series of tin iodide compounds. The laboratory course is examined by the preparation of a laboratory book, in which the students are expected to log experimental data and draw conclusions about their findings as well as answer questions that are included in the laboratory manual. In the first six weeks the students are given a 'fill in the boxes' sheet in which to write up their experiments in order to teach them an appropriate style for presenting their work. Laboratory books and write up sheets are handed in for marking at regular points throughout the semester.

A.1.5 Tutorial classes

Tutorial classes are designed to be guided by students needs. However, these classes typically go through the tutorial sheets which are handed out in the lectures. The tutorial classes are the main opportunity the students have to collect answer sheets for the tutorial questions.

A.2 Second Semester Course - Chemical Change & Organic Compounds

A.2.1 General Structure

The second semester course, *Chemical Change & Organic Compounds*, covers another two components of chemistry theory, namely, physical chemistry and organic chemistry. Students are taught these two subjects in 36 lecture classes, 12 three-hour laboratory classes and 12 tutorials. The core text is the same as for the first semester course the sixth edition of Raymond Chang's (1998) text *Chemistry* published by McGraw Hill. The course is assessed similarly to the first semester course with two topic tests (each worth 7% of the final grade), a laboratory write up (19%) and a final examination (67% of the final grade).

A.2.2 Physical Chemistry

The physical chemistry component of the course is taught in the first six weeks and covers content on thermodynamics, kinetics and reaction mechanisms as well as elementary quantum theory. In the thermodynamics component of the course students are introduced to the laws of thermodynamics and the related concepts of enthalpy, entropy and Gibbs free energy. The distinction is then drawn between kinetics and thermodynamics and a discussion of reaction order presented. Also included in the course is an introduction to spectroscopy and how that relates to quantum theory. Throughout the course students are given examples of how physical chemistry is used in industry and the natural world, such as in the production of methanol and acid rain. This material is assessed in the first topic test and the end of the year examination. The assessment of this material involves a mixture of both short answer and essay questions with some mathematical calculations required.

A.2.3 Organic Chemistry

The purpose of this second half of the second semester course is to introduce students to basic concepts in organic chemistry. The course covers the different organic chemistry functional groups along with their properties and reactions. Students are introduced to different types of isomerisation including stereochemistry, as well as oxidation and reduction reactions in organic chemistry. Polymerisation, organic synthesis and elementary reaction mechanisms, (e.g., S_N^1 and S_N^2 mechanisms) also are taught. Specific interest in paid to examples of bio-organic compounds. This topic is assessed in a test at the end of the second semester and in the final examination. Assessment questions range from essay to short answer type questions, with minimal mathematics required.

A.2.4 Laboratory Course

As in the first semester students are given a laboratory manual at the start of the course which contains all the details of the experiments. Again, the laboratory is staffed by a laboratory supervisor, a laboratory technician and a number of graduate student demonstrators.

In the first half of the laboratory course students carry out experiments in organic chemistry. This involves organic synthesis, for example, synthesising salicylic acid (aspirin). One of the more unusual experiments is the paper chromatographic separation of dyes extracted from jelly beans (a common New Zealand confectionery). In this first half of the course students are exposed to a number of techniques used in organic synthesis such as solvent-extraction, refluxing, and purification of liquids via fractional distillation. Students also are introduced to common wet chemistry techniques in elementary qualitative organic chemistry. In the second half of the course students carry out physical chemistry experiments including following the extent of reactions in order to determine kinetic and thermodynamic parameterss. Other physical chemistry experiments involve using UV-Visible spectroscopy and ion-exchange chromatography. As in the first semester, the laboratory course is examined by the preparation of a laboratory book, in which students are expected to have recorded experimental data, and drawn logical conclusions.

A.2.5 Tutorials

The tutorials for the second semester course followed the same format as for the first semester, with the primary focus on the questions on the tutorial questions handed out in lecture slots.

A.3 Direct Entry Course – Analytical Chemistry and Instrumental Techniques

A.3.1 General Structure

The direct entry course, *Analytical Chemistry & Instrumental Techniques*, introduces students to the principles and techniques of chemical analysis. This is taught in 36 lecture classes and 12 three-hour laboratory classes. The core text was Kellner's (1998) book *Analytical Chemistry* published by Wiley. The course is assessed by three topic tests (each worth one-sixth of the students final grade), and the laboratory write up (50%). There is no final examination for this course.

A.3.2 Lecture Content

The lecture course is specifically designed to complement the laboratory course and covers a variety of analytical chemistry techniques and procedures. Consequently, students are taught the background theory behind analytical techniques that they were using in the laboratory with special interest on spectroscopy and chromatography. This is then related to specific instrumental techniques, such as gas chromatography, high-performance liquid chromatography, and x-ray diffraction. The lecture course also teachers students about wet bench chemistry techniques - both quantitative and qualitative, as well as statistical methods of analysis necessary to analyse quantitative data.

A.3.3 Laboratory Course

The direct entry students have a different laboratory course than those normal students who study the course in their second-year of chemistry study. In the first weeks of the course the direct entry students carry out the standardisation and back titrations of the first semester course, as well as the pH titration (section A.1.4, p. 301). In the remaining parts of the laboratory course the students carry out a number of experiments using instrumental techniques including gas chromatography, infra-red spectroscopy, x-ray diffraction spectroscopy and atomic absorption spectroscopy. At the end of the laboratory course students are given unknown substances and have to use a variety of wet chemistry techniques to determine the chemical composition of this substance.

A.3.4 Tutorial Course

The direct entry students also attend a weekly tutorial – there are no scheduled tutorials for the mainstream students. The purpose of this is to help them with any difficulties they may have, and to cover some parts of the first semester first-year course not covered in the Year-13 syllabus. This material consists predominantly of valence bond theory.

APPENDIX B
CHEMISTRY ATTITUDES AND EXPERIENCES QUESTIONNAIRE (CAEQ)

B.1 Pilot Study

	Please indicate what YOU think about the following		
	Chemists		
1	athletic	_ _ _ _ _ _ _ _	unfit
2	socially aware	_ _ _ _ _ _ _ _	socially unaware
3	environmentally aware	_ _ _ _ _ _ _ _	environmentally unaware
4	flexible in their ideas	_ _ _ _ _ _ _ _	fixed in their ideas
5	care about the effects of their results	_ _ _ _ _ _ _ _	only care about their results
6	imaginative	_ _ _ _ _ _ _ _	unimaginative
7	friendly	_ _ _ _ _ _ _ _	unfriendly
8	inquisitive	_ _ _ _ _ _ _ _	indifferent
9	patience	_ _ _ _ _ _ _ _	impatient
	Chemistry research		
10	helps people	_ _ _ _ _ _ _ _	harms people
11	improves quality of life	_ _ _ _ _ _ _ _	decreases quality of life
12	solves problems	_ _ _ _ _ _ _ _	creates problems
13	advances society	_ _ _ _ _ _ _ _	causes society to decline
	Science documentaries		
14	enjoyable	_ _ _ _ _ _ _ _	boring
	Chemistry web sites		
15	interesting	_ _ _ _ _ _ _ _	boring
	Chemistry jobs		
16	challenging	_ _ _ _ _ _ _ _	easy
17	varied	_ _ _ _ _ _ _ _	repetitive
18	interesting	_ _ _ _ _ _ _ _	boring
19	satisfying	_ _ _ _ _ _ _ _	unsatisfying
20	exciting	_ _ _ _ _ _ _ _	tedious
	Talking to my friends about chemistry		
21	fascinating	_ _ _ _ _ _ _ _	dull
	Science fiction movies		
22	exciting	_ _ _ _ _ _ _ _	tedious

*Please indicate how **CONFIDENT YOU** feel about*			
1 Applying a set of chemistry rules to different elements of the periodic Table	Totally confident	_ _ _ _ _ _ _	Not confident
2 Achieving a passing grade in a chemical hazards course	Totally confident	_ _ _ _ _ _ _	Not confident
3 Reading the procedures for an experiment and conducting the experiment without supervision	Totally confident	_ _ _ _ _ _ _	Not confident
4 Designing and conducting a chemistry experiment	Totally confident	_ _ _ _ _ _ _	Not confident
5 Tutoring another student in a first year chemistry course	Totally confident	_ _ _ _ _ _ _	Not confident
6 Determining what answer is required from a written description of a chemistry problem	Totally confident	_ _ _ _ _ _ _	Not confident
7 Ensuring that data obtained from an experiment is accurate	Totally confident	_ _ _ _ _ _ _	Not confident
8 Proposing a meaningful question that could be answered experimentally	Totally confident	_ _ _ _ _ _ _	Not confident
9 Explaining something that you learnt in this chemistry course to another person	Totally confident	_ _ _ _ _ _ _	Not confident
10 Choosing an appropriate formula to solve a chemistry problem	Totally confident	_ _ _ _ _ _ _	Not confident
11 Knowing how to convert the data obtained in a chemistry experiment into a result	Totally confident	_ _ _ _ _ _ _	Not confident
12 After reading an article about a chemistry experiment, writing a summary of the main points	Totally confident	_ _ _ _ _ _ _	Not confident
13 Learning chemistry theory	Totally confident	_ _ _ _ _ _ _	Not confident

14 Determining the appropriate units for a result determined using a formula	Totally confident	_ _ _ _ _ _ _	Not confident
15 Writing up the experimental procedures in a laboratory report	Totally confident	_ _ _ _ _ _ _	Not confident
16 After watching a television documentary dealing with some aspect of chemistry, writing a summary of its main points	Totally confident	_ _ _ _ _ _ _	Not confident
17 Achieving a passing grade in a Part Two chemistry course	Totally confident	_ _ _ _ _ _ _	Not confident
18 Applying theory learnt in a lecture for a laboratory experiment	Totally confident	_ _ _ _ _ _ _	Not confident
19 Writing up the results section in a laboratory report	Totally confident	_ _ _ _ _ _ _	Not confident
20 After listening to a public lecture regarding some chemistry topic, explaining its main ideas to another person	Totally confident	_ _ _ _ _ _ _	Not confident

Please answer these questions about your LECTURE classes					
1 The lecture material was relevant to the objectives of the course	SA	A	N	D	SD
2 My lecturers were interested in my progress in chemistry	SA	A	N	D	SD
3 The concepts introduced in the lecture material were explained unambiguously	SA	A	N	D	SD
4 My lecturers encouraged me to study more chemistry	SA	A	N	D	SD
5 The lecture notes were interesting	SA	A	N	D	SD
6 The chemistry lecturers have made me feel that I have the ability to go on in science	SA	A	N	D	SD
7 The lecture notes were clearly presented	SA	A	N	D	SD
8 It was easy to find a lecturer to discuss a problem with	SA	A	N	D	SD
9 The lectures were presented in an interesting manner	SA	A	N	D	SD
10 The lecturers explained problems clearly to me	SA	A	N	D	SD
Please answer these questions about your TUTORIAL classes					
11 The tutorial problems covered all parts of the course	SA	A	N	D	SD
12 My tutors were interested in my progress in chemistry	SA	A	N	D	SD
13 The problems in the tutorial sheets were relevant to the course	SA	A	N	D	SD
14 My tutors encouraged me to study more chemistry	SA	A	N	D	SD
15 The tutorial sheets helped me understand the lecture course	SA	A	N	D	SD
16 The chemistry tutors have made me feel I have the ability to go on in science	SA	A	N	D	SD
17 The material presented in tutorials was useful	SA	A	N	D	SD
18 The material covered in tutorials was presented in an interesting manner	SA	A	N	D	SD
19 It was easy to find a tutor to discuss a problem with	SA	A	N	D	SD
20 The tutors explained problems clearly to me	SA	A	N	D	SD
Please answer these questions about your LABORATORY classes					
21 The laboratory manual contained instructions that were easy to follow	SA	A	N	D	SD
22 When writing-up experiments in my laboratory book, the relationship between the data and the results was clear	SA	A	N	D	SD
23 My demonstrators were interested in my progress in chemistry	SA	A	N	D	SD
24 The practical experiments were related to lectures	SA	A	N	D	SD
25 What is required in the write-up of an experiment is clear	SA	A	N	D	SD
26 My demonstrators encouraged me to study more chemistry	SA	A	N	D	SD
27 The theory behind the experiments was clearly presented	SA	A	N	D	SD
28 The purpose of the calculations required for laboratory books write-up was clear	SA	A	N	D	SD
29 The chemistry demonstrators have made me feel I have the ability to go on in science	SA	A	N	D	SD
30 The laboratory manual, experimental techniques and write-up were all interlinked	SA	A	N	D	SD
31 What was required in the questions when writing up the laboratory book was clear	SA	A	N	D	SD
32 It was easy to find a demonstrator to discuss a problem with	SA	A	N	D	SD
33 The experiments were interesting	SA	A	N	D	SD
34 The amount of work required when writing up the laboratory book was appropriate for the amount of the assessment	SA	A	N	D	SD
35 The demonstrators explained problems clearly to me	SA	A	N	D	SD

B.2 Final Instrument

	Please indicate what YOU think about the following		
		Chemists	
1	unfit	_ _ _ _ _ _ _ _	athletic
2	socially unaware	_ _ _ _ _ _ _ _	socially aware
3	environmentally unaware	_ _ _ _ _ _ _ _	environmentally aware
4	fixed in their ideas	_ _ _ _ _ _ _ _	flexible in their ideas
5	only care about their results	_ _ _ _ _ _ _ _	care about the effects of their results
6	unimaginative	_ _ _ _ _ _ _ _	imaginative
7	indifferent	_ _ _ _ _ _ _ _	inquisitive
8	impatient	_ _ _ _ _ _ _ _	patience
		Chemistry research	
9	harms people	_ _ _ _ _ _ _ _	helps people
10	decreases quality of life	_ _ _ _ _ _ _ _	improves quality of life
11	creates problems	_ _ _ _ _ _ _ _	solves problems
12	causes society to decline	_ _ _ _ _ _ _ _	advances society
		Science documentaries	
13	boring	_ _ _ _ _ _ _ _	enjoyable
		Chemistry web sites	
14	boring	_ _ _ _ _ _ _ _	interesting
		Chemistry jobs	
15	easy	_ _ _ _ _ _ _ _	challenging
16	repetitive	_ _ _ _ _ _ _ _	varied
17	boring	_ _ _ _ _ _ _ _	interesting
18	unsatisfying	_ _ _ _ _ _ _ _	satisfying
19	tedious	_ _ _ _ _ _ _ _	exciting
		Talking to my friends about chemistry	
20	dull	_ _ _ _ _ _ _ _	fascinating
		Science fiction movies	
21	tedious	_ _ _ _ _ _ _ _	exciting

*Please indicate how **CONFIDENT YOU** feel about*			
1 Applying a set of chemistry rules to different elements of the periodic Table	Not confident	_ _ _ _ _ _ _ _	Totally confident
2 Achieving a passing grade in a chemical hazards course	Not confident	_ _ _ _ _ _ _ _	Totally confident
3 Tutoring another student in a first year chemistry course	Not confident	_ _ _ _ _ _ _ _	Totally confident
4 Ensuring that data obtained from an experiment is accurate	Not confident	_ _ _ _ _ _ _ _	Totally confident
5 Proposing a meaningful question that could be answered experimentally	Not confident	_ _ _ _ _ _ _ _	Totally confident
6 Explaining something that you learnt in this chemistry course to another person	Not confident	_ _ _ _ _ _ _ _	Totally confident
7 Choosing an appropriate formula to solve a chemistry problem	Not confident	_ _ _ _ _ _ _ _	Totally confident
8 Knowing how to convert the data obtained in a chemistry experiment into a result	Not confident	_ _ _ _ _ _ _ _	Totally confident
9 After reading an article about a chemistry experiment, writing a summary of the main points	Not confident	_ _ _ _ _ _ _ _	Totally confident
10 Learning chemistry theory	Not confident	_ _ _ _ _ _ _ _	Totally confident
11 Determining the appropriate units for a result determined using a formula	Not confident	_ _ _ _ _ _ _ _	Totally confident
12 Writing up the experimental procedures in a laboratory report	Not confident	_ _ _ _ _ _ _ _	Totally confident
13 After watching a television documentary dealing with some aspect of chemistry, writing a summary of its main points	Not confident	_ _ _ _ _ _ _ _	Totally confident
14 Achieving a passing grade in a Part Two chemistry course	Not confident	_ _ _ _ _ _ _ _	Totally confident
15 Applying theory learnt in a lecture for a laboratory experiment	Not confident	_ _ _ _ _ _ _ _	Totally confident
16 Writing up the results section in a laboratory report	Not confident	_ _ _ _ _ _ _ _	Totally confident
17 After listening to a public lecture regarding some chemistry topic, explaining its main ideas to another person	Not confident	_ _ _ _ _ _ _ _	Totally confident

Please answer these questions about your LECTURE classes					
1 My lecturers were interested in my progress in chemistry	SD	D	N	A	SA
2 The concepts introduced in the lecture material were explained clearly	SD	D	N	A	SA
3 My lecturers encouraged me to take further chemistry papers	SD	D	N	A	SA
4 The lecture notes were interesting	SD	D	N	A	SA
5 The chemistry lecturers have made me feel that I have the ability to continue in science	SD	D	N	A	SA
6 The lecture notes were clearly presented	SD	D	N	A	SA
7 It was easy to find a lecturer to discuss a problem with	SD	D	N	A	SA
8 The lectures were presented in an interesting manner	SD	D	N	A	SA
9 The lecturers explained problems clearly to me	SD	D	N	A	SA
Please answer these questions about your TUTORIAL classes					
10 The tutorial problems covered all parts of the course	SD	D	N	A	SA
11 The problems in the tutorial sheets were relevant to the course	SD	D	N	A	SA
12 My tutors encouraged me to take further chemistry papers	SD	D	N	A	SA
13 The tutorial sheets helped me understand the lecture course	SD	D	N	A	SA
14 The chemistry tutors have made me feel I have the ability to continue in science	SD	D	N	A	SA
15 The material presented in tutorials was useful	SD	D	N	A	SA
16 The material covered in tutorials was presented in an interesting manner	SD	D	N	A	SA
17 It was easy to find a tutor to discuss a problem with	SD	D	N	A	SA
18 The tutors explained problems clearly to me	SD	D	N	A	SA
Please answer these questions about your LABORATORY classes					
19 When writing-up experiments in my laboratory book, the relationship between the data and the results was clear	SD	D	N	A	SA
20 My demonstrators were interested in my progress in chemistry	SD	D	N	A	SA
21 The practical experiments were related to lectures	SD	D	N	A	SA
22 What is required in the write-up of an experiment is clear	SD	D	N	A	SA
23 The theory behind the experiments was clearly presented	SD	D	N	A	SA
24 The purpose of the calculations required for laboratory books write-up was clear	SD	D	N	A	SA
25 The chemistry demonstrators have made me feel I have the ability to continue in science	SD	D	N	A	SA
26 The laboratory manual, experimental techniques and write-up were all interlinked	SD	D	N	A	SA
27 What was required in the questions when writing up the laboratory book was clear	SD	D	N	A	SA
28 It was easy to find a demonstrator to discuss a problem with	SD	D	N	A	SA
29 The experiments were interesting	SD	D	N	A	SA
30 The amount of work required when writing up the laboratory book was appropriate for the amount of the assessment	SD	D	N	A	SA
31 The demonstrators explained problems clearly to me	SD	D	N	A	SA

APPENDIX C
DEMOGRAPHIC PROFILE OF FIRST-YEAR CHEMISTRY CLASSES AT THE UNIVERSITY OF WAIKATO

An accurate description of the number of students enrolled in a course and the demographic profile of the students is difficult to obtain as students' change their enrolments on a daily basis. This occurs both through official channels and through students simply not turning up for assessment exercises. Additionally privacy laws within New Zealand are strict, and data can only be used for the intention for which it was collected, and students privacy must be maintained.

For the purposes of validating the data collected by the CAEQ however, an approximate demographic profile of both semester course was obtained using summaries of official university records at the *start of the year* (Table C.1). Although, this data is meant to give an indication of the students enrolled in the class it is by no means mean to represent an accurate description of the class profiles. This is especially true for the second semester course, where the students who change their enrolment intentions throughout the first semester are included in this description.

The number of students who attended the second week of laboratory classes was used to calculate response rate in the administration of the CAEQ. This data came from roll books and in terms of numbers gives a more accurate description of the class size. However, as this data contains no demographic information a description of the students in the class could not be elucidated from this source.

Table C.1

Class demographics for the three courses in which the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) was administered.

	First semester course (%)	Analytical chemistry course (%)	Second semester course (%)
Numbers attending second week of laboratory classes	**180**	**9**	**112**
Enrollment numbers as @ 08/02/02	**156**	**5**	**123**
Ethnicity			
New Zealand European	68.6	100.0	68.3
Maori/Pacific Islander	12.8	0.0	11.4
Asian/Indian[1]	14.7	0.0	16.3
Other	3.8	0.0	2.4
No data available	0.0	0.0	1.6
Gender			
Male	51.9	80.0	50.4
Female	48.1	20.0	49.6
No data available	0.0	0.0	0.0
Decile rating of contributing school[2]			
Overseas student	2.6	0.0	2.4
Low decile school	42.3	20.0	40.7
High decile school	50.0	80.0	51.2
No data available	5.1	0.0	5.7
Enrollment reason			
Chemistry major	16.0	20.0	21.1
Science degree (support)	38.5	40.0	42.3
Science degree (compulsory)	24.4	20.0	17.9
Interest	3.2	0.0	0.8
Other	0.6	0.0	0.8
No data available	17.3	20.0	17.1

[1] Indian students in New Zealand are typically immigrants from the Fijian Islands, rather than India or the subcontinent.