

National Key Centre for Science and Mathematics Education

**Ethnic Minority Science Students in New Zealand: Attitudes and
Learning Environments**

David Alexander Lillis

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ABSTRACT

This thesis describes a study of the attitudes towards science and learning environments among junior secondary school science students in New Zealand, focussing particularly on Maori and Pacific Island students. The rationale for the research was that ethnic minority group students often experience difficulties in adapting to modern science education. The study was restricted to forms three, four and five of the New Zealand education system in order to focus attention primarily on the development of recommendations for enhancement of science education outcomes which relate to the early years of science education.

The study aimed to investigate student attitudes towards science and their perceptions of their learning environments by using questionnaire surveys and interviews in order to produce complementary information about students' attitudes and perceptions. The study produced some unexpected findings. For example, Maori and Pacific Island students displayed more positive attitudes towards science than others, and female students displayed more positive attitudes than males. These findings contradict those of many previous studies.

The findings of the study are used to provide input to the development of recommendations for the enhancement of educational outcomes for all students, but especially for ethnic minority students in science.

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CHAPTER ONE

The main thing we have learned from educational research is that we have not learned much from education research.

Mary. M. Kennedy (1997)

NEW ZEALAND ETHNIC MINORITIES AND EDUCATION

1.1 Context and Background to the Research

1.1.1 Secondary Science Education in New Zealand

In New Zealand, science is compulsory for all students to the fifth form year. Up to and including the fifth form year, the national science curriculum includes the three core sciences – physics, chemistry and biology. At the fifth form level, students may also elect to study the core sciences individually and in greater depth. By the sixth form, the sciences are no longer compulsory and students may specialise in one or more of the core sciences. At the seventh form, students read for the University Bursary examination, formally the equivalent of the British A-levels, and some take examinations for university scholarships which involve the same course material as the University Bursary courses, but involve final examinations of a much higher level of difficulty.

This system caters for students of all backgrounds and ability. However, it is not clear that this system or the curricula which support it are ideally suited to meet the needs of all students, particularly those from non-western backgrounds (a brief description of the New Zealand education system is given in Appendix 1). It was consideration of this problem which motivated the present study undertaken by the author of this thesis, a European male, formerly a science teacher of Māori, Pacific Island, European and Asian students. The author determined to adopt no particular position as researcher apart from that of information gatherer, and to hold no preconceptions about the students to be researched, and felt that neither his ethnicity nor gender presented problems of credibility with ethnic minority or other students.

1.1.2 Science Education and Maori and Pacific Island Students

New Zealand's Maori and Pacific Island people do not perform as well educationally and socioeconomically as other groups. There are many factors which might contribute to educational disadvantages for Maori and Pacific Islanders. These include possible inappropriateness of curricula, restricted access to high quality educational services for some, the problem of English as a second language, as well as poverty, ill-health and low self-esteem.

Like Australia's Aboriginal people, Maori and Pacific Islanders belong to cultures which, until recent times, were traditional (see section 1.4, ii and iii for definition). After several generations of exposure to European culture, many no longer retain their purely traditional values and customs. However, Patterson (1998, in press) points out that 'the word traditional does not mean something which is more or less lost in the mists of antiquity. . . .' and that 'the narratives that form the core of the tradition of a group of modern Maori are inseparably woven into their ways of thinking and feeling'. This is probably true for Pacific Islanders as well as Maori.

The experience of many ethnic minorities subsumed into societies culturally and ethnically different from them is frequently that of alienation. It is probable that the alienation of Maori and other ethnic minority group students in New Zealand is common to many ethnic minority group students adapting to European culture (Valda Kirkwood, pers. comm.). Therefore, in order to better understand the problems of minority groups in education, comparative studies must be carried out to understand the educational experiences of these groups. Such a study is attempted in this thesis, the importance of which lies in informing teachers and policy-makers about different ethnic groups and, based on analysis and reflection, in suggesting ways in which their needs can be met more effectively. The utility of this research study is discussed further in section 1.3.

1.2 Maori and Pacific Island People

1.2.1 Maori and Pacific Island Populations in New Zealand

1.2.1.1 Maori

According to the 1991 census, New Zealand's Maori population (those who identify themselves ethnically as Maori) numbered 434,847. A greater fraction of Maori than others were under the age of 15 (37.5% by comparison with 23.2% for New Zealand as a whole). About 4.4% of Maori were over the age of 60 by comparison with 15.5% for New Zealand. Approximately 89% of Maori live in the North Island, particularly in Northland, Auckland, the Bay of Plenty and Waikato.

In 1987, the Court of Appeal released an important decision in the case of 'New Zealand Maori Council vs. the Crown'. A special relationship was found to exist between Maori and the Crown, based on partnership. This relationship requires the Crown to 'act reasonably' in respect of its dealings with Maori.

1.2.1.2 Pacific Islanders

The majority of Pacific Islanders in New Zealand are of Samoan, Cook Island Maori, Tongan, Niuean, Fijian and Tokelauan origin. The Pacific Islands population is young - just under half are of less than 20 years of age. About 67% live in Auckland, 16% in Wellington and the remainder are distributed unevenly across New Zealand, concentrated mainly in the larger cities. The total Pacific Islands population is considerably less than half that of the Maori population. In 1996, some 49,148 Pacific Island students attended New Zealand schools by comparison with 463,175 European students, 130,016 Maori, and 33,450 Asian students (New Zealand Ministry of Education, 1997). A government agency, the Ministry of Pacific Island Affairs, has the responsibility of dealing with issues affecting the economic and social wellbeing of Pacific Islanders in New Zealand.

1.2.2 The Educational Performance of Maori and Pacific Islanders

1.2.2.1 Maori

(i) Maori Culture

Many ethnic minority students in New Zealand have only a very rudimentary command of the English language. Additionally, certain of them, particularly those of Maori descent or those from the Pacific Islands, belong to cultures holding strong religious and cultural beliefs which may sometimes be incongruent with twentieth century western societal and scientific paradigms. It is possible that these factors can mitigate against their enjoyment of, and success in, education generally and science education especially. For example, Maori culture emphasises the extended family, or 'Whanau', as a central theme of daily life. In this paradigm, members cooperate rather than compete, and great importance is placed on community life. Thus, many Maori feel a sense of alienation in present-day New Zealand society and often experience difficulties in adapting to an education system in which students are required to engage in open academic competition.

(ii) Maori Education Statistics

Maori educational statistics do not compare favourably with those of other groups. In 1974, 28.1% of European students passed the University Entrance examination compared with 4.6% of Maori students. The statistics for recent years are very similar and demonstrate consistently lower achievement levels for Maori students than for other groups. For example, publicly available New Zealand Ministry of Education analyses of the performance of Maori and other students in the 1993 and 1994 national examinations show that in 1993 some 41% (81% were assessed) of Maori females achieved passing grades of A, B or C in the national School Certificate examination by comparison with 65% of all females (91% were assessed). Only 36% of Maori males (74% were assessed) achieved passing grades by comparison with 59% of all male students where 88% were assessed (Education Trends Report, 1994).

Similar performance gaps are evident at all levels of national examination. In the same year, in the University Bursaries and Scholarships examination, 58% of Maori females achieved passing grades (66% were assessed) by comparison with 76% of all

females (84% were assessed); 57% of Maori males achieved passing grades (62% were assessed) by comparison with 72% of all males (85% were assessed). In 1993, out of 9,770 Maori school leavers, 33.5% left school without any formal qualification, 24.7% with school certificate as their highest qualification, 25.5% with 6th form certificate and 16.3% with seventh form certificate. In 1994, around 40% of Maori students were successful in School Certificate (grades A, B or C) and in Sixth Form Certificate examinations (grades one to five) compared with over 60% of non-Maori students (Education Trends Report, 1994).

(iii) Maori Student Retention Rates

Since 1990, retention rates for Maori students in seventh form, the final year of high school in New Zealand, have increased from 15% to over 27% (Statistics Returns, 1997). Since the late 1980s, the number of Maori children enrolled in early childhood education has more than doubled from 12,000 to over 28,000 children. A very important initiative for Maori education is *Te Kohanga Reo*. Kohanga Reo first began in 1982, and provides Maori language immersion programmes for children under five years of age. These programmes have experienced considerable growth since 1990, both in the numbers of Maori children enrolled and in the number of centres opened throughout New Zealand. By 1994, there were more than 13,000 children attending Kohanga Reo and in 1997 there were more than 800 centres. Some 50% of all Maori children enrolled in early childhood education presently attend Kohanga Reo. Between 1976 and 1994, the number of Maori enrolments in primary schools increased by 25% and in secondary schools by 43%. During the same period there was a 25% decline in numbers of non-Maori children in primary schools and a 10% decline in secondary schools.

(iv) State Schools for Maori

The success of Kohanga Reo led to the establishment of state schools for Maori at the primary level, *kura kaupapa Maori*. Kura kaupapa teach all subjects through the medium of Maori and numbers of kura increased from six schools in 1990 to 43 schools in 1995. Two Wananga (public-funded tertiary institutions which offer degree courses emphasising Maori language and culture) were established in 1993 and are intended to provide Maori students with tertiary education and training

designed to meet their needs. Between 1989 and 1994, enrolments increased from 5,000 to more than 21,000. Correspondingly, Maori enrolments increased from 3.7% of total tertiary enrolments in 1989 to 10.4% in 1994. The numbers of graduates doubled between 1990 and 1993 (6.4% of all New Zealand university graduates). Altogether, in 1993, there were 335 schools offering some form of Maori medium education, catering for some 18,000 Maori students (Education Trends Report, 1994).

(v) Maori at the Tertiary Level

Maori enrolments at the tertiary level demonstrate a distinct unpopularity of science courses. In 1993, at the Bachelors level, 107 Maori were enrolled in the humanities, 122 in education, 141 in the social sciences, 139 in business and commerce. In the same year, only 38 Maori enrolled in the natural sciences, 12 in engineering, and only 3 in mathematics. Postgraduate enrolments show the same preference for the humanities (16) and commerce (24) as opposed to the natural sciences (5).

The proportion of Maori leaving school and proceeding to further study at colleges of education and universities is still less than half that for non-Maori. Nevertheless, in recent years there have been significant improvements in the retention and performance of Maori in education:

- In 1994, 63% of Maori stayed to the sixth form compared with 27% in 1984.

In 1997, there were 38 kura kaupapa Maori and 15 new kura were due to open over the next three years (Statistics Returns, 1997).

- The number of children learning te reo in primary schools is now more than 44,000, of whom 44% are Māori (Statistics Returns, 1997).
- The number of students in Maori medium education has now reached 20,000 (Statistics Returns, 1997).
- Maori students enrolled in universities, polytechnics and colleges of education in 1994 increased by 2,625 or 14.2% (Statistics Returns, 1997).
- Of the 28,952 Maori children enrolled in early childhood education in 1994, 47% were enrolled in kohanga reo (Statistics Returns, 1997).

1.2.2.2 *Pacific Islanders*

Similarly to Maori, in all New Zealand public examinations the performance of Pacific Island students compares unfavourably with others. In the School Certificate examination of 1994, only 33% of papers sat by Pacific Island students gained passing grades of A, B, or C compared with 65% of others. A similar gap exists at the higher levels of examination. In the University Bursary examination, 48% of Pacific Island students gained passing grades compared with 78% of others. In 1994, 24% of Pacific Island students left school without a formal qualification compared with 16% of others, and only 5% compared with 20% of others obtained University Bursary (Education Trends Report, 1995).

At the tertiary level, Pacific Island students demonstrate similar preferences to Maori for education (780), the humanities (1220), the social sciences (591) and business (1388), with few opting for the natural sciences (359) or mathematics (20) (Education Trends Report, 1995).

1.2.2.3 *Recent Immigrants*

Within the New Zealand education system there are students from many minority-groups, including Maori, Pacific Island and smaller numbers from eastern Europe. Since 1990, more than 60% of immigrants have come from Asian countries. Chinese are the most numerous of New Zealand's Asian immigrant populations (45,000 in 1991). Indians are also numerous (31,000 in 1991), and there are small populations of Philipinos and Cambodians, numbering 5,000 and 4,000 respectively in 1991 (Vasil & Yoon, 1996). Asians also make up New Zealand's most highly educated group as over 20.4% of Asian immigrants arrive in New Zealand with university qualifications by comparison with 8% of New Zealanders as a whole (Vasil & Yoon, 1996).

New Zealand's total population rose from just under 2.5 million to 3.5 million between 1960 and 1990, though only 6% of that growth came from immigration. This growth occurred because, for most of the 1980s, fewer immigrants came to New Zealand than left. In recent years, however, the number of immigrants granted residency has risen steadily from 25,673 in 1992 to 54,811 in 1996. By comparison,

Australia accepted fewer than 90,000 immigrants in 1996, though its population is more than five times that of New Zealand's. New immigrants are possibly attracted by an improved New Zealand economy. Unemployment in New Zealand in 1997 experienced its lowest levels for several decades at 6.2%.

1.3 About this Study

1.3.1 The Research Problem

The examination performance data of section 1.2 indicate clearly that Maori and Pacific Island people experience significant problems in education, both in retention within the education system, and in achievement. Under-performance is significant in science education, where Maori and Pacific Island achievement is clearly below that of other groups. The present study is intended to shed light on this problem by investigating particular aspects of student attitudes and learning environments which may relate to cultural background.

1.3.2 Practical Significance and Rationale for the Study

The study is intended to investigate the attitudes towards science and perceptions of learning environments among Maori, Pacific Island and other students in New Zealand, and to consider the problems encountered by students from non-western cultures in adapting to western high school science education.

Educational research is intended to increase our knowledge of the teaching-learning process, thereby increasing the wider knowledge-base for professional practice which can influence teacher, teaching and learning effectiveness in present-day and future classrooms. Additionally, students learn about learning from witnessing adults in the process of learning. They see the value of persistence and become aware of an abundance of resources which contribute to learning. Comparisons of attitudes and learning environments between ethnic minority group students in New Zealand with similar students in other countries, particularly third world countries (see Chapter

Two, section 2.5), may give rise to findings which should enable improved education policy to be developed. The findings could also assist in the design of curricula suited to ethnic minority group learners and help teachers to better understand the needs of this particular group of students. The findings should also be of considerable interest to other researchers in science education generally and to those working in curriculum design and the education of minority group students.

Additionally, teachers may benefit through improved interpersonal behaviour in the classroom, perhaps of particular utility in other countries characterised by high cultural diversity such as Australia, the United States and Great Britain, where considerable sensitivity is needed to accommodate the needs of students of widely differing backgrounds. Fisher and Fraser (1991) have reviewed past and current attempts to include such work in teacher education programmes, but Fraser (1989) reports that little progress had been made up to that time in the incorporation of psychosocial learning environment research in teacher education. Thus, there is potential for the findings of this study to make a substantial contribution to the enhancement of teacher education through enhanced understanding of the problems and needs of ethnic minority group students. Creton, Hermans, and Wubbels (1990), considering the utility of psychosocial environment research, proposed improvements to teacher education programmes which would assist teachers in this regard. Their study focussed on generic teacher interpersonal behaviour, but the author of the present study contends that there is a further need to focus on the needs of minority group students in respect of communication, leadership and discipline. However, these issues are beyond the scope of this study.

1.3.3 Theoretical Significance

Research into how associations between different environments can influence school achievement has been conducted by Marjoribanks (1991) and Moos (1991). Marjoribanks has shown how the home environment can interact with the school environment and co-determine achievement, while Moos has investigated the links between school, home and parents' work environments. The home environment and parents' work environments are merely parts of the wider culture in which the child

develops and grows. Thus, there is good reason to investigate the associations between the school environment and the broader culture, particularly for groups which presently under-perform in education, and to examine those associations in the context of constructivist theory (see Chapter Three). This study therefore makes an important contribution to our understanding of the associations between student attitudes, learning environments and cultural backgrounds.

1.3.4 Research Questions

In order to set a framework for the study, the principal research directions to be undertaken were articulated as research questions. Five research questions are addressed in this study:

1. Are there any differences in students' attitudes toward the present science curriculum between ethnic minority groups and others?
2. Are there any differences in students' perceptions of their learning environments between ethnic minority groups and others?
3. Are there any associations between ethnic minority group students' perceptions of their learning environments and their attitudes to science?
4. Are there any associations between ethnic minority group students' perceptions of their learning environments and their achievements in science?
5. Are there any associations between ethnic minority group students' attitudes to science and their achievements in science?

These research questions and the methodologies for addressing them are discussed in detail in Chapter Four.

1.4 Glossary of Key Terms

In this section, key terms and descriptors used in this thesis are defined.

(i) Psychosocial Development

The psychosocial development of students in education refers to the ways in which individuals resolve biological and psychological changes within themselves in respect of environmental expectations made up of social norms and roles (Rogers, 1989), and includes '*qualitative changes in thinking, feeling, behaving, and relating to others and to oneself*' (Chickering & Reisser, 1993, p. 2).

(ii) Traditional Society

A society deriving its cultural identity and values from tradition.

(iii) Traditional Students

Students whose ethnic background is from a traditional culture.

(iv) Lower Form Level

Forms three to five in the New Zealand education system.

(v) Upper Form Level

Forms six and seven in the New Zealand education system.

(vi) Ethnicity

'Ethnicity' refers to a classification of individuals based on a shared sociocultural heritage that includes similarities of religion, history, and common ancestry (Pederson, 1988 p. vii). Ethnicity is frequently a function of nationality and race, a combination of geographic and biological variables. For the purposes of this study, participants self-identify their ethnicity.

(vii) Race

A biological, immutable classification that generally categorises people on the basis of the colour of their skin (Robinson, 1993).

(viii) Culture

Culture refers to an individual's total way of living and to the shared values, beliefs, norms, and traditions of a group of people who choose to affiliate with a particular group (Testa, 1994).

(ix) Acculturation

Acculturation is that process by which an immigrant's attitudes and behaviour change towards those of the dominant cultural group as a result of exposure to the new cultural system (Orozco, Thompson, Kapes, & Montgomery, 1993, p. 149).

(x) Maori

People of a common ethnic heritage who are the indigenous people of New Zealand and who self-identify as Maori.

(xi) Pacific Islanders

People of a common ethnic heritage derived from several Islands in the Pacific including Tonga, Samoa, Niue and Fiji and who identify themselves as such.

(xii) European

People who refer to themselves as White, Anglo, Caucasian, or from a predominantly European heritage. This term is chosen because it is most commonly used in the literature.

(xiii) Socioeconomic Status

Socioeconomic status pertains to one's relative position on measures of wealth, power and status within a particular society or culture (Mueller & Parcel, 1981).

1.5 Overview of this Thesis

Maori and Pacific Island students consistently under perform in science education. The study described in this thesis was conceived as a way of understanding the reasons for this under-performance and suggesting ways in which this problem could be addressed. Understanding this problem and addressing it are of importance because of the great practical economic and personal significance that educational failure has for these groups.

There are several discrete aspects to the design and implementation of this study which are described in the eight chapters of this thesis. In Chapter One, an overview of the research problem and the contextual background is presented. Chapter Two discusses the New Zealand education system, trends in science education in non-western countries, cultural practices and science education, and the constructivist view of learning. In Chapter Three, notions of science and science learning, constructivism and traditional thought styles are discussed. Chapter Four outlines the interpretive framework for the study, and includes a discussion of the research methodologies used. The five research questions addressed in this study are presented and the implementation of the research techniques explained. In Chapter Five, the results of the implementation of an attitudinal questionnaire survey (the Test of Science Related Attitudes survey) of the minority group students are presented and discussed. In Chapter Six, the results of the implementation of a learning environments survey (the Constructivist Learning Environments Survey) are discussed. Chapter Seven discusses the findings of interviews with teachers and students. Chapter Eight summarises the findings of the study and presents conclusions and recommendations for further research.

CHAPTER TWO

While significant numbers of Maori achieve well in the education system, far too many do not. A key issue for New Zealand's economic and social development is that the present disparities and gaps in participation, retention and achievement are progressively eliminated. Over the next year the Government will work with Maori and the wider community to develop an education strategy designed both to raise Maori educational levels to match those of other New Zealanders, and to support the maintenance of Maori language and culture. (New Zealand Government Education Policy Statement, 1997).

EDUCATION INITIATIVES AND TRENDS IN SCIENCE

EDUCATION IN NON-WESTERN COUNTRIES

This chapter describes initiatives for enhancing educational outcomes for Maori and Pacific Islanders, and discusses the relationship between cultural practice and science education. Brief discussions of the experiences of ethnic minority groups in other countries are given, a review of recent science education initiatives internationally is given, and the chapter concludes with a survey of the economics of education as it pertains to ethnic minority groups.

2.1 Intervention for New Zealand's Ethnic Minority Groups

2.1.1 Education Policy-Making in New Zealand

The regulation of the education sector is currently spread across a number of acts and regulations. The most important act, the Education Act 1989, incorporates numerous amendments arising from the education reforms of 1989, 1990 and later (a detailed account of the recent developments in New Zealand education is given in Appendix 2.1). This act affects all aspects of the education sector. A major concern is to ensure

that education legislation does not impose unnecessary compliance costs, nor discourage worthwhile innovation.

Four key strategies drive the New Zealand Government's approach. They are:

1. Continuing to strive for quality
2. Ensuring that the education system can meet demand
3. Building a system which responds well to the changing needs of individual New Zealanders and of New Zealand workplaces, as well as to international influences and technological change
4. Raising the educational achievement of all students, including those at risk of failure.

In developing policy initiatives for education, the New Zealand government saw three inter-related themes flowing from the objectives, environment, and strategic focus outlined above:

1. Lifting educational attainment
2. Building capacity to meet demand
3. Integrating education, social and labour market policies.

This act was reviewed in 1994/95 with the aim of giving legislative support to government policy; eliminating unnecessary regulation; providing a general legislative base for supporting a responsive education system; reducing compliance costs for the sector; and ensuring that the legislation is comprehensible. Other recent policy initiatives include the Ministerial Consultative Group on Teacher Workload, established in 1996 to address concerns about teachers' workloads.

Education policy relating directly to Maori include many initiatives described in the Ministry of Education's Ten-Point Plan which gave expression to the establishment of Te Kohanga Reo (see section 1.1.2.1), initiatives for increasing the involvement of Maori parents in schools, and Maori language development courses. Educational policy relating to Pacific Island students is addressed in the Plan for Pacific Island Education discussed in section 2.1.3.

2.1.2 Legislative Intervention for Maori

New Zealand's legislative intervention for the empowerment of Maori has in recent years focused on formalising mechanisms for honouring the Treaty of Waitangi. The Waitangi Tribunal was established by the Treaty of Waitangi Act 1975 in order to make recommendations on claims relating to the practical application of the principles of the Treaty. The Act was amended by the Treaty of Waitangi Amendment Act 1985 to enable specific claims to be made. In recent years, the New Zealand parliament has recognised the Treaty and accepted the need for redress for wrongs committed in the past. The Waitangi Tribunal has recommended the return of land at Orakei (Bastion Point), and other cases relating to claims on land and fisheries are being heard.

2.1.3 Education Initiatives for Maori

In recent years, consultations have been held with teachers, school principals and boards of trustees throughout New Zealand to facilitate effective Maori participation in the Education Development Initiative scheme (EDI). The EDI process aimed to encourage communities to review local education services and to consider whether they could be organised more effectively. Discussions have centred on Maori parents' expectations such as the establishment of bilingual classes, total immersion schools, and the involvement of their students in a national monitoring programme.

In the 1994/95 financial year, funding was provided for many initiatives to enhance Maori educational outcomes to a total of over \$197 million. These included funding for Te Kohanga Reo National Trust, sessional funding for chartered Kohanga, Kohanga developing centres, Maori advisers, resource teachers of Maori, teachers (bilingual discretionary), Maori language factor funding, teacher training, colleges of education, Te Kohanga Reo National Trust, Maori specialist courses, bilingual courses, administration of Manaaki scholarships for Maori students, Maori Education Trust and vocational training (Statistics Returns, 1997).

Since 1995, there has been an expansion of initiatives to enable more Maori students to learn through the medium of Maori language. In 1994/95, a \$30 million increase in funds was provided solely for Maori medium education in addition to the \$93 million

allocated for Maori language initiatives annually. A number of iwi (Maori councils) have also developed education plans and several more are presently in the process of developing them. Maori communities have been encouraged to become involved in the consultation process on Education Development Initiatives which have attempted to induce communities to examine local education services and to consider whether they could be organised differently or better. For Maori communities, this often means looking at establishing bilingual or total immersion schools, amalgamating rural schools, or combining classes in some other way.

As a response to concerns over the low participation and achievement rates of Maori in the fields of mathematics, science and technology, Te Puni Kokiri (the Ministry of Maori Development) established an advisory committee to address these issues. The National Association of Maori Mathematicians, Scientists and Technologists (NAMMSAT) developed out of these discussions. NAMMSAT aims to facilitate increased participation and achievement by Maori in the fields of mathematics, science, and technology by using a number of strategies which have the following aims (NAMMSAT, 1995).

- To promote the sciences in all areas of education and training
- To promote the sciences in primary and secondary schools
- To target Maori students in recruitment for tertiary study in the sciences
- To provide links between industry and Maori students
- To assess and develop support for Maori students in the sciences at tertiary level
- To encourage the professional development of Maori teachers of science
- To promote and provide support for Maori in applying for mathematics, science and technology scholarships, fellowships and contracts
- To promote and support the development of the Maori body of knowledge of the sciences
- To develop and encourage the support of the science industry for Maori
- To provide support for Maori currently working in the fields of science, mathematics and technology
- To expand into the international arena of education for indigenous peoples.

NAMMSAT has organised science camps and in 1997 organised a 'Leadership in the Sciences' Wananga (symposium) for senior Maori science students. Additionally, NAMMSAT is developing and maintaining a national database of Maori involved in mathematics, science and technology, and has developed and maintained strong links with similar overseas indigenous groups such as the American Indian Science and Engineering Society (AISES) in the United States. NAMMSAT is currently developing the Hangarau (technology) curriculum in te reo Māori (Munn, 1995).

Laudable as these initiatives are, it must be admitted that progress towards raising the educational profile of Māori, though real, is nevertheless slow. This may partly be because of a perception on the part of Māori that these initiatives implicitly reinforce a dominance of western values as well as dominance and superiority of western science over indigenous scientific knowledge.

2.1.4 Education Initiatives for Pacific Islanders

Policy relating to Pacific Island students is given expression in the Ministry of Education's Plan for Pacific Island Education which describes initiatives such as the Aim High Project, in which eight schools with large Pacific Island enrolments are taking part in a data gathering exercise in tandem with a teacher development programme. Other initiatives include the Pacific Island Schools and Community Liaison Project run by the Ministry of Education involving six clusters of schools aiming to increase parental involvement in school life, a teacher development programme, and a new Samoan language programme (see section 2.3.2.4).

2.2 Cultural Practice and Science Education

2.2.1 Introduction

This section discusses the world views of 'traditional' societies and examines how conflict between orthodox science teachings and these world views can impede success in education. Most present-day Maori and Pacific Islanders are not purely

traditional in that most have lived in a western culture for several generations and many espouse western values and life-styles. However, many still hold to cultural beliefs and mores and this must be considered in any investigation of their socio-economic and educational performance. Many have espoused Christianity, particularly Pacific Island immigrants, and it is reasonable to conjecture that literal beliefs in the teachings of the Bible may sometimes conflict with what is taught in the science classroom. Perhaps, a more correct term for present day urban Maori and Pacific Islanders is '*pseudo-traditional*', embodying the notion that a residual traditional style of thinking is common amongst these people, but also that western society has exercised a profound influence on their thinking and lifestyles.

There are some Maori today who are intimately connected with some of the roles and responsibilities connected with kaitiakitanga [the responsibility to care for the natural world], but very many of us have lost touch with some of those traditions and practices that helped the land to sustain itself. (Henry, 1995, p. 45)

2.2.2 The World Views of Traditional People

Davey (1972), Wilson (1981) and other workers have examined the interaction of cultural practice and science and concluded that cultural factors may give rise to conflictual problems in science education. A central problem for traditional students is that of a dual (bipolar) world view which Dart and Pradham (1967) have termed 'mythological' and 'scientific'. Cockright (1974) reaffirmed this finding and reported that many African school children explained natural phenomena in terms of traditional cultural beliefs irrespective of their exposure to high-school science. Sawyer (1979) suggested that traditional students often leave behind scientific thinking when entering their home environment. As examples of this duality, Baimba (1991) relates how some Sierra Leonean children, who at school have been taught the value of purifying water, nevertheless retain a belief that running water is purified by spirits or angels. Such children frequently explained everyday phenomena such as the motion of a swinging bridge in terms of witchcraft rather than as the result of dynamic forces. Baimba coined the phrase '*reversal effect*' to explain how in the lives of these students it is frequently their cultural values and beliefs which predominate rather than western scientific ideas.

Thaman (1992, 1993) has argued further that exposure to the educational values of a culture alien to the learner will inevitably result in teaching and learning difficulties. There may be many specific causes of such difficulties, but Serpell (1993) believes that the prime cause is the dislocation between the goals of the curriculum and the cultural goals of the group to which learners belong. Serpell sees technological mastery of the environment as one of western society's major educational goals. This conflicts with the indigenous belief in nature as an integral part of the ecoculture which is to be nurtured and respected. The technological mastery model on which western education is founded also gives rise to conflict with indigenous notions of education. The western model includes gradation of schooling, projection of grading into child development, the stigmatisation of the unschooled, condescension in teacher-pupil relationships, and the concept of educational expertise (Thaman, 1995). These educational norms are not characteristic of either Maori or Pacific Island thinking and differences in conceptualisation of education are experienced by teachers as well as pupils (John Fiso, pers. comm.).

Although our training commits us to the practices of the modern school curriculum, our personal identities are often rooted in indigenous norms of socialisation. (Thaman, 1988).

2.2.3 The World Views of Maori

Although the majority of Maori hold western values, there are many communities in which Maori traditional culture remains strong and in which Maori language is spoken as the first language. Maori religious and cultural beliefs are not held as strongly as formerly, particularly among urban Maori, and may not of themselves give rise to significant conflictual difficulties. Indeed, the last 50 years has seen a great exodus of Maori from rural settings to the cities. In 1936, only 10% of Maori lived in cities or boroughs, but by 1976 76% of Maori lived in cities (Spoonley, 1988). However, conflictual difficulties resulting directly from Maori beliefs, values and norms almost certainly abound for some Maori students, and a profound sense of cultural alienation, keenly felt by many Maori, can serve to amplify problems within the education system.

Even today, Maori protocol implicitly involves a belief in pre-European deities which are addressed when Maori make formal speeches on Marae (Wally Penetito, Victoria University; pers comm.). Additionally, there are strong expectations on young Maori, particularly those being groomed for leadership roles, to fulfil not only the academic expectations of the education system, but also to fulfil cultural and behavioural expectations made on them by their communities (Penetito, pers comm.). Patterson indicates that Maori traditional beliefs can impede the transition to scientific ways of thinking, but makes the distinction between those who have been brought up in strongly traditional Maori families and those, perhaps the majority, who have not (John Patterson, Massey University; pers comm.). Moreover, the reaction of New Zealanders of European descent to Maori cultural values is not always favourable.

Maori spiritual values may not be compatible with the spiritual beliefs Christian parents desire to instil in their children. (Letter to the editor of the Evening Standard, 22 May 1986)

and

Maori culture is based upon and run through with a totally anti-Christian involvement with the spiritual realm. (Concerned Parents Association Newsletter, September, 1986).

Evidently, in addition to coping with life in a culture different from their own, Maori people frequently must cope with the sentiments of others which are intolerant of Maori cultural values.

2.2.4 The World Views of Pacific Island People

Pacific Island peoples, of whom Samoans and Tongans are the most numerous in New Zealand, still hold strong cultural and religious beliefs, although these have become less strongly held among those who have resided in New Zealand over more than one generation (Annette Karipa, Ministry of Pacific Island Affairs; pers comm.). These beliefs include a strong belief in spiritualism, ghosts, myths and legends, the importance of the extended family (the Aiga), the importance of love and respect and, in recent decades, the growing importance of Christianity (John Fiso, Rongotai College; pers comm.). Pacific Island youth are required to straddle the two worlds of

western civilisation and their native cultures. This poses insurmountable problems for many (Annette Karipa, pers comm.).

For Samoans, learning is a continuous process aimed at acquiring the knowledge, skill and values necessary for survival in society (Levy, 1995). This notion is central for Samoan culture, or Fa'a Samoa. For Tongans, vital cultural norms include the supernatural, kinship, rank and conformity, restraint behaviour and compassion (Thaman, 1988). For example, in Tongan society the ideal person is *poto*. A person is said to be *poto* if he or she uses knowledge in ways which are beneficial to the group or community. Pacific Island cultures generally encourage sameness and frown upon individualism and western notions of success (John Fiso, pers comm.).

The importance of spiritualism, for example, is now much lower for Pacific Islanders who were born in New Zealand than for those who have recently emigrated, but is nevertheless a vital part of the lives of many (Annette Karipa, pers comm.). However, for many second and third generation Pacific Islanders, superstition is still a dominant force in their lives (John Fiso, pers comm.) and the old myths and legends still have great meaning. As with Maori, it is probably incorrect to class most Pacific Islanders in New Zealand as belonging to a traditional culture, and the term 'pseudo-traditional' is again probably more accurate.

In Chapter Three (section 3.4), cultural practices, beliefs, values and norms characteristic of traditional societies and western society are compared. In the next section, the differentiated approaches to problem-solving between traditional people and western people are discussed.

2.2.5 Traditional and Scientific Problem Solving

Dart (1972) and Davey (1972) reported that in traditional societies knowledge is perceived as static, passing on unchanged through successive generations. Trowbridge (1974) has noted that Nepali children display approaches to problem solving which often reflect the adult society of the culture in which they live. He reported that Nepali children are taught to approach a problem by recalling a

'traditional' solution. By comparison, a western child will usually have been taught to 'deal with' a problem situation and will have been encouraged to 'come up' with a solution. In Chapter Three (section 3.3), an approach to understanding how children learn and build upon prior knowledge, and how learners approach problem solving, is discussed. This approach is known as constructivism.

Gay and Colle (1967) reported that the main goals of Kpelle children in Liberia are maintenance of the past, conformity and imitation of their elders. Baimba (1991) believes that this is common in many African traditional societies in which 'teaching students to think is opposed to traditional thought.' Thus, teaching and learning by rote has become a prevailing theme in secondary science education in these societies and the 'meaningless' (for them) material presented is assimilated purely for the purposes of satisfying the requirements of succeeding in the education system. Urevbu (1984) believes that even the small number of students who achieve success in the examination system often acquire only the 'know why' of nature and rarely the 'know how', and that traditional students have been brought up to believe that it is the responsibility of others to apply understanding. Thus, Fensham (1985) could claim that the present-day science curriculum has been largely ineffective for many African countries for the majority of students who will never continue with formal scientific education after completing secondary school.

Baimba asserts that science education might serve the interests of traditional students better if it were presented as a medium for linking traditional and scientific perspectives on nature and knowledge. Ogawa (1986) has articulated the interconnectedness of science and the socio-political economies of non-western nations, noting that science and technology have in themselves become truly international 'cultures' and non-western countries therefore cannot divorce these cultures from their own. This perspective is one which may not have been espoused by all Maori, and there has developed in New Zealand a growing movement towards separatist education systems for Maori and others, although many Maori do not wish to lose touch with mainstream education (Penetito, pers comm.).

This section has discussed the differences between western and traditional scientific problem-solving. Knowledge of these differences provides a platform for enhancement of their scientific learning. In section 2.5.1 a modern approach to science curriculum philosophy, *Science For All*, which is of great relevance to science education in non-western countries, is discussed.

2.3 The Education of Ethnic Minorities

2.3.1 Ethnicity, 'Race' and Education

There is considerable anecdotal evidence that primary and secondary-level students from cultures greatly different from twentieth century western culture may experience conflict between their traditional religious and cultural beliefs and paradigms of western scientific education (Valda Kirkwood, pers. comm.). Many investigations have been carried out into the experiences of students of non-western cultures in adapting to a western education system at the high school level (see section 2.5.5 for references). One rationale for such studies is that it is necessary to know how groups of students differ in order to determine what interventions and services are appropriate (Cheatham, Tomilson, & Ward, 1990).

One of these studies was that carried out by Baimba (1991) who researched the attitudes of Sierra Leonean students towards the existing junior science curriculum. He found that there was considerable negativism towards the curriculum and strong perceptions among students that science held little relevance to their daily lives. It is probable that this holds true for ethnic minority students generally. In fact, there has been little empirical research that indicates whether or not:

1. there are attitudinal differences towards education between ethnic students and others, notably European students;
2. there are differences in the psychosocial development of ethnic minority students; and
3. what these differences might be.

For example, Cheatham (1991) observed that little is known about the role that ethnicity plays in the psychosocial development of university students and that the characteristics that distinguish ethnic minority students from their counterparts must be taken into account.

Children from ethnic minority groups are exposed to stresses that can affect any child; for example, those of demanding school work, health issues, life events, social conflicts and difficult economic circumstances. In addition, ethnic minority children can also experience two other sources of stress, one related to racism and the other to their dislocated family background (Dwivedi, 1993, 1996a, 1996b). Low income levels, night shifts, long working hours, overcrowding and bad housing are common experiences amongst ethnic minority families and all increase the risk of health problems and impact on their childrens' psychological development (Braun, 1997). Racism can lead to direct or indirect racial discrimination and abuse; inequality and disadvantage in employment, housing, educational and training opportunities; unequal access to health care, welfare, local amenities, environmental quality, and to the undermining of culture, identity and self image. Many ethnic minority group students experience bullying and racial abuse in schools. Racism therefore denigrates and dehumanises communities leading to low self-esteem and depression (Fernando, 1992).

A popular study by Herrnstein and Murray (1994) does not consistently use the term 'race.' Due to its pejorative connotations, they prefer the word 'ethnicity.' Further, for them, the word 'intelligence' carries with it 'undue affect and political baggage' (p. 22). Subsequently, they employ the more neutral term 'cognitive ability' (p. 22). Herrnstein and Murray declare that the category of ethnicity is legitimate and valid because clearly 'There are differences between races, and they are the rule, not the exception.' (p. 272). They define races as 'groups of people who differ in characteristic ways' (p. 272). They also state that 'The rule we follow here is to classify people according to the way they classify themselves.' (p. 271).

2.3.2 Factors Influencing the Educational Performance of Minority Groups

Many factors may influence the lives and educational experiences of ethnic minority people. These may include the influence of gender, acculturation, socioeconomic status and language. A brief discussion of each of these influences is presented in this section.

2.3.2.1 Gender Differences

Any study of attitudinal differences towards education between ethnic groups must account for the role of gender differences (Straub, 1987; Taub & McEwan, 1991). It is widely accepted that women historically have not experienced professional and economic parity with males, both in western societies and in many others. For example, the *Task Force on Women, Minorities, and the Handicapped in Science and Technology* (1989) found that in the United States women and minorities seldom enter fields that require advanced mathematics and science degrees. Yet, at that time jobs requiring mathematical and science skills were growing at nearly double the rate of all jobs. As a result, one of the fastest growing sectors of the US economy was significantly under-represented by women and minorities.

This under-representation of females and minority males may derive from such factors as negative attitudes toward mathematics and science, limited exposure to extracurricular activities in mathematics and science, and lack of information about mathematics and science-related careers. The most influential factors, however, are low participation rates and lower performance levels in advanced courses and on standardised tests by comparison with white males (Clewell, 1992, cited in Century, 1994). According to Oakes (1990), schooling rests at the heart of the issue. She argues that females and minority males are losing ground to white males in three areas: opportunities to learn, achievement, and decisions to study science and mathematics.

Female students' lack of confidence, lack of encouragement from adults and diminished belief in the value of science and mathematics may be related to the under-representation of women in higher mathematics and science programs and in mathematics and science professions (Gardner, et al., 1989; Antony, 1994; Eccles,

1989; Blake, 1993; all cited in Century, 1994). As girls reach higher grades in school, they are more likely than boys to demonstrate lack of confidence in their ability to achieve in science and mathematics activities and are less likely to participate in upper-level science and mathematics classes (Antony, 1994; Kahle, 1991; cited in Century, 1994). Indeed, the gender gap in science may be increasing (AAUW, 1990; WEEA, 1991; cited in Century, 1994). By their senior year in high school, girls are unlikely even to approach the participation and achievement levels of boys in science courses (Holmes, 1991; cited in Century, 1994).

Differences in achievement between Europeans and ethnic minorities may partly reflect shortcomings in traditional science programs as well as the demands of a rapidly changing society. Such inequities have serious implications for the success and satisfaction of students in school and the workplace. For these reasons, the research study described in this thesis will include a categorisation of the ethnic student population by gender in addition to form level and school (see Chapters Five and Six).

2.3.2.2 *Socioeconomic Status*

Socioeconomic status is held to be an important element in many branches of psychological research (Gottfried, 1985). Luzzo (1992) observed that it is a methodological flaw not to consider socioeconomic status as a separate variable of psychological research. Arbona (1990) suggested that social investigations should take into account the influence of socioeconomic status, and the author of the present study believes that socioeconomic status should be considered in educational studies more than has hitherto been the case. Two widely used measures of psychosocial development are the Four Factor Index of Social Status developed by Hollingshead (Gottfried, 1985) and the Duncan Socioeconomic Index (Mueller & Parcel, 1981). However, the literature is inconclusive as to which of these widely accepted measures is preferable. The inclusion of socioeconomic status as an influencing factor in the present study was considered, but was deemed to be beyond the scope of the study and is more usefully addressed in a related study.

2.3.2.3 *Acculturation*

Acculturation refers to how peoples' attitudes and behaviours change when exposed to a dominant group (Orozco, Thompson, Kapes, & Montgomery, 1993). It was decided not to consider acculturation in the present study because instruments which are available to measure acculturation measure only for specific races and ethnicities. That is, no instrument was found that measures the acculturation of more than one race simultaneously, and those which were found measured only the acculturation of ethnic minorities in the United States (African Americans or Hispanics).

If it were possible to measure accurately the acculturation of multiple ethnic minority individuals, there would remain the problem of accounting for the acculturation of European students who represent the dominant groups in New Zealand. Therefore, it seemed unhelpful and beyond the scope of this study to investigate what Olmedo (1979) referred to as an 'elusive construct'.

2.3.2.4 *Language*

For most Maori, instruction through the English language poses few difficulties as this is their first language. A more pressing issue for them is the retention of Maori as a vital part of their cultural heritage. However, for many Pacific Islanders, particularly recent immigrants, language presents considerable difficulties and many students are forced to take courses in remedial English (Education Trends Report, 1995). *Ta'iala mo le Gagana Samoa i Niu Sila* (Samoan in the New Zealand Curriculum), the draft of the first community language curriculum within The New Zealand Curriculum Framework, was launched in September 1994. It is the first of the new curriculum statements to span both early childhood education and schools. The New Zealand Ministry of Education has also called for teacher professional development proposals to support the implementation of the new Samoan curriculum statement.

It is clear that language frequently poses formidable obstacles to learning for many ethnic minorities around the world. For example, a report of the Research Division of the Scottish Examination Board discussed research into the extent to which pupils whose first language is not English under-performed in the 1989 Scottish Certificate

of Education Ordinary and Standard Grade Examinations in English, relative to their performance in other subjects. Their findings showed that in the British O-level examinations performance in English was approximately half a grade worse than would be predicted by performance in other subjects (Sharp & Fitzpatrick, 1991).

2.3.3 Taking Account of Cultural Background

It is clear that low educational success, low employment levels, low occupational status and income are common problems for many ethnic minorities. School-age children of minority groups also appear to face particular difficulties, which often include a sense of isolation and alienation.

This sense of alienation, frequently already manifest at secondary school, may become particularly acute at the tertiary level, perhaps less so in some of the more 'culturally acceptable' university faculties such as law, business and the arts in which there exist established ethnic minority group role models, but certainly in the sciences where academic competition is intense and the nature of the work can easily lead to isolation and a reduction in social contacts with one's cultural peers. Fraser (1994) states that there has been a realisation that, at the level of the individual learner, 'meaningful learning is a cognitive process of making sense, or purposeful problem solving, of the experiential world of the individual in relation to the totality of the individual's already constructed knowledge'. It seems reasonable that the 'experiential world' and 'already constructed knowledge' depend on many societal and cultural paradigms which pervade a person's life. Effective education must accommodate this notion but must also account for the notion that the nature of the classroom environment has a powerful influence on the achievement of students over a range of desired educational outcomes (Fraser, 1994).

It should be noted that, in the majority of curriculum studies up to the 1970s, no systematic account was taken of either the cultural or ethnic background or of the experiences that learners bring to school (Young, 1973). Thus, Chaplin (1964) could report that textbooks were being produced for African schoolchildren without the traditional cultural background of the pupils being taken into consideration. Furthermore, Fensham (1985) reported that the secondary mathematics and curricula

in many countries involved three main deficiencies. These included an exaggerated importance of rote recall of facts of little social utility, under-familiarity with fundamental concepts to allow their scientific worth to be experienced and understood, and an under-involvement of life experiences and social applications, and then only as exemplars rather than as the ethos of learning in science. Clearly, educational under-performance still characterises many minority groups around the world. The problems experienced by these groups are, of course, shared by non-minority groups. Clark (1969) has summarised and classified the problems faced by minority groups in education. These include:

1. Low literacy levels
2. Higher than average failure rates at all educational levels
3. Higher than average drop-out rates at the secondary level
4. The experience of the curriculum as alienating
5. The high cost of education relative to income levels
6. The inadequacy of physical plant and facilities
7. High student/teacher ratios.

It was partly in recognition of pervasive problems such as these that the present study was conceived.

2.3.4 The Psychosocial Development of Ethnic Minority Students

In addition to those factors which may affect the educational performance of minority groups, consideration must be given to factors which may influence research into minority group educational issues. Ford (1983) suggested seven items which may affect the psychosocial development of ethnic minority students in education which should be considered when working with such students. These are:

1. *Cultural bondage*: Cultural allegiance can assume greater importance to the ethnic minority student than individuality or autonomy.
2. *Cultural diversity*: The diversity of the ethnic or culture group is often viewed as vitally important to the student.
3. *Cultural assimilation*: The assimilation of ethnic minority groups into the predominant culture may be viewed as an unwanted necessity by ethnic minority students.
4. *Cultural pluralism*: The concept of a melting pot, an illusion of sameness, may be viewed as a myth or hoax by ethnic minority students.

5. *Cultural values*: Allegiance to the goals and preferences of the group may be viewed as more important to the student than individualised thinking.
6. *Social paranoia*: Ethnic minority students are frequently suspicious of the predominant culture.
7. *Social transference*: The ethnic minority student may tend to exhibit transference to the teacher or counsellor, as these are seen to represent predominant European culture.

None of these items are specifically addressed in the present study, although the possibility of influences of some or all of these factors was borne in mind by the researcher, both during the implementation of the research, and during interpretation of the findings (see Chapter Five).

2.4 Ethnic Minorities in Europe and the United States

In this section, brief discussions of minority groups in other countries and a summary of the problems common to ethnic minority groups in Europe and the United States are presented in order to provide a global context for understanding ethnic minorities in New Zealand.

2.4.1 Europe

The second half of the twentieth century has seen migrations of huge numbers of people within Europe and into European countries from outside. Present day Europe is facing major transformations which include moves towards European unification, the re-emergence of nation-states in Eastern Europe, a rise in importance of ethnic minority groups, and the rise of nationalism and the extreme right.

In Western Europe, ethnic minorities now derive mainly from Africa, the Caribbean, Asia and Eastern Europe. For example, at the time of the 1989 census, there were 14 major ethnic groups living on Estonian territory. The proportion of Russians had increased more than six-and-a-half times since 1940 and the entire system of schools and cultural institutions in the affected areas had become Russian speaking. Even major ethnic groups in Estonia, such as the nearly 50,000 Ukrainians, 30,000

Belarussians and 17,000 Finns, had no schools or cultural societies in their native language (Destination Estonia, 1997). Such massive influxes of people from ethnic backgrounds dissimilar to the predominant culture naturally creates great difficulties for the education systems which must cater for students whose experiential world view is frequently quite different from that of the predominant culture, and who often speak the language of their adopted country only as a second language.

The difficulties of ethnic minorities in Europe have been expressed concisely by Aouatef (1997), an immigrant Moroccan now living in The Netherlands. She presents a description of the status of ethnic minority groups in The Netherlands which reflects the experiences of minorities in many countries around the world.

In The Netherlands the position of ethnic minorities differs in all sorts of areas. Cultural diversity often seems to go hand in hand with social inequality. The level of education of immigrants is lower than that of the national population. Turks and Moroccans score particularly badly in this respect. The educational level of immigrant women is slightly lower than that of immigrant men. This difference is strongly manifested in the Turkish and Moroccan population groups: seven out of ten Turkish and Moroccan women have received no education beyond primary level, compared with six in ten Turkish and Moroccan men. Education is an important factor on the labour market. A low level of education or none at all often means no job. Recent research shows that employment rates of Turkish and Moroccan women are lower than those of nationals.

Aouatef Rajab (Youth for Development and Cooperation, May, 1997).

2.4.2 Ethnic Minorities in the United States

2.4.2.1 Minorities and Predominant White Institutions

Similar problems to those expressed above appear to be endemic in the United States at all levels of the educational system. For example, referring to the present status of ethnic minority students in the United States, Testa (1994) writes:

Ethnic minority students report that they feel isolated and ignored, that they are subjected to racism, prejudice and patronising attitudes, and that they feel alienated and uncomfortable. (Testa, pp. 2-3)

For Testa, understanding cultural difference begins with recognising the impact of ethnic minorities enrolling in predominant white institutions. Predominant white institutions are institutions which were not founded with the intention of educating

minority groups, but rather for educating the white middle class (McEwan, Roper, Bryant, & Langa, 1990). Gunnings (1982) believes that ethnic minority students bring to predominant white institutions unique mores, customs and influences. Hawkins (1989) believes that ethnic minority students must adjust to environments that are different from what they are used to (p. 177). Further, Cheatham has stated:

. . . there is a specific and unique history and set of attendant expectations that ethnic minority students bring to campus that are rooted in the dynamics of the family and the culture and in the repertoire which develops as a function of the complex interactions between family members and the external environment. (Cheatham, 1991, p. 23).

Experiences of racism towards ethnic minorities in the United States are also well researched and documented (Commission on Civil Rights, 1990; Henley, Powell, & Poats, 1992).

2.4.2.2 African-American and Hispanic Minorities

The African-American and Hispanic ethnic minority groups are the largest in the USA (Fenske & Hughes, 1989) and, along with Native Americans, are most likely to come from economically disadvantaged backgrounds (Wehrly, 1988). Students of these ethnic minority groups have widely differing needs and display different rates of psychosocial development to White students (Testa, 1994). Many investigations have been undertaken to determine how students, when examined by ethnicity and educational class level, differ in psychosocial development (Winston, 1990; Chickering & Reisser, 1993) and a number of workers believe that there is a need for more research in this area (Gilson, 1990; Upcraft & Moore, 1990).

The belief that predominant white institutions are principally Eurocentric and unable to comprehend the need to respond to the educational and cultural needs of African-Americans (McEwan et al., 1990) is frequently reported in the literature on African-American students. Allen (1985) reported that African-American students face great difficulties on predominant white institutions and that, by comparison with white students, African American students have lower persistence rates and academic achievement, lower likelihood of enrolment in graduate programs, poorer overall psychosocial adjustment and lower occupational attainment and earnings after

graduation. The parallels between African-Americans and Hispanics in the United States and Maori and Pacific Islanders in New Zealand are clear.

2.5 Trends in Science Education in Non-western Countries

Because of clear cultural and socio-economic similarities between Maori and Pacific Islanders and other indigenous people in non-western countries, a review of recent developments in science education in non-western countries is presented here to provide a context and referent for consideration of improved teaching and learning for the ethnic minority groups in this study. A description of a recent development in the New Zealand curriculum, Technology Education, is given for reference in Appendix 2.2.

2.5.1 Science for All

2.5.1.1 The Philosophy of Science for All

Fensham (1985) has articulated the seminal desirable requirements of the Science for All movement. These include the following:

1. Curriculum content should be chosen which has demonstrable personal and social relevance to learners and considers students' prior conceptions and experiences as a starting reference point.
2. Learning should embody achievement objectives and criteria which should be realisable for most learners while admitting different levels of achievement.
3. Topics for study should always be in evidence so as to elucidate the component parts of learning.
4. Teaching practice should utilise demonstration and practical themes as much as possible.
5. Topics for learning should be chosen to be relevant and meaningful to learners so that the acquisition of cognitive and practical skills should develop naturally from them.
6. Appraisal of learning and assessment methods should take into account the prior beliefs and experiences of learners in addition to their achievements in the many aspects of the curriculum.

These six features of the Science for All movement provide a useful framework for working towards solution of the problems facing educators who have responsibility for the education of ethnic minority students, as well as for assisting the enhancement of the teaching pedagogy.

2.5.1.2 *Recent Science for All Initiatives*

The United States' National Committee on Science Education Standards and Assessment National Research Council (1993) described the premise of science for all.

The commitment to Science for All implies inclusion not only of those who traditionally have received encouragement and opportunity to pursue science, but of women and girls, all racial and ethnic groups, the physically and educationally challenged, and those with limited English proficiency. Further, it implies attention to various styles of learning and differing sources of motivation. Every person must be brought into and given access to the ongoing conversation of science (Hoffman & Stage, 1993).

The new paradigm for science learning emphasises engagement and meaning in ways that are not consistent with past practices. The anticipated outcome of this new approach to teaching is a higher level of student achievement in the sciences. This constructivist teaching and learning model calls for learning that is:

1. Hands-on: students are actually allowed to perform science as they construct meaning and acquire understanding.
2. Minds-on: activities focus on core concepts, allowing students to develop thinking processes and encouraging them to question and seek answers that enhance their knowledge and thereby acquire an understanding of the physical universe in which they live.
3. Authentic: students are presented with problem-solving activities that incorporate authentic, real-life questions and issues in a format that encourages collaborative effort, dialogue with informed expert sources, and generalisation to broader ideas and application.

The essential ingredient which characterises the Science for All approach and which differentiates it from other teaching and learning paradigms is the special consideration given to students' prior experiences and native culture. In this, the Science for All paradigm is entirely congruent with the constructivist ideal.

2.5.2 Curriculum Developments in Non-Western Countries

Since the 1970s, many third world countries have formulated education policies designed to promote and assist in the development of culture-based science curricula. Knamiller (1984) has emphasised the potential of indigenous technologies in developing science curriculum content and Kelly (1980) has recommended an issue-based approach science education which aims to make school science more congruent with community needs. Several Asian countries have established similar science education policies. Seng (1979) has emphasised that science and technology education should be compatible with cultural heritage, that curricula must be compatible with the cultural environment and that teaching and learning practice should harmonise with cultural concepts and values.

In Columbia, the Foundation para la Aplicacion Ensanza de las Ciencias has adopted a learner-centred policy which assumes that education for development should begin with a knowledge of what is needed to realise human potential for tackling community problems and that the appropriate knowledge and skills are then fostered in school curricula (Knamiller, 1984).

Ogunniyi (1986) suggests that, for many African counties, science curricula should include topics such as mechanised farming, disease control, particularly for malaria, the production of food and the provision of drinking water. Vielfaure (1980) worked with rural students in Zambia who often lacked access to scientific equipment. His approach was to lead these students to elicit the scientific principles which underlie many of the traditional activities of their cultures. These included traditional home-building, medicine and bellow-making. This venture was reported by Williams (1982) and drafted into a unit series entitled *Third World Science*. Similarly, Knamiller (1983), working with rural students in Ghana, proposed a series of issue-based topics which he believes would be of immediate relevance and usefulness to rural communities in Ghana. These include agricultural topics and topics relating to crop pests and small industries. Similar ranges of local community topics have been developed and implemented by the Zimbabwe Environmental Science programme.

In the Philippines, curriculum development has been decentralised in certain regions in order to assist teachers to develop teaching modules in accordance with local needs. In Thailand, a new Competence-Based Teacher Education programme (CBTE), discussed by Baimba (1994), has gradually replaced the old content-oriented teacher training system. The new system recognises as paramount the capacity of teacher trainees to induce positive educational outcomes in students and make science more meaningful to non-western learners.

Knamiller (1983) reported that in the 1980s and early 1990s Bangladesh and Zambia promoted science fair movements in order to bring science to the population. Ahmed (1979) reported that in India there has been increasing emphasis on giving teachers appropriate work experience and the acquisition of skills for the improvement of living conditions. This includes work on such diverse topics as water filters or crops and fertilisers, as well as the promotion of scientific thinking so that students bring new knowledge and skills to their communities. Students also utilise local knowledge of medicine and weather so that these traditional beliefs can be investigated scientifically 'to perhaps discover the kernel of truth in this neglected store of knowledge' (Ahmed, 1979).

2.5.3 The Relevance of Science Curricula

2.5.3.1 The Notion of Relevance in Education

Educational relevance is perceived differently by different parties. In particular, perceptions of relevance among consumers (students, teachers and parents) often differ considerably from those external to the classroom (government, policy-makers and curriculum developers). A seminal problem identified by several workers (Al-Hidabi, 1982; Igboaka, 1981; UNESCO. - APEID, 1981) is a persistent incongruity between policy and implementation. Baimba (1991) explains this as deriving from the fact that what is relevant to learners is ambiguous. For example, Fafuwa (1967) reported that in the 1960s African governments viewed industrialisation as necessary to advancement and were seeking to prepare workers trained in the sciences and technology whereas some researchers promoted science education based on traditional knowledge (see section 2.5.2).

Consumers, however, frequently hold opposing views to those of policy-makers. In Australia, for example, in submissions to the National Review of Education for Aboriginal and Torres Strait Islander Peoples (1994), many indigenous groups articulated concerns about the relevance of existing forms of education in addition to the needs and circumstances of indigenous students and communities. Conversely, non-indigenous groups tended to express concern that existing forms of education are not reaching indigenous people. By comparison with the views of governments and policy-makers, consumers (students and parents) see education as a key to improving their standard of living. Education is often viewed as a means of escape from the drudgery of rural living (Emina, 1983).

2.5.3.2 The Status of Academic Subjects

For the purposes of university entrance the physical sciences are regarded as having high status in many African countries, whereas subjects such as home economics, craft and agriculture have historically been perceived as of low status (Chaplin, 1961). This apparently continues to the present day. Baimba (1991) reports on the low status of agricultural science in Sierra Leone which, even for admission to the Department of Agriculture at the local university, was not considered to be a core subject. Baimba (1991) recounts a conflict over curriculum relevance at a primary teachers' college in Sierra Leone which aims to prepare school teachers to contribute to community development in addition to school teaching. The policy of this institution was to give rural pupils equal opportunities with urban pupils to succeed in the national school secondary school entrance examination (Knamiller, 1984). Baimba (1991) believes that this is a reflection of the high status accorded to formal qualifications.

A second disagreement emerges regarding the kind of scientific knowledge which learners should acquire. Fensham (1986) believes that the best approach is one which focuses 'about and from science', particularly for those who are non-scientists, and that inductive elitist science education is appropriate only for the upper levels of schooling. Instead, Fensham argues, Science for All should promote everyday topics easily recognised by students. These should include Senses and Measurement, Human Body, Health, Nutrition and Sanitation, Food, Population, and Pollution and

Energy. However, Munby and Russell (1987) believe that this approach will inevitably de-emphasise the intellectual component of science.

Baimba (1991) argues that a core topic approach may not be the best suited to third world countries in which there may be few competent trained teachers to teach core content curricula. Lawton (1975) articulates that science possesses intrinsic truth criteria, structure and methodology which Baimba believes may be neglected by teachers untrained in modern scientific method and teaching pedagogy. Baimba (1991) argues further that different science curricula for 'science-bound' students and other students (the other 'all') is also unsatisfactory, and may leave unanswered the questions as to who should receive what type of science education and why.

2.5.4 New Curricula for Indigenous Students

Driver and Oldham (1985) have developed a constructivist science curriculum model which is predicated on constructivist thinking on content, consideration of pupils' prior understanding and experiences in each topic, constructivist views on the learning process, and knowledge of teachers' knowledge and experiences of learning. The aims and objectives of this curriculum are consistent with constructivist beliefs about humans, teaching and learning which are to enhance the development of pupils' scientific thinking and to encourage positive attitudes towards science. These aims and objectives apply for all students learning science, but the model has also been adapted specifically for the traditional students of Sierra Leone (Baimba, 1991). In the context of a traditional cultural background, there is the additional requirement that the curriculum should teach how to cope with the everyday problems faced by people of those cultures: low levels of technology, low standard of living, and perhaps disease and famine. The specific objectives of the new curriculum were:

1. to understand the 'why' of things and how this impinges on daily life;
2. to see science as a human artefact which has been devised to uncover the 'why' about the natural world;
3. to encourage children to explore and investigate in a scientific manner;
4. to encourage a depth of interest in science sufficient for some students to wish to pursue a scientific career; and
5. to encourage application of scientific knowledge for everyday problem-solving.

An instructional guide was produced for this curriculum which was intended to promote the constructivist paradigm which views learning as evolving through a process of active construction of meaning by the learner. In this paradigm, the teachers' practical knowledge of the learning environment, including students, schools and curricula, assists in the planning and management of the learning process. It is the opinion of the author that an appropriate modification of the Driver and Oldham science curriculum model, similar to that of Baimba, has considerable potential to enhance science educational outcomes for New Zealand ethnic minorities and could reasonably be trialed at the secondary level. However, trials of new curriculum models are best carried out in the light of understanding of both the personal and academic attributes of students, such as is obtained through examination of student attitudes and learning environments. For this reason, attitudinal and learning environment questionnaire surveys have been incorporated into the research design of this study.

2.5.5 Studies on Science Education in Non-western Countries

Many studies of science education in non-western societies have been undertaken which provide useful background to the present study because many of the problems experienced by non-western countries, particularly third world countries, are similar to those of ethnic minority students in western countries. These include studies of Sierra Leonean junior science (Cole, 1975; Cockright, 1974; Baimba, 1991); a study of high school science in Africa (Fensham, 1986); South Africa (Helm, 1980); Zambia (Hoppers, 1980); Nigeria (Taiwo, 1975; Igboaka, 1981); several countries in west Africa (Chaplin, 1964); Liberia (Gay & Cole, 1967); Egypt (Selim & Shringley, 1983); Thailand (Karnphanit, 1986); Israel (Lazarowitz & Lazarowitz, 1979; Menis, 1983); Yemen (Al-Hidabi, 1982); India and Pakistan (Morehouse, 1967); the Philippines (Seng, 1979); the Americas (Gallagher & Dawson, 1984). Studies conducted in the South Pacific include Waldrip & Giddings (1993); Waldrip (1995) and Waldrip & Wong (1996).

Other sources which provide useful background to the problem of minority group students or students of non-western cultures and high-school education in science

include the following studies which examine these issues more generally: cross-cultural teaching in science (Dart & Pradham, 1967); education and colonialism (Kelly & Altbach, 1978); class, culture and the curriculum (Lawton, 1975), and third world science (Williams, 1982).

2.6 Educational Economics and Ethnic Minorities

2.6.1 Rationale for the Survey of the Economics of Education

Any discussion of the status of minority groups within the education system must be carried out in the light of economic considerations. The author of the present study contends that a genuine enhancement of secondary education for Maori and Pacific Island students, particularly of science education outcomes, has considerable potential to lead to direct improvements in educational outcomes and therefore to improved health and socio-economic outcomes. In this section, a review of the economics of education as it relates to ethnic minority groups, is presented. The key economic issues considered here will later underpin the development of a set of recommendations for the enhancement of science education outcomes for ethnic minority students.

2.6.2 Human Capital and Ethnic Minorities

2.6.2.1 The Concept of Human Capital

Human capital can be considered to be the stock of the means of production in existence which embodies past and present technical know-how (Vaizey, 1972). Human capital and its ongoing development are critically dependent on a sound educational infrastructure. To understand the career and schooling choices made by individuals, the principal of wealth maximisation is often assumed, whereby courses of action are taken which yield a stream of income with the greatest present value (Fleisher & Kneisner, 1984) or the greatest rate of return on educational investment. In New Zealand such a wealth maximisation approach is probably not widely adopted amongst Maori and Pacific Islanders, but may frequently be adopted by Asian immigrants and Europeans.

2.6.2.2 *The Untapped Potential of Maori and Pacific Islanders*

In New Zealand, 23% of employed Maori men work as machine and plant operators and 26% of Maori women in the sales and service fields. These are the most common occupations for Maori. Maori are also heavily over-represented in the 'elementary occupations' such as labouring (15% of Maori men) and clerical work (22% of Maori women). The majority of employed Pacific Islanders work in the manufacturing industry (Education Trends Report, 1995). Generally, they are concentrated in the low-skilled occupations and only 14% are employed in the managerial, professional or technical occupations by comparison with 34% for all ethnic groups. In March 1995, 18% of the Pacific Islands labour force aged 15 to 24 were unemployed, compared with 13% for the total labour force in the same age group (Education Trends Report, 1995).

2.6.3 **The Socio-Economic Background to Education**

Vaizey (1972) reviewed an extensive body of literature on education, income and social mobility available in the 1970s and drew the following conclusions:

1. The overall levels of both educational attainment and income generally rise from year to year.
2. The distribution of the years of schooling tends to be more equitable than the distribution of income and is moving towards greater equity.
3. The absolute attainment gap between the well and poorly educated tends to grow from year to year, as does the gap between rich and poor.
4. The distribution of educational resources tends to become increasingly differentiated.

Vaizey's conclusions relating to educational attainment gaps between rich and poor, and the inequitable distribution of educational resources, appear to have particular relevance to ethnic minority groups such as Maori and Pacific Islanders. Vaizey also surmised that the overall relationship between educational attainment and occupational status had not changed greatly up to the time of his research. Vaizey concluded that education can reinforce, rather than diminish, social inequities, thus

underscoring the great importance of improving educational outcomes for socially disadvantaged groups such as Maori and Pacific Islanders.

2.6.4 Social Returns to Investment in Education

In many countries, education is funded from an exchequer or treasury which also disburses money for other public-good enterprises relating to health, social welfare, defence, scientific research and other activities. Therefore, a central question is that of the most desirable balance of expenditure on these activities. New Zealand's educational initiatives for minorities have centred largely around the provision of services including total immersion Maori language institutions such as *Te Kohanga Reo* and *Kura Kaupapa Maori* at the pre-school and primary levels, remedial programmes and *Wananga* at the tertiary levels.

Measures of educational outcomes of greatest utility to public investment decision-making are those which include externalities (Vaizey, 1972). Weisbrod (1962) listed the principal external benefits of education. These include: the improvement in social environment through a higher educated citizenry; employment-related effects where educated workers confer benefits on their colleagues through increased flexibility, productivity and social contact; society in general which benefits through the added economic value from enhanced literacy and numeracy and through a population which is more law-abiding as a result of having more highly educated members. The author contends that an improved science educational base for ethnic minorities which encouraged educational success and the uptake of careers involving scientific training and understanding would have significant economic value through increased employment and enhanced productivity, as well as significant secondary spin-offs such as a reduction in crime and improvements in health.

2.6.5 The Social Demand for Education

2.6.5.1 The Social Demand Model

Any modern educational system must be capable of adapting to student pressures and student choices. This is the 'social demand' approach, and is fundamentally different

to the 'manpower' approach which expects that the educational system will respond according to the projected manpower demands of the economy. In this regard, ethnic minority groups often view education as a means to achieving freedom from drudgery and achieving a level of economic success which otherwise would not be available (Emina, 1983).

2.6.5.2 Student Choice of Academic Subjects

For ethnic minority students, as for all students, the choice of subjects taken at the higher levels within the secondary system and at the tertiary level is determined by a combination of factors which may include the perceived difficulty of the subject, the employment and earning prospects arising from each subject and the 'contagion effect', in which the choices of certain students may influence the choices of others (Stone, 1965). It is quite possible that for many ethnic minority group students such 'contagion' effects may act in tandem with conflictual difficulties which arise because of an incompatibility between the prior experiences and conceptions of ethnic students and education.

2.6.5.3 Differences in Ability

Individual differences in ability or intelligence also affect the demand for investment in human capital (Fleisher & Kneisner, 1984). Katz and Ziderman (1980) have also suggested that education performs a valuable function in screening people for occupations, as well as in contributing to worker skills. Able persons have greater access to highly-paid occupations, independent of the amount of schooling acquired. Maori and Pacific Islanders in New Zealand gain tertiary level qualifications at a lower rate than others (see section 1.2.2). Although the reasons for their low educational attainment are not a reflection of intelligence differences, nevertheless, the ability of these groups to enter the highly remunerated professions is markedly reduced.

2.7 Summary of Chapter Two

This chapter has provided an overview of interventions and initiatives for enhancing the educational outcomes for Maori and Pacific Islanders, and an overview of educational policy-making in New Zealand. The world views of Maori and Pacific Islanders in relation to science education and the differentiated approaches to problem solving between traditional and western people were discussed and recent trends in science education around the world described as background for the development of initiatives to enhance educational outcomes for Maori and Pacific Islanders. The particular problems of educating ethnic minorities were described, their under-performance in education noted, and possible psychosocial differences between minority groups and others which may contribute to difficulties experienced by these groups discussed. Finally, a brief discussion of the economics of education as it pertains to ethnic minority groups was presented.

Despite all of the research which has been conducted into the science education of minority groups, students in third world countries, and Maori and Pacific Island students in New Zealand, this study is very important in informing about the attitudes and learning environments of these students and relating these to their cultural backgrounds and academic achievements, thus providing valuable insights for teachers which may assist in the development of more effective educative techniques.

In Chapter Three discussions of the nature of school science and traditional knowledge, and the relationships and complementarities between them are given. An introduction to constructivism, a system for thinking about education predicated on the notion that the prior knowledge and experience of the learner is central to learning, is also presented in order to provide a framework which will underpin the research described later in this thesis.

CHAPTER THREE

. . . new approaches to professional development are especially critical as we align curriculum, instruction, and assessment practices with research on teaching and learning. Research finds that students learn by actively constructing new knowledge in a holistic way and connecting it with their prior knowledge.

(NCREL Policy Briefs, Report 4, 1997)

SCHOOL SCIENCE, CONSTRUCTIVISM AND TRADITIONAL KNOWLEDGE

3.1 Introduction and Overview

3.1.1 Introduction

This chapter presents a survey of the relevant literature on school science, commonly held perceptions of science and science learning, and the relevance of these perceptions to the problems of ethnic minority group students in the science classroom. The survey is intended to explain how constructivist theory may provide a useful framework for interpreting the findings of the present study, to discuss knowledge in traditional societies, and to establish a correspondence between cultural practices and the experience of science education. The central themes and ideas explored in this chapter will provide a strong conceptual foundation for the development of recommendations for enhancement of science education outcomes for Maori and Pacific Island students. These recommendations are discussed in Chapter Eight.

3.1.1.1 *Overview of this Chapter*

Section 3.2.1 gives a brief discussion of the notion of competence and its importance for success in life. In section 3.2.2 socio-cultural considerations in science education and learning processes in science are presented. It is contended that the social and cultural backgrounds of students help to shape their attitudes and must be considered in any discussion of the science education of traditional or

'pseudo-traditional' students. In section 3.2.3 a brief discussion of how school science is perceived by workers in the field of science education is given. The perceptions of professionals in the field of science education inform about the nature of high school science curricula and provide a contextual background against which the difficulties of students may be viewed.

Section 3.2.4 discusses scientism, the principle that the world has an objective reality which is independent of human perceptions of it.

Section 3.3 discusses the seminal principles of constructivism and articulates the constructivist premise that the prior knowledge and experience of the learner is central to learning. It is contended that this is particularly true for students of traditional societies because their socio-cultural experiences are so different to those of western students for whom secondary-level curricula in many countries have been specifically devised (Testa, 1994).

In section 3.4, the effects of cultural practices, beliefs and cultural norms on science education are considered and comparisons made of the ways in which children of traditional cultures and western children think about the world. It is contended that there is much to be learned from a comparative study of the similarities and differences in which both traditional and pseudo-traditional ethnic minority students and western students think and feel about the world.

3.2 Science and Science Learning

3.2.1 Education for Competence

It can be argued that a fundamental motive for education is to nurture competence. In discussing the development of competence, Chickering (1969) used the analogy of a three-tined pitchfork. In his analogy, the tines denote intellectual competence, physical and manual skills, and social and interpersonal competence. The handle of the pitchfork, the most important part, is the sense of competence:

. . . the confidence one has in his ability to cope with what comes and to achieve successfully what he sets out to do (p. 9).

The ability to experience competence is thought to influence later developmental attributes, particularly those of autonomy and identity, due to the difficulty experienced if students feel unable, or incompetent, in the areas of intellectual, physical, and social competence. These issues must be addressed for all students and actively remediated for many ethnic minority students.

3.2.2 Socio-cultural Considerations in Science Curriculum

Kelly & Altbach (1978) have referred to the 1960s and 1970s as the periods of academic imperialism, a time during which many new science curricula were developed in western countries and subsequently adopted in many third world countries. However, during the 1980s, it was recognised that science education must accommodate the cultural context and those whose needs it serves (Maddock, 1981). Previously, little account was taken of the experiential world of children in curriculum development (Young, 1973). However, it became evident that there were deficiencies inherent in many science curricula. Cole (1975) suggested that in traditional societies science was not taught for the purposes of gaining knowledge and skills, but in order to prepare students for public examinations. Further, Hewson (1986) argued that western science curricula do not encourage students in traditional societies to think scientifically in the contexts of their own cultures. More recently, a number of workers have called for greater harmony to be achieved between school science and the experiential world of school children of traditional cultures (Gallagher & Dawson, 1984).

Support for socio-cultural considerations in science curricula has been given through the increased profile of constructivism, which takes account of the beliefs, intents and emotions of learners and recognises the profound influence that experience has on the way in which students perceive and interpret the natural world (Driver & Oldham, 1985). Formerly, empiricist-inductivist theory placed little importance on the learner's conceptions. Constructivist thinking argues that children construct interpretations of and explanations for the natural world long

before formal science education begins. Several writers (Sutton, 1980; Gilbert, Osborne & Fensham, 1982) have argued that the more which is known about learners' alternative conceptions, the more easily can teachers promote effective learning experiences in order to modify those conceptions.

These developments in current thinking about science education have led to a view of science learning as a process of conceptual change rather than concept acquisition (Cosgrove & Osborne, 1985; Hewson, 1981; Posner & Hertzog, 1982; Shuell, 1987). In particular, Posner (1982) has argued that the constructivist view on learning has great relevance to curriculum design. In this paradigm, the curriculum is viewed as the set of learning experiences which enable learners to develop understanding (Driver & Oldham, 1985). This view opposes the prior views of Morehouse (1967) and Ziman (1969) who believed that science curricula are largely culture-free and capable of easy adaptation to different cultural contexts. In this connection, Fensham (1985) stated that the secondary curriculum in science and mathematics in many countries was characterised by rote recall of facts not socially useful, little familiarity with concepts to enable usefulness to be experienced, and the involvement of life experiences as exemplars rather than as the essence of science learning. Further, Hodson (1988) has argued that acquired scientific knowledge and skills may fail to find applicability because many contemporary science curricula embody a confused philosophical stance and because many teachers have inadequate views on the nature of science.

3.2.3 Perceptions of Science and Science Learning

The period of curriculum innovation of the 1960s and 1970s coincided with change in the philosophy of science and the prevailing views of science methodology were confused and often contradictory (Martin, 1979). Hempel (1966) described school science as a narrow empiricist-inductivist approach, while Cawthron & Rowell (1978) described school science as an empiricist-inductivist approach consisting of stages which include observation and experimentation, generalisation, hypothesising, attempted verification, proof or disproof and the formulation of objective knowledge.

Smoliez and Nunan (1975) articulated four premises which they termed the 'ideological pivots of the image of science'. These are: the anthropocentric view of the universe in which humans control nature through the medium of science; the principle of quantification and demystification of the world in which everything in nature is amenable to quantification; faith in the progress of science, and the analytic ideal, in which the whole is comprehended through study of the components. By comparison, Nadeau and Desautels (1984) believe that school science assumes five myths. These are: *naive realism*, the belief that science reflects nature as it actually is; *pedagogical neutralisation*, the belief that humans perceive things as they really are; *blissful empiricism*, the belief that scientific knowledge flows directly from observation and that knowledge can be imprinted on the mind item by item; *pedagogic attenuation*, or the belief that observation means to examine alternately in order to note as many details as possible; *credulous experimentation*, or the belief that experimentation allows verification of hypotheses.

Hodson (1985) has summarised the kinds of observations made by workers such as Smoliez and Nunan (1975) and Nadeau and Desautels (1984) and gave the four following observations:

1. Science provides factual truths about the world through detached observation.
2. Scientific knowledge flows directly from observation of nature.
3. Scientific hypotheses are tested through reliable empirical methods.
4. Science is unaffected by socio-historic and economic factors.

These observations reflect the nature of science itself as well as of how it is carried out at the professional level. However, school-level science is not professional-level science and is learned and conducted by students who are not yet socially or intellectually mature. For this reason, it is probably unwise to assume that students do or do not make the assumptions articulated by Smoliez and Nunan and Nadeau and Desautels. In the next section, an important paradigmatic view of school-level science is discussed.

3.2.4 Scientism

Cawthron and Rowell (1978) have articulated a prevalent view of school science as objective, unbiased and possessing a critical and impeccable method. Eastman (1969) believes that this image is promulgated through a school's hidden curriculum through a process known as 'scientism'. Eastman described scientism as an activity based on the ontological thesis which presumes the existence of real, isolated entities, independent of human perception. Duschl (1988) contends that the content of textbooks, the attitudes of teachers', scientific inquiry and classroom verbal interactions demonstrate that school science is promoted as absolute truth. Gordon (1984) supports this view in noting that in most lessons science teachers tend to move towards conclusions so that there is always a sense of the lesson moving towards a particular direction, thus suggesting to students that there is an overriding truth to be uncovered. In many cases, students' responses to questioning must accord with a 'yes' or 'no' delineation with no allowance for other alternatives.

Nadeau and Desautels (1984) contend that scientism embodies an attitude towards science that encompasses both the idea that it involves special knowledge and as an activity which has a cognitive basis. However, the implicit premises on which scientism is based, that humans can observe the external world directly and immediately and that induction generates generic laws, have been challenged in recent decades. Popper (1959) believed that science derives from theories or propositions which scientists construct in order to understand nature, rather than from passive observations. He contends that the seminal feature of scientific method is that it should seek to falsify hypotheses and conjectures about the natural world, and not merely to validate theories by citing particular instances which happen to accord with those theories. Thus, science may be seen as a collective suite of theories which have not yet been refuted (Charlesworth, 1982). The views of Kuhn (1970) accord with those of Popper but, in addition, emphasise the importance of the revolutionary nature of change in science and the recognition of the contribution of an international community of scientists. In summary, Hodson (1986) has identified five points of note for science teachers and curriculum designers:

1. Observation is unreliable and theory dependent.
2. Techniques of scientific observation have to be learned.
3. Account must be taken of students' existing conceptual frameworks.
4. A discovery learning approach must be considered.
5. Science is not value-free.

Scientism presents a common-sense conceptual framework for articulating the practice of science. However, to understand the cognitive processes which are involved in the learning of science at the secondary level requires a conceptual framework which accounts for the immature thinking of children encountering scientific concepts for the first time. The most widely accepted conceptual framework for understanding how people learn is known as constructivism. In section 3.3, discussions of the central themes and tenets of constructivism are presented.

3.3 Constructivism

3.3.1 A Survey of Constructivist Thinking

Constructivist theories of learning are partly based on the views of Bruner, Piaget and Ausubel and involve the recognition of knowledge as a psychological entity rather than as an objective entity in the real world. The dominant theme in constructivist thinking is the importance of meaning as constructed by individuals in attempting to make sense of their world (Wittrock, 1974). Thus, learning is dependent both on the absorption of external information and also on the prior beliefs, experiences and emotions of the learner. In constructivist thinking, the curriculum is the total set of learning experiences which enables the learner to develop understanding (Driver & Oldham, 1985). Claxton (1984) extended the constructivist paradigm in stating that the actions and intuitions of individuals arise out of personal theories about the world which govern descriptions and explanations which each individual holds about the natural world. Claxton refers to these descriptions and explanations as 'mini-theories'. These mini-theories may be either conscious or subconscious. Examples of subconscious theories which are developed almost automatically through life experience are theories about weight,

height, forces and impulse. For example, children quickly internalise theories about forces and impulse when jumping from a height or catching heavy objects. In these situations, bending the legs when jumping or allowing free movement of the hand when catching a heavy or fast-moving object increases the time over which decelerative forces act and therefore reduces the average forces acting on the body so that damage to the body is minimised or eliminated.

Gilbert, Watts, and Osborne (1985) have discussed the possibility that students may have different kinds of knowledge even of the same topics. Kirkwood (1988) has proposed five kinds of science knowledge: *Scientists' Science*, in which meaning is agreed by a constituency of professional scientists; *Curriculum Science*, in which textbook writers present appropriate aspects of scientists' science; *Teachers' Science*, which is teachers' versions of curriculum science; *Childrens' Science*, or the early conceptualisations made by children and the meanings they attribute to science words, and *Students' Science*, which is the result of a fusion of teachers' science and childrens' science.

The conceptions of and about science held by students are different from those of scientists and have been viewed and labelled differently by various educational workers. Ausubel (1968) called these different conceptions *preconceptions*; Helm (1980) called them *misconceptions*, while Gilbert, Osborne, and Fensham (1982) called them *Childrens' Science*. Hewson (1981), Shuell (1987) and Posner & Hertzog (1982) have each supported the notion of learning as conceptual change through addition to existing conceptions based on the understanding that students hold differing conceptions to scientists.

Recently, Matthews (1995) has argued that New Zealand that is not likely to achieve a high level of scientific literacy because its education leaders and policy-makers have adopted a particular constructivist stance which is relativistic and discounts the value of subject-matter competence. Matthews believes that objectives such as 'making sense of the world' rather than learning about the world, and of 'making sense of living things' rather than learning about living things, is misguided. Matthews also believes that constructivism has obscured the

debate on Māori science education, the position of girls in science, curriculum development, teacher education and assessment. Matthews argued for greater recognition of the intellectual rigour required in scientific endeavour and of the demands science makes on learners. Matthews presented a very negative picture of constructivist science education in New Zealand and suggested that review and remediation was urgently necessary. However, many New Zealand educational researchers and policy developers disagreed strongly with Matthews' analysis and recommendations and a series of responses was collated (Bell, 1995). This response attacked Matthews' analysis as 'unscholarly', based on factual errors, and deficient in academic rigour. The debate has also been documented and discussed extensively by researchers at the University of Auckland (Access, 1995). The New Zealand debate on the position of constructivism seems likely to continue well into the next century.

3.3.2 The Constructivist Model for Learning

Christensen (North Central Regional Educational Laboratory, May 1997) writes that in the United States schools and teachers have been creating behavioural goals and objectives, that curricula have been tightly sequenced according to a belief that the best way to learn is to master small bits of knowledge and then integrate them into major concepts, and that assessment practices have tended to focus on measurement of knowledge and skills, with little emphasis on performance and understanding.

He argues that the key notion in this new constructivist theory is that people learn best by constructing their own understanding actively. Christensen articulates the bases of the constructivist paradigm for learning as follows:

1. All knowledge is constructed through a process of reflective abstraction.
2. Cognitive structures within the learner facilitate the process of learning.
3. Cognitive structures in individuals are in a process of constant development.
4. If the notion of constructivist learning is accepted, then methods of learning and pedagogy must agree.

The constructivist classroom presents the learner with opportunities to build on prior knowledge and understanding to construct new knowledge and

understanding from authentic experience. Students are allowed to confront problems full of meaning because of their real-life context. In solving these problems, students are encouraged to explore possibilities, invent alternative solutions, collaborate with other students (or external experts), try out ideas and hypotheses, revise their thinking, and finally present the best solution they can derive.

Contrast this approach with the typical behaviourist classroom, where students are passively involved in receiving all necessary critical information from the teacher and the textbook. Rather than inventing solutions and constructing knowledge in the process, students are taught how to 'get the right answer' using the teacher's method. Students do not even have to 'make sense' of the method used to solve problems.

(North Central Regional Educational Laboratory, May 1997).

3.3.3 Learning through Conceptual Change

Strike and Posner (1982) proposed the idea that conceptual change takes place when the present conception is shown to be inadequate and when the new conception proves to be comprehensible, plausible and potentially fertile as a source of new concepts. This view has also been advanced by Pines and West (1986). The findings of more recent research (Confrey, 1990; Hashweh, 1988; Hills, 1989) are that prior to institutionalised instruction, students hold systems of concepts or beliefs which are very different from accepted scientific theories, and that, despite instruction, many students do not acquire scientific concepts and continue to hold their own belief systems. However, Tobin (1993) argues that basing classroom teaching methods on constructivist notions of conceptual change has diminished the power of constructivism as a way of thinking about education, and in particular, about science education. Independently, Rumelhart and Norman (1978) proposed three pathways for change in cognition. These are: through accretion (adding new conceptions to existing structures); through tuning (modifying the present structure), and through restructuring present conceptions. Driver and Oldham (1985) have summarised constructivist views on learning as follows:

1. Humans are purposive and interact actively with the environment to make sense of it.
2. Humans construct knowledge through social interactions and experience with the physical environment.
3. The knowledge and beliefs of individuals influence constructed meaning.

4. Constructing meaning is an active process.
5. Understanding is not the same as believing.
6. The learning of scientific ideas involves conceptual change.

Clearly, constructivist thought provides a conceptual framework for describing the ways in which humans learn and make sense of the world. In section 3.4.3, the relevance of constructivism to the present study of traditional ethnic minority groups is discussed.

3.3.4 Constructivism and Ethnic Minority Students

The constructivist view is that the prior knowledge and experiences of the learner are fundamental in constructing meaning. This notion may be especially pertinent for learners from traditional cultures such as Melanesian and Polynesian secondary students because of the strong traditional beliefs held by people from those cultures which often conflict with western scientific thinking. Williams (1982) has articulated the great importance of tradition, myth and legend in how people interpret their environment, in contradiction to the notion that science is independent of culture (Morehouse 1967; Ziman, 1969). That the prior conceptions of the learner have such great importance for constructing meaning (the constructivist view) is of particular importance for students from traditional ethnic backgrounds, simply because their prior experiences and conceptions are likely to conflict with what is taught in a science classroom. Thus, in order to ensure that school science is relevant to those students, new ways must be found to make students' prior conceptions more compatible with and complementary to scientific ideas. In this context, a constructivist view of curriculum development which recognises both the pre-school and out-of-school dispositions has recently gained recognition (Driver & Oldham, 1985; Bell, 1990). This curriculum could be modified to cater for ethnic minority group students in respect of content, students' cultural background, prior ideas and scientific conceptions. However, to design an effective constructivist curriculum, proper account must be taken of the students' attitudes, prior beliefs and perceptions of their learning environments. The *Test of Science Related Attitudes* (TOSRA) survey and the *Constructivist Learning Environment* CLES survey instruments discussed in Chapters Four, Five and Six are appropriate instruments for informing such curriculum design.

3.4 Cultural Practices, Beliefs and Science Education

3.4.1 Beliefs, Values, Norms and Differences in Thinking

3.4.1.1 Beliefs, Values and Norms

In Chapter Two (section 2.2), the world views of Maori and Pacific Island people were discussed generically. In this section, the beliefs, values and norms held by these cultures and which characterise their worldviews are compared with those characteristic of western culture.

Culture may be described as the basis of the structure, stability and security that both individuals and society must possess if they are to sustain themselves. Beliefs are a fundamental part of culture and may be thought of as propositions which are accepted as true whether or not they are verifiable (Baimba, 1991). The belief systems of ethnic minority group people include shared knowledge, myths, legends and superstition (Baimba, 1991). These provide a means of transmitting important features of social life and culture. Prior beliefs which traditional ethnic minority students might bring to school include belief in the supernatural, veneration for ancestors and belief in natural divinities. Such beliefs may act as guidelines for behaviour and determine the individual's reactions to modern experiences, and may also lead to conflictual problems in today's education system.

Cultural norms also influence behaviour. They specify standard rules which dictate acceptable or appropriate behaviour. Josiah (1988) has summarised and described some of the norms commonly held by traditional societies in Africa. These include respect for the dead, respect for age, respect for authority, the dominance of men over women and the division of sex roles. These norms are also strongly held in Māori and Pacific Island cultures (John Fiso, pers. comm.). By comparison, Josiah described a value as an important belief which takes the form of a preference which is considered to be justified. The three attributes - beliefs, norms and values - shape the lifestyle of a person and make people of traditional cultures different to those from western cultures.

Logan and O’Hearn (1982) compared the values of traditional and western societies in terms of the seminal values espoused by these societies. Table 3.1 summarises their findings and compares cultural attitudinal values, beliefs and norms held by traditional and western societies which characterise the lifestyles of children in those countries.

Table 3.1: Life-styles of Traditional and Western Children (after Logan & O’Hearn)

	Traditional	Western
Desired Traits	Obedience & Responsibility	Independence & Achievement
Economic Role	Production	Learning for future Production
Purpose	To carry on	To prepare for a new life
Education/Learning	Through work and participation	Through schooling
Social Orientation	Offering to others	Doing for self
Children’s Image	Small adults	Future Adults
Shared Parent-child Activities	Work	Work & Shared Play

According to Logan and O’Hearn’s view, the beliefs, norms and values of a society are not merely important artefacts of the society, but fundamentally shape the world view and lifestyle of the society. A similar comparison can be made of the cultural beliefs, norms and values which shape the lifestyles of adults in traditional and western societies (see Table 3.2 below).

Table 3.2: Life-styles of Traditional and Western Adults (after Logan & O’ Hearn)

	Traditional	Western
Time Orientation	Continuity with the Past	Towards the future
Life Space	Circumscribed	Linear
Guidance	From elders	From peers and teachers
Locus of wisdom	Elders and Tradition	Adults and Experts
Relationships	Vertical	Horizontal
Life Focus	Group, family, tribe	Individual
Feelings	Group regulated	Delayed satisfaction
Purpose	‘Be’; Get along	‘Do’; Get ahead
Economic Orientation	Subsistence cycle	Production/supply; investment/thrift
Jobs	Already there; necessary to survive	To be made; necessary for advancement
Meaning	Carry on Tradition	Prepare for the future
Values	Harmony vs. fatalism	Optimism vs. fear of failure
Identity	From Continuity and Place in Group	From one’s future role

Although many urban Maoris and Pacific Islanders may not strictly belong to purely traditional cultures, it is clear that many of the characteristics identified by Logan and O' Hearn are true for a significant proportion of them.

3.4.1.2 *Cultural Differences in Thinking*

The many differences in thinking between western people and non-western people have been reported extensively. Cheatham (1990) has considered the differences in thinking between western people and African Americans. In comparing Africentrism with Eurocentrism, Cheatham stated:

unlike the Western philosophical system, the African tradition has no heavy emphasis on the individual. The individual's being is authenticated only in terms of others. (p. 375).

This is:

. . . epitomised in the traditional African self-concept: 'I am because we are; and because we are, there I am.' (p. 375).

This world view characterises people of many traditional societies, including those of Polynesian descent. By comparison, the North American Eurocentric point of view:

. . . dichotomises the world into knowable parts, is less emotional, stresses self and independence, emphasises the clarity and precision of the written word, is oriented towards a linear view of time, stresses individualisation and difference rather than collaboration, and values youth rather than age. (Cheatham, 1990, p. 375).

Beliefs, values and norms not only influence lifestyle, but also shape the styles of thinking of people. This is of direct relevance to how children view the world and learn in the classroom.

3.4.2 Knowledge in Traditional Societies

3.4.2.1 African Societies

Josiah (1988) has classified the types of knowledge characteristic of traditional societies as follows: knowledge of others, common sense knowledge, working (technical, scientific, political) knowledge, and perceptual knowledge of the external world. The passing on of knowledge is frequently effected through imitation of elders. Baimba (1991) points out a disadvantage of this system of transmission of knowledge. This is that innovation is de-emphasised in favour of traditional ideas. In traditional African societies, for example, knowledge does not follow the pattern 'what is, is right' but rather the pattern, 'what has been, is right' (Josiah, 1988). In this paradigm, children learn what their parents or tribe wants them to learn. Differences in thinking between children of traditional societies and western children may be manifested in attitudes towards prediction of events, attitudes towards cause and effect, attitudes towards experiment, attitudes towards confession of ignorance, attitudes towards coincidence, chance and probability, and attitudes towards time. Such differences in attitudes must be accounted for in an effective science curriculum.

3.4.2.2 Maori and Pacific Island Knowledge

Maori have a view of the world which is deeply spiritual. Maori tribes traditionally trace their descent from one of the canoes in which their ancestors first came to New Zealand - Tainui, Te Arawa, Matatua, Aotea, Kura-hau-po, Tokomaru, Takitimu, Horouta and others. The traditional Maori approach to resources encompasses an understanding of how natural elements were formed and replenished, and governs how they should be used. Making the least impact possible on the natural world and taking only what from the earth what is directly needed characterise Maori culture.

Each individual has a responsibility to respect and care for the natural world. This is the Maori concept of *kaikitanga* or stewardship (Wally Penetito, pers. comm.). Central to this concept is the recognition that members of the present generation have responsibilities passed on to them by preceding generations to care for nature and to oversee a balance between human need and resources. Pacific Island

knowledge bears strong similarities to Maori knowledge, involving myths and legends, the importance of the extended family or 'aiga' (see Chapter Two), love and respect for others, particularly family members (John Fiso, pers. comm.).

3.4.3 Acceptance of Traditional Knowledge

Horton (1967) believed in concentrating on the similarities rather than the differences between Western and African thought and concluded:

. . . like atoms, molecules, and waves, . . . the gods serve to introduce unity into diversity, simplicity into complexity, order into disorder, regularity into anomaly. (p. 231)

Horton saw the main difference between African thought and Western science not as a Western monopoly rationalisation or inquiry, but instead a tendency towards depersonification of the thinking process. Horton believed that once the importance of literacy was apprehended, traditional thinking and action becomes comprehensible to Western people.

Mead (1995) has stated that the scientific community is intimidating to Maori because it does not respect traditional views. It has frequently been argued that 'Maori do not do science' because Maori knowledge acquisition is not objective, relying mainly on religious faith, rational, mixing the supernatural with the everyday. Nor is it cooperative, relying on authority rather than challenge and consensus (Dickison, 1994). It seems probable that Pacific Islanders experience a similar intimidation and unease about western education.

3.4.4 Traditional and Western Thought Style

Baimba (1991) has compared the styles of thought of traditional and western people (see Table 3.3).

Table 3.3: Traditional and Western Thought-styles (after Baimba, 1991)

	Traditional	Western
Education	Through Participation	Skills Training
Thinking	Pre-ordained; repetitive	Systematic
Intellectual Perspective	'We'	'I'
Intellectual Attitude	Acceptance of Circumstances	Inquiry
Causality	'Cosmic' cause	Material cause
Problem-solving	Traditional techniques	New Solutions

Although there are clear differences between traditional and western thought-styles, it has been suggested that the processes whereby these different thought-styles evolved may have been similar (Horton, 1971). Horton cited the lack of developed awareness within traditional cultures of alternatives to established beliefs as the most significant difference to western thought in which, he believes, such an awareness is well developed. Ingle and Turner (1981) listed six aspects of 'closed' thinking characteristic of traditional cultures which may affect the efficacy of science education. These aspects are listed below.

1. *Attitudes towards the prediction of events*
The traditional attitude is to excuse each failure. The western approach is to reconsider the theory.
2. *Attitudes towards cause and effect*
The traditional attitude is to protect theories by citing other causes when a proposed cause has been demonstrated to be untrue.
3. *Attitude towards experiment*
Traditional thinkers wait for events to happen in order to demonstrate the truth of a prediction or theory. Western attitudes encourage experimental testing of theories.
4. *Attitudes towards confession of ignorance*
The traditional attitude is to avoid confessing ignorance.
5. *Attitudes towards coincidence, chance and probability*
Traditional attitudes do not readily admit the possibility of events occurring by chance.
6. *Attitudes towards time*
The traditional attitude is that life was better in the past. This legitimates the handing-down of beliefs because they derive from better times.

For any given individual, of course, these attitudes may or may not hold true, but it appears that schoolchildren can often hold more than one domain of knowledge about the world. In fact, it was consideration that traditional attitudes may conflict with the demands of the science classroom which suggested the adoption of an attitudinal survey – the TOSRA Survey (see Chapter Five). This survey is discussed in the next section.

3.4.5 Dual Knowledge Domains

Dart and Pradham (1967) reported that schoolchildren from traditional cultures often account for the natural world in two types of explanation - mythological and scientific, both from members of the same groups and from a single individual. For example, the phenomenon of earthquakes may be accounted for in terms of deities and in terms of more scientific explanations such as the action of fires at the centre of the earth. Solomon (1983) reports that even able western students may hold two dissimilar domains of knowledge - life-world knowledge and scientific knowledge, and can cross over between the two quite easily. However, western students are more likely to utilise the latter domain while children of traditional cultures are more likely to cling to their life-world knowledge. Because of the detached nature of the scientific domain, traditional students are also more likely to drop science when they leave school. When formal education is over, traditional beliefs and values may assume dominant roles in the lives of these students.

It has been asserted that inquiry-based styles of teaching in which students may question teachers' assertions and test for truth are not appropriate for traditional societies in which conformity has higher social value than ingenuity (Wilson, 1981) and where knowledge is seen as static, to be passed from generation to generation (Dart, 1972; Davey, 1972). School science may then represent a system imposed on students who already have a belief system about the natural world. Clearly, the task which must be tackled by the present education system is that of integrating the requirements of students from traditional or 'pseudo-traditional' cultures with modern science education.

3.5 Summary of Chapter Three

This chapter has provided an overview of the available literature on cultural considerations in science curricula, the nature of science learning, constructivism, the impact of cultural beliefs, values and norms on science education, and knowledge in traditional societies. This overview has provided the necessary contextual background for understanding the possible dislocations between modern science education and the needs and expectations of students from non-western cultural backgrounds.

In particular, consideration of the differing educational needs of ethnic minorities, modern trends in science education, the differentiated ways in which various cultures enact problem-solving, cultural and 'thought-style' differences between Maori, Pacific Island and European students suggested the research questions presented in Chapter Four. These thought-style differences are often predicated on attitudinal differences and differences in learning environments among students from different cultural backgrounds. It is contended that only through enhanced understanding of these differences will it become possible to understand the divergent needs of students and devise more effective ways of meeting their educational needs.

Through consideration of the cultural and thought-style differences between Maori, Pacific Island and European students, a research design and interpretive framework for the research described in this thesis were developed and are presented in Chapter Four in order to provide the framework underpinning the attitudinal and learning environment research described in Chapters Five, Six and Seven of this thesis.

CHAPTER FOUR

But we still argue about designs, still worry about how to know if our designs are yielding reliable knowledge.

Mary Kennedy (1996, p. 5).

RESEARCH DESIGN AND INTERPRETIVE FRAMEWORK

4.1 Introduction and Overview

The social sciences admit great scope for the act of observation to influence the system under observation. In the social sciences, the methodologies used, the data collected and the use of data cannot but reflect to some degree the views of the researcher. Burrell & Morgan (1979) have pointed out three assumptions which affect choice and implementation of research methodology. These are:

1. *Ontological assumptions* relating to the nature of the social phenomena under consideration. These raise questions as to whether reality is external to individuals and imposes itself on them or is the product of consciousness, and whether reality is objective or the result of cognition.
2. *Epistemological assumptions* concerning the basis of knowledge, its acquisition and communication. These raise questions as to whether knowledge can be acquired or must be experienced. The particular views held by researchers influence how they may wish to carry out research. If the viewpoint held is that knowledge is objective and tangible, then an appropriate stance to adopt, similar to that adopted in the natural sciences, is that of the observer. This stance is known as the positivist approach, the approach adopted by the researcher and author of the present study, a European male and former teacher. If knowledge is viewed as personal and subjective, then other stances may be appropriate. These may include interaction and involvement with the subjects whose behaviour is under investigation. This stance is known as the anti-positivist approach.

3. Assumptions which relate to *human nature* and the interactions between humans and their environment. One position which may be adopted is that of the human as an initiator of his or her actions. The opposite position is that of the human as responding to his or her external environment.

Bearing these assumptions in mind, a positivist approach to the research study was selected, with the researcher adopting the role of observer when appropriate in order to minimise possible influence on the conduct of the research. The adoption of this approach now guided the choice of research methodologies.

This chapter introduces and discusses the research methodologies used during the course of this study. In particular, a discussion of the qualitative and quantitative research methods used to elicit information about student attitudes and learning environments, the five research questions which underpin the entire study, and the overall research design are discussed in section 4.2. In section 4.3 descriptions of the statistical procedures used in data analysis, and the process used for implementing and analysing the TOSRA and CLES surveys are presented. Section 4.4 discusses in depth the qualitative methods used in the study and explains how interviews with teachers and students were conducted. In section 4.5 a detailed discussion of the quantitative methods adopted in the study is presented. Section 4.6 gives a philosophical perspective on the research methodologies used, including possible objections to these methods. Finally, section 4.7 describes the research samples and describes two pilot studies which were carried out in order to validate the TOSRA and CLES survey instruments.

4.2 Research Design

4.2.1 Research Methodologies

The research methodologies adopted in this study included:

1. Quantitative approaches involving questionnaire surveys
2. Qualitative approaches which include interviews with teachers and students.

The simultaneous use of both quantitative and qualitative approaches was designed to facilitate the gathering of a greater range of information than either quantitative or qualitative techniques alone could provide. Questionnaire surveys and statistical analysis allow careful extrapolation and generalisation to a wider population, while interviews allow much uncodified information to be elicited which could not have been captured by statistical approaches alone.

4.2.2 Research Questions

The research questions addressed in this study (see Chapter One, section 1.3.1) are listed here for discussion:

1. Are there any differences in students' attitudes toward science curriculum between ethnic minority groups and others?
3. Are there any differences in students' perceptions of their constructivist learning environments between ethnic minority groups and others?
3. Are there any associations between ethnic minority group students' perceptions of their learning environments and their attitudes to science?
4. Are there any associations between ethnic minority group students' perceptions of their constructivist learning environments and their achievements in science?
5. Are there any associations between ethnic minority group students' attitudes to science and their achievements in science?

Research questions 1 and 2 involve questionnaire surveys of ethnic minority group student attitudes towards the present science curriculum and their learning environments (see sections 4.3.2 – 4.3.5), canvassing of teachers' perceptions of their students' attitudes and cultural backgrounds, and interviews with students. Research questions 3, 4 and 5 involve correlation of the findings of the TOSRA and CLES surveys, teacher appraisals of the academic achievement of the students concerned, and interviews with teachers and students (see section 4.5.2). Teachers' perceptions of learning environments, curricula and their understanding of science were elicited in order to enhance present knowledge of the interpersonal dynamics of classrooms, and to help to identify areas of teaching practice in need of remediation.

Following analysis and reflection on the research findings recommendations for improving student attitudes and achievements were developed and refined. The development of recommendations for improving student attitudes and achievement required reflection on all information acquired during the course of the research and making considered deductions on how best to facilitate learning in science for ethnic minority groups in order to enhance their science education outcomes.

4.2.3 Research Design

The research design adopted for the study involved the following steps:

1. Conducting a survey of student attitudes to science using a modified form of the TOSRA questionnaire (Fraser, 1981). By 'student attitudes' is meant enjoyment, leisure interest, career interest, attitudes to scientific inquiry etc. The implementation of this survey is described in Chapter Five.
2. Conducting a survey of student perceptions of their learning environments using the revised Constructivist Learning Environment Survey (CLES) questionnaire (Taylor, Fraser & White, 1994). The implementation of this survey is described in Chapter Six.
3. Conducting interviews with teachers and students. The teacher and student interviews are described in Chapter Seven.

4.2.4 Rationale for Research Design and Methodology

Questionnaire surveys (Cohen & Manion, 1986; Wiersma, 1991; Mayher & Brause, 1991) are appropriate research instruments for studies which aim to enhance our knowledge of student attitudes and perceptions of learning environments by enabling the gathering of multiple information in a manner conducive to statistical and other analysis and interpretation. If the target population is sufficiently large, then meaningful extrapolation and generalisation to the wider population can be made.

In tandem with teacher and student interviews, the TOSRA attitudinal survey can provide an understanding of how students' cultures and beliefs interface or conflict with the science classroom. The survey of students' perceptions of their learning environments using the CLES survey is also seminal to the study because of the possibility that causal links between the holding of strong traditional beliefs, and

difficulties in adapting to a scientific education may be traced or inferred, although Fraser (1994) emphasises that educational studies generally aim to investigate the associations between outcomes and learning environments and that causal conclusions cannot strictly be drawn.

4.3 The Quantitative Research Methods Used

4.3.1 The TOSRA Questionnaire Survey

The TOSRA survey is designed to address multiple meanings relating to the term 'Attitude to Science', using scales comprising statements to which students respond by providing numerical values according to their level of agreement with those statements. A detailed discussion of the individual scales and the implementation of the TOSRA survey is given in Chapter Five.

4.3.2 TOSRA Implementation and Analysis

The TOSRA survey was implemented according to the following steps:

1. Before implementation of the main survey, a pilot study was carried out in order to validate the survey instrument (this is discussed in Chapter Five, section 5.2).
2. The internal consistency reliability or Cronbach alpha (Cronbach, 1951) for each scale, and the discriminant validity (the degree to which the chosen scale uniquely measures a particular attitude) of each scale were both calculated.
3. Standard measures (mean scores and standard deviations) were calculated in order to validate the survey information and to provide summary statistics about the target populations.
4. A factor analysis was performed (the factors being ethnicity, gender, form level, school, and school type) in order to determine associations between different survey scales, learning environments, cultural beliefs and attitudes.
5. A MANOVA analysis was applied on the entire set of questionnaire responses in order to determine whether particular variables had significant main effects on subgroup scale means.
6. ANOVA analysis was applied on the entire set of responses in order to determine whether between-group scale mean differences were significant.

7. Multivariate tests of significance were carried out in order to look for differences between ethnicity, gender, form level, school and type of school for all scales, and assess possible interactions between these factors.

4.3.3 The CLES Questionnaire Survey

The survey of students' perceptions of their learning environments was implemented using the revised Constructivist Learning Environment Survey (CLES). The original CLES (Taylor & Fraser, 1991) was developed to assist teachers to reflect on their epistemological assumptions and reshape their teaching practice. That questionnaire addressed four scales: Autonomy, Knowledge, Collaboration and Reflection. The revised CLES (Taylor, Fraser, & White, 1994) was developed later for teachers interested in constructivist reform of high school science and mathematics. The five CLES scales are discussed in Chapter Six, section 6.1.3.

The intentions of the revised questionnaire are to investigate psychosocial classroom environments from the perspectives of students so that action may be taken to:

1. Make science and mathematics seem relevant to life outside school.
2. Encourage students to engage in reflective negotiation.
3. Encourage students to participate in the design, management and evaluation of their learning.
4. Empower students to express concern about the quality of teaching and learning activities.
5. Enable students to experience the uncertain nature of scientific and mathematical knowledge.

These intentions accord well with the intentions of the present study. Thus, the CLES questionnaire was considered to be a suitable instrument for the survey of student perceptions of their learning environment.

4.3.4 CLES Implementation and Analysis

The CLES survey was administered in the following steps:

1. A pilot study was carried out using the CLES survey (see Chapter Six, section 6.2).

2. Statistical analyses similar to those used with the TOSRA survey were carried out. Cronbach alpha reliabilities, group means and standard deviations for each scale were calculated.
3. MANOVA analysis was applied in order to determine whether the factors had significant effects on subgroup scale means.
4. ANOVA analysis was applied in order to determine whether differences between scale means are significant.
5. Multivariate tests of significance were adopted in order to look for differences between ethnicity, gender, form levels, type of school and assess possible interactions between these variables.

4.3.5 Limitations of the Questionnaire Surveys

The limitations of the questionnaire surveys adopted in this study include unavoidable constraints on sample numbers and selection, and the possibility that some of the responses made by students might not be representative. It is recognised that surveys such as the TOSRA and CLES admit the possibility that some students will fake responses. However, this was minimised by allowing students the choice of remaining anonymous and by stating clearly that students' responses would not be used for the purposes of grading.

Additionally, use was made of group means (class average) for comparative purposes. However, the validity of the class average as a meaningful indicator has been questioned, given that multiple learning environments can exist within a given class (Tobin & Gallagher, 1987). Thus, for the purposes of this study, it was necessary to assume that the class mean is a valid statistic.

4.3.6 About the Statistical Procedures Used in this Study

Sections 4.3.6.1 to 4.3.6.4 introduce the main statistical procedures utilised in the analysis of the questionnaire surveys.

4.3.6.1 *T-tests*

T-tests are used to compare means between two distributions. A standardised score, the t-value, is computed which determines whether or not the means of two

populations are significantly different on the basis of their distributions. T-tests are used in this study to investigate differences in survey responses between groups defined by ethnicity, gender, form level etc.

4.3.6.2 ANOVA (*Analysis of Variance*)

One-way ANOVA tests the significance of the differences between distributions where there is one variable but more than two levels (e.g. in the comparison of mathematics test scores for three forms where the students are a single group, the three forms represent three levels within the group, and the test score represents a single dependent variable). Analysis of the means and variances of the levels can be refined using one of a number of post-hoc tests such as the Sheffe and the Student Newman-Keuls tests .

Two-way ANOVA is used where there is more than one factor or variable (e.g. the test scores of a set of students analysed by gender and form level, where gender and form level are two factors, and the test score is the single dependent variable). One-way and two-way ANOVA are used in this study to compare distributions in questionnaire survey scores between groups (ethnicity, gender, form level, school etc).

4.3.6.3 MANOVA (*Multivariate Analysis of Variance*)

MANOVA is used to determine whether a grouping variable (e.g. age or educational intervention) affects a dependent variable (e.g. attitude) by using the F distribution to determine whether this ratio is different from a chance expectation. MANOVA is used in this study to examine the effects which different variables (ethnicity, gender, form level etc) have on the dependent attitudinal and perception variables defined by the questionnaire survey scales.

4.3.6.4 Cronbach Alpha (*Test of Reliability*)

The Cronbach Alpha test of reliability is one of a number of tests of internal consistency, known as interclass correlations, frequently used in the validation of questionnaire surveys. The higher the reliability value returned, the greater is the reliance which can be placed on the validity of the survey. In this study, it is used to

estimate the degree of confidence which can be placed in the survey responses of participant students.

4.4 Perspectives on the Quantitative Methodologies Used

4.4.1 Quantitative Research in Education

Quantitative research in education seeks to determine relationships, effects and causes. The quantitative research methodology used in this study aimed to investigate the attitudes of minority group students towards their studies in science and their perceptions of their learning environments from a perspective based on constructivist theory. This theory serves to:

1. Focus the researcher's theoretical procedures on the relationship between students' cultural backgrounds, prior knowledge and attitudes towards science.
2. Extend the researcher's experience and information base for the development of recommendations for the enhancement of curricula and teaching practice.

The quantitative research techniques involving questionnaire surveys of student attitudes towards science and perceptions of their learning environments were designed to produce information complementary to that of the qualitative interview approaches.

4.4.2 Objections to the Quantitative Research Methodologies

A variety of research approaches are available to the researcher which accord with the positivist approach to investigating the social behaviour of humans. These include the use of surveys and designed experiments, each of which admit quantitative analysis of the information gathered. However, the ontological and epistemological underlay of positivist research methodologies have been subjected to question. Kirkwood (1988) articulated and summarised the main objections raised about the positivist approach and gave reasons for treating such approaches with caution.

1. All values, beliefs and assumptions which shape the social community also shape any research intended to investigate the community.

2. The intentions of the natural and social sciences are completely different.
3. Knowledge cannot be simply an objective, value-free product of an impartial observer.
4. The means and ends of social sciences research are inextricably interrelated.
6. Theory and observation are inextricably interrelated.

However, the researcher of the present study believes that these objections are largely theoretical and are not necessarily manifested in a particular research endeavour. More immediate and pressing problems may be expressed in practice when, for example, students respond to interviews and questionnaires in ways that are not representative, or when the presence of an observer induces change in the behaviour of subjects. It was problems such as these which the researcher sought to address.

4.5 The Qualitative Methods Used

4.5.1 Rationale for Conducting Interviews

A feature of this study was the use of interviews with teachers and students, both in order to elicit teacher opinion and to serve as a basis for the development of recommendations for enhancement of student science education outcomes. Although science transcends culture, the teaching and learning of science cannot be completely separated from the lives and beliefs of students. Thus, effective science curricula must aim to encourage minority group students, particularly those deriving from traditional societies, to feel comfortable in the science classroom by recognising their cultural backgrounds and beliefs about the natural world, and by emphasising the contributions of non-western people to science.

Interviews were held with teachers and students in order to inform curriculum design by eliciting information about ethnic minority and other students additional and complementary to that acquired in the questionnaire surveys.

4.5.2 Interviews with Teachers and Students

Interviews with both students and teachers were designed to address the following research questions:

1. What feelings do ethnic minority group students have towards science?
2. Is teaching these students rewarding?
3. What is the importance of science to these students?
4. Why do few ethnic minority group students continue studies in science during senior secondary and tertiary years?

The interviews were to be used to sample teachers' opinions and gather other relevant information (Cohen & Manion, 1986; Wiersma, 1991; Brause & Mayher, 1991). The interviews were designed as *less formal* interviews. In *less formal* interviews the interviewer accesses a suite of key issues which are raised in conversational style in order to minimise any effects on student behaviour. The key useful features of interviews are that they provide extensive opportunities for questioning, probing for related information, and for data reduction. However, interviews have the disadvantages of being labour and cost intensive, providing multiple possible sources of error (interviewer, instrument, coding, sampling etc), and may be unreliable (Cohen & Manion, 1986).

The plan followed for organising and conducting interviews with teachers and students was as follows:

1. A standardised suite of interview questions was prepared in the light of the findings of the questionnaire surveys (the interview questions are given in Chapter Seven).
2. Informal discussions were held singly with teachers and the key responses recorded.
3. Informal discussions were held with students in groups of three from each class and key responses recorded.
4. The findings which emerged from the interviews were synthesised and documented.

The implementation and findings of the interviews with teachers and students are discussed detail in Chapter Seven.

4.5.3 The Ethnographic Approach

The interview method chosen by the researcher embodies an *ethnographic* approach which focuses on the manner in which humans make sense of their social environment. A central tenet of the ethnographic method is that the social nature of humans is best understood from the perspectives of the subject and that the researcher must share the environment and frames of references of the subject - the *idiographic* approach. In accordance with this belief, the researcher proposed to conduct interviews on site in an informal manner, assuring students of the confidentiality of their responses and making clear to them the great importance of truthful and representative discussion.

In conducting educational research, the seminal features of the ethnographic-idiographic method summarised by Kirkwood (1988) were borne in mind:

1. *The research is empirical and involves data collection.*

The present study is empirical in that the questionnaire surveys and interviews essentially constitute tests of student attitudes and opinions, generating a body of information and requiring data collection, summation and the eliciting of research findings.

2. *The research is contextual and the researcher attempts to comprehend his or her subjects and their behaviours in a given context.*

To achieve context faithful to the learning environments considered in this study, the researcher implemented the surveys on-site. Interviews were also conducted on-site and in groups, having already achieved some familiarity with classes through prior implementation of the questionnaire surveys and prior discussions with teachers.

3. *The researcher must be aware of the environment of the research so that there is little or no undue influencing of the behaviour of the subjects or change induced in the environment.*

To enhance his awareness of the learning environments concerned, the researcher briefed teachers extensively and was also briefed by teachers prior to the study. Only then did the researcher implement the surveys and conduct interviews.

4. *The research is personal and the researcher is placed within the environment.*

Considerable efforts were undertaken to establish informality so as to encourage students to voice opinions freely.

5. *The research is subjective and the relationships between the researcher and the subject must be accounted for.*

The researcher bore in mind the possible effects his presence would have on the students, but believed that these were minimal because student interviewees had already experienced his presence at school and in class.

6. *The research must be flexible and, where appropriate, several research methodologies used together and the findings of the different methods contrasted.*

In order to maximise the effectiveness of the study and to obtain complementarity of findings, both quantitative and qualitative research methodologies were adopted, and both teachers and students were to be interviewed. The approach taken, involving informal interviews in groups, was chosen in accordance with the ethnographic-idiographic model, described by Kirkwood, in which the researcher shares the environment and frames of reference of the teachers and students.

4.5.4 Objections to the Ethnographic Method

Objections have been raised about the ethnographic-idiographic method. These include questions about reproducibility, reliability and validity. Miles (1979), for example, believed that qualitative research is intuitive, primitive and unmanageable. Attempts have been made to address such problems inherent in qualitative research. For example, LeCompte & Goetz (1982) have attempted to improve the external reliability of qualitative techniques by encouraging the examination of several questions on the part of the researcher. These are:

1. What is the status of the researcher?
2. How were the subjects selected?
3. What is the nature of the social situations and conditions?
4. What are the analytic constructs and premises?
5. What are the main methods of data collection and analysis?

The researcher of the present study felt that by careful design of the research process and careful inference from any information gathered, problems relating to ontological and epistemological assumptions could largely be avoided.

4.6 Perspectives on the Qualitative Methodologies Used

4.6.1 Objectives of the Qualitative Research

Qualitative research is based on the notion of context sensitivity and on the belief that the physical and social environment greatly influences human behaviour. Qualitative research is often carried out for the purpose of understanding social phenomena.

The qualitative research methods used in this study investigated the cultural beliefs characterising the target groups concerned and which may create preconditioned attitudes and conceptions mitigating against success in school science. In particular, this part of the study investigated the relationships (if any) between the holding of strong traditional cultural beliefs and the consequent formation of particular attitudes towards education generally, and science education in particular.

Thus, qualitative research was carried out in order to complement the findings of the questionnaire surveys and specifically in order to:

1. investigate the cultural beliefs which characterise the ethnic groups concerned, and especially any which might create preconditioned attitudes which mitigate against success in high school science;
2. investigate the relationship (if any) between the holding of traditional cultural beliefs and the fostering of negative attitudes towards education generally, and science education in particular; and
3. investigate the development of students' scientific conceptions and attitudes towards science from a perspective based on constructivist theory (a description of constructivist theory was presented in Chapter Three, section 3.3).

A brief description of the interview methods used is given in Chapter Seven, section 7.3.

4.6.2 A Constructivist Approach to Qualitative Research

Constructivism is concerned with the intents, beliefs and emotions of individuals and recognises the importance of prior experience on the way the world is experienced and interpreted (Driver & Oldham, 1985). Constructivism also provides a framework for interpreting multiple aspects of educational environments which are founded on the needs of individuals. By comparison with the constructivist approach, the empiricist-inductivist tradition places no particular emphasis on the learner's own conceptions.

Because constructivist theory (MacKinnon & Erickson, 1988) also assumes that the establishment of a knowledge base about teachers is essential before addressing the subjectively reasonable beliefs of teachers (Fenstermacher, 1978), a study of the teachers and their perceptions of their students was carried out in addition to interviews with students. A brief biography of each of the teachers concerned is given in section 7.2.3.

4.6.3 Objections to the Qualitative Research Methodologies Used

The internal reliability of qualitative research may be enhanced by using several researchers, participant researchers, peer review and recorded data collection. However, many qualitative methods remain incapable of admitting broad generalisations or of providing objective benchmarks for verification of theory. It can also be argued that such techniques investigate meanings and behaviours but not the factors which give rise to them. Additionally, in many human scenarios, there are individuals who are able to impose their own definitions on the other participants, often because of an imbalance of power (Bernstein, 1974). Examples of such situations might include a teacher and pupils, or a sports referee and the sporting participants. In scenarios such as these, subjects' behaviours are influenced by a particular agent located within the system and it may be wrong to infer specific causes to particular patterns of behaviour.

Clearly, there have been historic differences of opinion amongst educational philosophers and researchers about the relative merits of quantitative and qualitative research methodologies. Cohen & Manion (1986) identified a 'great philosophical

debate' between the advocates of determinism and voluntarism. However, a position adopted by some workers is that the positivistic quantitative approach and the anti-positivistic approach are not mutually exclusive or antagonistic. Rather, these methods may be regarded as complementary and may help to offset biases in each other (Reichardt & Cook, 1979). Schwartz & Jacobs (1979) have also argued that qualitative techniques are essentially methods of scholarly inquiry, while quantitative techniques determine the predictability and controllability of situations.

During the course of this study, the researcher attempted to avoid making explicit or implicit assumptions regarding student perceptions and attitudes, or about the learning environments concerned. Nevertheless, it was recognised that certain assumptions are unavoidable in qualitative research. For example, it was assumed that student interview responses were representative of the students themselves, reflected truthfully their learning environments, and that trends in responses made by particular categories of student (Maori, Pacific Island, European etc) may be extrapolated meaningfully to their wider groups.

4.7 Data Sources and Collection

4.7.1 Research Samples

4.7.1.1 Target Student Numbers

An unavoidable limitation of the research methodology used in this study is its necessary confinement to a very small fraction of the total population of the relevant ethnic minority group students in New Zealand. It was hoped to include at least 500 ethnic minority group students in the survey, but actual numbers of participants (579) were constrained by the resources available and the number of schools (6) willing to participate in the study.

4.7.1.2 Selection of Participant Schools

Initially, it was planned that careful selection of schools using a rigorous stratified random sampling procedure would help to broaden the applicability of the research

findings. Alternatively, a cluster sampling approach (Cohen & Manion, 1986) or purposive sampling could have been adopted in order to constrain the number of schools and therefore the number of participant students to manageable limits. It was also hoped that the schools would be distributed geographically as widely as practicable so that the ensuing data would not be biased towards one region or to any particular socio-economic stratum. However, participant schools were eventually selected on the basis of accessibility and willingness to participate in the study.

The target populations comprised students from forms three, four and five. Schools with significant numbers of ethnic minority group students on their roles and which indicated willingness to participate in the research project were listed, contacted by telephone and invited to participate in the study (the participant schools are described briefly in Chapter Five, section 5.3.1).

4.7.1.3 Restriction of Participant Form Levels

The range of form levels was restricted in order to maximise the generalisability of the data. Thus, if any differences were maintained from the first science year to higher form levels, it could be inferred that such differences were due to ethnicity. If any differences between the first year and upper form level students were seen to decrease, this could indicate that secondary level science education has a neutralising effect on ethnicity, possibly related to psychosocial development. If the differences were greater between the first year and higher form levels, this could indicate that secondary science education has a less positive influence on ethnic minority students than on other student populations.

4.7.2 The Pilot Studies

Pilot studies were carried out prior to the implementation of the main surveys, the main purpose of which was to validate the TOSRA and CLES questionnaires. The pilot studies were also intended to give the researcher experience in the implementation of questionnaire surveys and in participant observation. The results of these studies were analysed using the same statistical procedures later used in analysing the results of the main part of the study (see sections 5.2 and 6.2).

4.8 Summary of Chapter Four

Chapter Four has discussed the research methodologies used in this study. The research design and the five research questions of the study were presented, descriptions of the statistical methods used given, and the procedures adopted for implementing and analysing the TOSRA and CLES surveys presented. Additionally, an introduction to the quantitative and qualitative and research methods used in the study was given.

In summary, this chapter has set out the plan by which the research conducted in this study was carried out. Chapter Five begins the discussion of the technical details of the research actually undertaken and describes the implementation, analysis of, and findings of the TOSRA survey.

CHAPTER FIVE

TRIAL AND IMPLEMENTATION OF THE TOSRA SURVEY

It wasn't just designs that preoccupied researchers. We argued about the use of covariates, the reliability of change scores, the appropriate use of analysis in nested school designs, ways of teasing out interaction effects, and every other conceivable methodological issue you could imagine.
(Mary Kennedy, 1996, p. 5)

5.1 Introduction

This chapter describes the implementation and the findings of the TOSRA Attitudes to Science Survey, carried out in order to compare attitudes towards science among Maori, Pacific Island students and others.

5.1.1 The Research Questions

In this chapter, a pilot study involving trial and main survey of the TOSRA are discussed (rationales for conducting these surveys were discussed in Chapter Four). Specifically, the survey of student attitudes relating to research question 1, and an investigation of associations between student attitudes to science and their achievements in science (research question 5), are discussed in this chapter. The survey on student perceptions of learning environments relating to research questions 2, 3 and 4 is described in Chapter Six.

5.1.2 Contextual Background

Significant differences in attitudes towards science between non-western students and western students have been reported by several workers (extensive discussions of this were given in Chapters One, Two and Three). For example, Novick & Dudvani (1976) reported significant attitudinal differences between Israeli students which appeared to relate to cultural background in that students from non-western

backgrounds displayed significantly less positive attitudes than those from western backgrounds.

Other recent research has sought to establish a link between socio-economic and other cultural influences and attitudes towards science. Jegede & Fraser (1989) reported a correlation between socio-cultural factors and attitudes towards science and they proposed the idea that the less positive attitudes which characterise students of non-western backgrounds may result from an inhibitory consequence of those socio-cultural factors. Wilson (1981) has suggested that negative attitudes towards science may derive from the alienating nature of school science.

It was with these and other similar findings in mind that the author implemented the surveys described in this and the next chapters and analysed the data.

5.1.3 About the TOSRA

The TOSRA consists of 70 items arranged in seven Likert-type scales (Likert, 1932) designed to address multiple meanings relating to the term 'Attitude to Science'. These meanings accord with Klopfer's (1971) categories of attitudinal aims. Each scale comprises ten questions distributed throughout the survey questionnaire. The scales are:

1. Social Implications of Science

This scale attempts to measure students' manifestation of favourable attitudes towards science and scientists.

2. Normality of Scientists

This scale also measures attitudes to scientists as people and embodies the notion that scientists are normal people rather than the eccentrics often portrayed in the media.

3. Attitude to Scientific Inquiry

This scale measures students' attitudes to the methods of scientific inquiry promoted at secondary school and embodies an acceptance of scientific inquiry as a way of thought.

4. Adoption of Scientific Attitudes

This scale measures the degree to which students have adopted general 'scientific attitudes'.

5. Enjoyment of Science Lessons

This scale measures students' enjoyment of science learning experiences.

6. Leisure Interest in Science

This scale measures students' development of interest in science and science-related activities.

7. Career Interest in Science.

This scale measures students' interest in pursuing a career in science.

These scales are discussed in the TOSRA Test of Science Related Attitudes Handbook (Fraser, 1981). In particular, the *Normality of Scientists* scale measures attitudes to scientists as people as a manifestation of attitudes to science generally. Fraser pointed out that the *Adoption of Scientific Attitudes* scale is intended to measure specific attitudes considered important in the work of scientists (Cohen, 1971).

5.2 A Pilot Study: Validation of the TOSRA

5.2.1 Implementation of the Pilot Study

Prior to the main study (see section 5.3), a pilot study was carried out in order to validate the TOSRA questionnaire and give the researcher experience in implementing and analysing data generated by the TOSRA. The class concerned comprised 13 senior female physics students, characterised by their teacher, MR, as of above average ability. The survey was implemented on 11 March 1998 and the questionnaire forms scored manually using the Test of Science Related Attitudes Score Key.

5.2.2 Survey Data and Summary Statistics

The mean score and standard deviation for each scale were calculated for each student and are given in Table 5.1 below (for brevity, **socimp** denotes *Social Implications of Science*; **normsci** denotes *Normality of Scientists*; **attinq** denotes *Attitude to Scientific Inquiry*; **adoptatt** denotes *Adoption of Scientific Attitudes*; **enjoyless** denotes *Enjoyment of Science Lessons*; **leisintr** denotes *Leisure Interest in Science*; **careerin** denotes *Career Interest in Science*. In this, and all following tables, the symbol μ denotes the scale mean and σ denotes the scale standard deviation.

Table 5.1: Summary Statistics for each Pilot Study Scale

Student ID	socimp	normsci	attinq	adoptatt	enjoyless	leisintr	careerin
1	38	41	36	38	36	26	24
2	38	44	31	32	36	24	24
3	34	41	49	39	36	28	36
4	36	39	45	41	35	26	30
5	37	35	44	41	41	31	28
6	33	36	40	43	27	30	39
7	34	30	33	40	38	23	26
8	33	35	34	40	25	26	28
9	39	32	25	36	42	21	28
10	40	33	39	42	44	40	41
11	20	29	37	40	24	15	21
12	40	41	38	39	40	25	36
13	36	37	40	36	23	20	26
μ	35.2	36.4	37.7	39.0	34.4	25.8	29.8
σ	5.2	4.7	6.3	2.9	7.2	6.0	6.3
α	0.55	0.49	0.51	0.60	0.41	0.57	0.47

The scale means vary between 25.8 for the *Leisure Interest in Science* scale and 39.0 for the *Adoption of Scientific Attitudes* scale. Mean correlations were also calculated, varying between slightly negative and 0.76, suggesting that the scales were measuring distinct, if overlapping, attitudes. The Cronbach alphas varied between 0.47 and 0.60. Fraser (1986) stated that, in learning environment research, alpha coefficients greater than 0.7 indicate satisfactory internal consistency, while Nunally (1978) suggested a critical value of 0.6. The calculated alphas therefore indicated somewhat unsatisfactory scale reliability, probably an artefact of the small sample size.

5.2.3 Comparison with a Prior TOSRA Implementation

To validate the pilot study a comparison was made with a prior implementation of the TOSRA survey conducted in 1977 on Years 7-10 students in metropolitan Sydney (Fraser, 1981). Table 5.2 gives the pilot study scale means and variations, along with those of the Sydney study.

Table 5.2: Pilot and Sydney Studies Scale Means and Variations

SCALE	Pilot Study		Sydney Study	
	μ	σ	μ	σ
Social implications of Science	35.2	5.2	37.3	5.2
Normality of Scientists	36.4	4.7	36.3	4.9
Attitude to Scientific Inquiry	37.7	6.3	35.9	6.7
Adoption of Scientific Attitudes	39.0	2.9	38.4	4.2
Enjoyment of Science Lessons	34.4	7.2	33.5	8.6
Leisure interest in Science	25.8	6.0	26.9	8.4
Carer Interest in Science	29.8	6.3	28.8	8.4

It is evident that the pilot study scale means and variations are similar to those of the Sydney study. In particular, the results for the *Adoption of Scientific Attitudes* scale are not only similar to the corresponding Sydney study results in its mean value, but also in that its variability is the lowest of the seven scales. This suggests that student responses were consistently more homogenous for this scale than for others.

5.2.4 Conclusions on the Pilot Study

The results of the pilot study compared well to a prior implementation of the TOSRA. The pilot study yielded sensible results which supported the use of TOSRA instrument for use in the main part of the study and provided worthwhile practical experience.

5.3 The Main Study: Results of the TOSRA Survey

5.3.1 The Participant Schools and Students

In this section, a brief description of the range of participant schools and target students in the main study is given. Since the main focus of the study is to compare the attitudes towards science among ethnic minority students with others, the classification of ethnic minority students is necessarily broad and encompasses only four groups: Maori, Pacific Island, Asian and Europeans. The key comparisons of the study are those drawn between Maori, Pacific Island and European students. Here, no distinction is made between Asians of Chinese or related ethnicity (eg. Malaysian, Taiwanese, Hong Kong etc), or of Indian or related ethnicity (eg. Pakistani, Sri Lankan etc).

(i) RO College

RO College is a public boys' school in which the researcher taught for three years between 1987-1989. It is situated in the Wellington suburb of Kilbirnie, a working class catchment close to Wellington airport. The school roll has declined markedly from some 800 students in the late 1980s to just over 400 today. Of these, approximately 50% self-identify as either Maori or Pacific Islanders. Some 120 RO students participated in the survey, distributed over several classes within each form level in order to avoid the possible biasing effects of streaming (a breakdown of the ethnic backgrounds of participant RO students is given in Table 5.3). The survey was administered to several classes throughout the day on Wednesday 4 March 1998. The class teacher, DR, assessed the classes involved as a little below average for their form levels by comparison with other years and other schools.

(ii) SP College

SP College is a Roman Catholic boys' school situated in Kilbirnie, about 1 km from RO College. The roll is presently about 600 students of whom approximately 40% identify as of Maori or Pacific Island ethnicity. SP's classes are unstreamed, and so there was no concern about possible bias of survey results. Some 144 SP students participated in the survey during the mornings of Tuesday 17 March and Wednesday 18 March 1998.

(iii) TT College

TT College is a co-educational school of some 400 students situated in the suburb of Taita in Lower Hutt, some 20 km north of Wellington. Of these, 40% identify as of Maori or Pacific ethnicity. TT College classes are not streamed. Some 64 TT College students participated in the survey which was administered throughout the day on Tuesday 10 March 1998.

(iv) RT College

RT College is a co-educational school located in the rural township of Marton, approximately 165 km north of Wellington. It supports the surrounding rural community, and a small base of local manufacturing and service industries. The school roll is presently about 400 students by comparison with a roll of over 1,000 in 1988. Of the present enrolment, about 50% identify as Maori. The decline in the school roll relates to the closure of several industries in the region following a downturn in the economy. There are very few Pacific Island students at RT College. RT College classes are unstreamed. Some 88 RT College students participated in the survey which was conducted on Friday 27 March 1998.

(v) MG College

MG College is a public girls' school situated in the working class catchment of Mt. Albert in Auckland. The roll is presently about 450 students, of whom 60% identify as of Maori or Pacific ethnicity. Some 68 MG students participated in the survey which was administered by MR, senior science teacher at the college, throughout the day on 16 March 1998.

(vi) SMW College

SMW College is a public girls' school situated in the affluent catchment of Thorndon in Wellington. The roll is presently about 500 students, of whom 20% identify as of Maori or Pacific ethnicity. Some 116 SMW students participated in the survey which was administered throughout the day of 13 May 1998.

A breakdown of the ethnic backgrounds of participant students is given in Table 5.3.

Table 5.3: Participant Students by Form Level and Ethnic Background

SCHOOL & FORM	EUROPEAN	MAORI	PACIFIC Is	ASIAN	TOTAL
RO 3	32	6	9	8	55
RO 4	4	6	4	5	19
RO 5	5	8	12	13	38
TT 3	16	5	0	1	22
TT 4	7	6	5	1	19
TT 5	9	8	2	0	19
SP 3	30	7	13	3	53
SP 4	26	1	11	5	43
SP 5	37	1	4	2	44
MG 3	14	1	7	1	23
MG 4	12	0	5	7	24
MG 5	12	0	5	0	17
RT 3	23	6	0	1	30
RT 4	17	5	0	1	24
RT 5	17	16	0	0	33
SMW 3	19	3	3	1	26
SMW 4	40	3	9	5	57
SMW 5	21	6	4	2	33

The TOSRA was thus administered to a total of 579 students from the six participant schools. The sample sizes involved are considered large enough to provide meaningful insight into the attitudes of Maori, Pacific Island, Asian and European science students in New Zealand. All seven of the original scales of the TOSRA were utilised in the survey in order to elicit as much information as possible about student attitudes.

The following sections discuss the TOSRA scale means in respect of the factors ethnicity, form level, gender, school attended, and type of school (ie. single-sex or coeducational).

5.3.2 Overall Scale Means for the Main Survey

5.3.2.1 *The TOSRA Scales: Initial Results*

Initially, scale means, standard deviations (variations) and Cronbach alpha reliabilities for the entire target student population, irrespective of ethnicity, form level or gender, were calculated. These data are presented in Table 5.4 below, along

with scale means and standard deviations (variations) for the Sydney study (Fraser, 1981) for comparison.

Table 5.4: Survey Scale and Sydney Study (in brackets) Means and Variations

Scale	Mean	Standard Deviation	Minimum	Maximum
Social Implications of Science	26.7 (37.3)	6.0 (5.2)	10.0	46.0
Normality of Scientists	26.6 (36.3)	5.9 (4.9)	12.0	50.0
Attitude to Scientific Inquiry	23.4 (35.9)	6.7 (6.7)	10.0	43.0
Adoption of Scientific Attitudes	25.2 (38.4)	5.7 (4.2)	10.0	45.0
Enjoyment of Science Lessons	30.1 (33.5)	9.6 (8.6)	10.0	50.0
Leisure Interest in Science	36.7 (26.9)	8.2 (8.4)	11.0	50.0
Career Interest in Science	33.5 (28.8)	8.3 (8.4)	11.0	50.0

The means vary from 23.4 for the *Attitude to Scientific Inquiry* scale, to 36.7 for the *Leisure interest in Science* scale. It is evident that most of these means are quite different to the means for the Sydney study. In five cases the means are smaller than the Sydney study means and, in two cases, greater.

The *Standard of Academic Achievement* scale represents qualitative judgements made by teachers on the academic level of a selected subset of the students involved, used for correlative purposes only (see section 5.4) and to address research questions 4 and 5 (see section 5.1.1). These students were selected to cover the entire range of ethnic backgrounds, form levels and gender of the study. Teachers were required to appraise the overall academic achievement of their students on a scale from 1 to 5, where 5 denotes 'excellent' achievement (a top student), 3 denotes 'average' achievement (an average student for age and form level) and 1 denotes 'poor' achievement (a below average student) etc. These teacher appraisals were judged to be the most convenient and accurate way of providing a credible measure of student achievement given the varying natures of each school, curriculum and class. More objective approaches, such as calculating average marks in school examinations or utilising students' class rankings, would have required more teacher input and would not have addressed the problem of inter-class and inter-school variability. In total, 81

students were appraised in this way, giving a scale with a mean of 2.86 and a standard deviation of 1.28. For the calculation of correlations with the TOSRA scales (this is addressed in 5.4.1), these values were multiplied by a factor of seven in order to achieve numeric magnitude consistent with the main survey scale means.

5.3.2.2 Discussion of Total Population Scale Means

The scale means are all smaller than those of the Sydney study except for the *Leisure Interest in Science* and *Career Interest in Science* scales. The less positive attitudes to science than for the Sydney study evident in five of the seven scales may reflect the working-class socio-economic catchments of several of the participant schools. Additionally, all of the participant schools have large ethnic minority enrolments from educationally under-performing groups, possibly depressing the means still further. Also, several of the classes concerned were appraised by their teachers as below average in academic ability and attitude for their form level by comparison with other years and other schools (e.g. each of the RO forms involved in the study and the fifth form at SP).

5.3.3 Inter-Scale Correlations

5.3.3.1 Alpha reliabilities and Scale Intercorrelations

Calculation of inter-scale correlations were performed using the Pearson 2-tailed Correlation Coefficient (significant at the 0.01 level). Table 5.5 below gives the calculated inter-scale correlations, mean correlations, and Cronbach alphas for each scale.

Table 5.5: TOSRA Inter-scale Correlations and Mean Correlations

SCALE	socimp	normsci	attinq	adoptatt	enjoyless	leisintr	careerin	Mean Correlation	Alpha
socimp	1.00	.55	.31	.57	.57	.48	.56	.51	.79
normsci		1.00	.31	.45	.42	.30	.43	.41	.77
attinq			1.00	.38	.37	.31	.33	.34	.81
adoptatt				1.00	.64	.60	.64	.64	.73
enjoyless					1.00	.70	.72	.67	.91
leisintr						1.00	.77	.62	.86
careerin							1.00	.67	.89

The Cronbach alphas vary from 0.73 to 0.91, indicating strong internal reliability of each of the scales. The majority of the inter-scale correlations are moderate or quite high, but there are several notably low correlations. For example, the *Attitude to Scientific Inquiry* scale correlates poorly with the *Normality of Scientists* and the *Leisure Interest* scales. This suggests that the *Attitude to Scientific Inquiry* scale is actually measuring an attitude independent of, if overlapping with, the other two scales. Of the seven survey scales, the *Enjoyment of Science Lessons* scale correlates the most highly with other scales. It correlates particularly highly with the *Leisure Interest in Science* and *Career Interest in Science* scales, suggesting that the scales are not measuring independent attitudes.

The high correlations also suggest that student enjoyment of science lessons may be a powerful determinant of future career interest in science. This perhaps underscores the profound influence of the secondary teacher in creating an enjoyable and productive classroom environment, thereby potentially encouraging the further pursuit of scientific study and possibly the eventual pursuit of scientific careers.

5.3.3.2 *A Factor Analysis of the Survey Responses*

A factor analysis was carried out on the entire suite of responses in order to determine whether the pattern of scale item responses was consistent with the influence of seven factors (the seven scales of the survey). A principal components analysis direct obliminal approach was adopted for this analysis, assuming seven factors and allowing 25 iterations for convergence. By comparing the significant elements for each factor (component) directly for each survey item, it is straightforward to discern which of the seven factors correspond with particular TOSRA scales. Table 5.6 gives the factor elements corresponding with all 70 items of the survey.

Table 5.6: Principal Components Matrix Elements corresponding with TOSRA Scale Items

Item	socimp	normsci	atting	adoptatt	enjyless	leisintr	careerin
1	.49						
8	.29						
15	.38						
22	.34						
29	.47						
36	.46						
43	.46						
50	.55						
57	.33						
64	.55						
2			.17				
9			.33				
16			.29				
23			.33				
30			.33				
37			.31				
44			.29				
51			.31				
58			.33				
65			.21				
3		.41					
10		.38					
17		.47					
24		.28					
31		.40					
38		.41					
45		.41					
52		.43					
59		.43					
66		.48					
4					.18		
11					0.00		
18					.13		
25					.16		
32					.17		
39					.26		
46					-.13		
53					.30		
60					-0.06		
67					.33		
5						.21	
12						.19	
19						.22	
26						.21	
33						-0.01	
40						-0.02	
47						.13	
54						-0.02	
61						.18	
68						0.02	
7				.17			
14				.25			
21				.25			
28				.23			
35				.15			
42				.14			
49				.23			
56				.16			
63				.16			
70				.32			
6							.12
13							.13
20							.21
27							.18
34							0.01
41							.20
48							0.09
55							.22
62							0.02
69							.12

In Table 5.6 the matrix elements shown, though small, are significantly larger than other matrix elements of the analysis which are not shown. This suggests moderate correspondence with the TOSRA scale items. Nevertheless, it is evident that component 1 corresponds with the scale *Social Implications of Science*; component 2 with *Attitude to Scientific Inquiry*; component 3 with *Normality of Scientists*; component 4 with *Career Interest in Science*; component 5 with *Adoption of Scientific Attitudes*; component 6 with *Enjoyment of Science Lessons*; and component 7 with *Leisure Interest in Science*.

The close correspondence of the seven components found from the principal components analysis with the seven survey scales lends credibility to the findings of the survey by demonstrating that the factor structure of the item responses corresponds closely with that of the original TOSRA questionnaire and, further, that the meanings assumed by the respondents to the survey scales and items are congruent with those intended.

5.3.4 Mean Differences between Ethnic Groups

5.3.4.1 Comparison of Scale Means by Ethnicity

Table 5.7a gives the scale means for the four ethnic groups of the study, without discriminating by form level, school attended, gender or country. Table 5.7b gives for reference the minimum and maximum scores for each scale. In all, 92 Maori, 91 Pacific Island, 340 European, and 41 Asian students who returned legible and completed questionnaires were included in the calculation of scale means by ethnicity, giving 564 responses in total (some 15 scripts were rejected as illegible or because they had been completed incorrectly).

Table 5.7a: Scale Means and Variations for all Ethnic Groups

Ethnicity		socimp	normsci	attinq	adoptatt	enjoyless	leisintr	careerin	Mean
Maori	μ	28.1	27.4	23.8	26.7	30.7	36.6	33.2	29.5
	σ	5.6	5.1	6.8	6.0	9.6	8.0	7.9	
Pacific Island	μ	26.9	28.3	24.7	24.1	27.9	34.1	31.8	28.2
	σ	5.2	4.8	6.7	4.6	8.8	7.4	8.3	
European	μ	26.4	25.7	22.7	25.1	30.6	37.5	32.5	28.6
	σ	6.3	6.1	6.5	5.9	9.9	8.4	8.4	
Asian	μ	26.1	28.1	25.3	25.3	29.0	35.7	32.1	28.8
	σ	5.35	5.97	7.30	5.52	8.30	7.48	7.80	

Table 5.7b: Minimum and Maximum Scores for all Ethnic Groups

Ethnicity		socimp	normsci	attinq	adoptatt	enjoyless	leisintr	careerin
Maori	Min'	13	15	10	14	10	16	20
	Max'	42	39	42	45	50	50	50
Pacific Island	Min'	11	18	12	13	10	11	11
	Max'	39	46	43	37	49	50	49
European	Min'	10	12	10	10	10	14	12
	Max'	46	50	43	42	50	50	50
Asian	Min'	15	15	10	12	10	17	19
	Max'	37	42	40	37	44	50	50

A most interesting feature of the scale means by ethnicity is that Maori students returned scale means comparable with, and even above, those of the other groups. As for the entire survey student population, the *Attitude to Scientific Inquiry* scale was the lowest, and the *Leisure Interest in Science* scale the highest.

Although it is not strictly rigorous to compare the means of the scale means, nevertheless, this statistic provides a single measure of overall attitudes as a direct basis of comparison for different participant groups across the range of attitudes addressed in the TOSRA. This statistic appears to indicate that the Maori students concerned display slightly more positive attitudes towards science than others.

T-Tests were conducted in order to assess the significance of the differences between Maori and Pacific Island scale means. The rationale for this analysis is the recognition that there are cultural similarities between Maori and Pacific Islanders which might give rise to similar attitudes towards education generally and science

education in particular. These include their traditional cultural origin, a recent history of domination by another ethnic group (European), low socio-economic status within their wider communities, low educational attainment, and widespread disaffection with the education system imposed upon them.

For three scales the means for Maori and Pacific Islanders were significantly different ($p < 0.05$, $t = 1.645$). These were the *Adoption of Scientific Attitudes*, *Enjoyment of Science Lessons*, and the *Leisure Interest in Science* scales. A t-Test was also conducted to compare Maori and Europeans. This test also indicated significant differences on the same three scales.

That ethnic minority students should hold more positive attitudes towards science contradicts most previous research such as that of Novick & Dudvani (1976) who reported significant attitudinal differences between students of differing ethnic backgrounds in Israel. Students from non-western backgrounds displayed significantly less positive attitudes than those from western backgrounds. In another study, Malone & Fleming (1983) found virtually no differences between European and Hispanic students in a study conducted in the United States. However, Waldrup (1995), in a study of South Pacific school laboratory classrooms, found that students from Papua New Guinea, the Cook Islands, Fiji, Solomon Islands, Tonga, Tuvalu, Vanuatu and Western Samoa held more positive attitudes towards science than Australian and North American students. It is unclear whether this difference is ethnic-based or relates to socio-economic or school environment factors. Waldrup suggested that South Pacific students may be more appreciative of their limited educational opportunities than students from other countries.

5.3.4.2 *Scale Means by Ethnicity: Significance Tests*

A MANOVA showed that ethnicity was a significant main effect on scale mean differences. Appendix 5.1 gives as an example the results of a MANOVA performed on NORMSCI as a dependent variable with ethnicity as independent factor. Table 5.8 gives the results of a one-way ANOVA applied on the survey scale means with ethnicity taken as a single independent factor.

Table 5.8: ANOVA on Scale Means with Ethnicity as Independent Factor

SCALE		Sum of Squares	Mean Square	F
SOCIMP	Between Groups	253.22	63.30	1.74
	Within Groups	24556.71	36.32	
	Total	24810.00		
NORMSCI	Between Groups	554.03	138.50	**
	Within Groups	21144.59	31.27	
	Total	21698.62		
ATTINQ	Between Groups	766.11	191.52	**
	Within Groups	30336.61	45.41	
	Total	31102.72		
ADOPTATT	Between Groups	363.53	90.88	*
	Within Groups	20372.04	30.45	
	Total	20735.58		
ENJYLESS	Between Groups	1161.87	290.46	*
	Within Groups	62222.47	92.45	
	Total	63384.34		
LEISINTR	Between Groups	1420.28	355.07	**
	Within Groups	44389.43	66.55	
	Total	45809.71		
CAREERIN	Between Groups	285.79	71.45	1.01
	Within Groups	46769.60	70.43	
	Total	47055.40		

(* denotes $p < 0.05$; ** denotes $p < 0.01$)

(For this and all ANOVAs discussed in this thesis, k is the number of populations being compared; df denotes 'degrees of freedom' ($df = k-1$), and F is the critical statistic which determines acceptance or rejection of the null hypothesis which assumes that the means of multiple distributions are equal; * denotes $p < 0.05$; ** denotes $p < 0.01$)

For ethnicity as an independent factor, all scale means for each ethnic group are significantly different from the others except for the *Social Implications of Science* ($F = 1.74$) and the *Career Interest in Science* ($F = 1.01$) scales. Maori students displayed slightly more positive attitudes towards science than European and Asian students.

5.3.5 Mean Differences between Form Levels

5.3.5.1 Comparison of Scale Means by Form Level

Table 5.9 below gives the scale means by form level for all participant students. In total, 210 form three students, 186 form four and 168 form five students were included in the calculations of scale means by form level.

Table 5.9: Scale Means and Variations by Form Level

Form		socimp	normsci	attinq	adoptatt	enjoyless	leisintr	careerin	Mean
3	μ	26.1	26.3	23.2	25.0	27.1	36.7	31.3	28.0
	σ	5.8	5.4	6.7	5.7	9.3	8.2	8.2	
4	μ	26.9	27.7	23.5	25.8	32.7	38.3	33.4	29.7
	σ	6.3	6.4	6.9	5.9	9.8	8.3	8.7	
5	μ	26.7	26.6	23.5	24.8	31.1	36.3	33.1	28.9
	σ	6.0	5.9	6.7	5.5	8.9	7.8	7.8	

For the scales *Social Implications of Science*, *Normality of Scientists*, *Attitude to Scientific Inquiry* and *Adoption of Scientific Attitudes*, the calculated means only vary to within approximately 1.5 scale points or less.

There is a small but significant variation in the mean of the scale means with increasing form level and a slight increase (greater positivism) in attitudes towards science in forms 4 and 5 with respect to form 3. By comparison, Fraser (1981) reports that Year 7 students had significantly higher means than Year 8 students in Australia, and several other workers have reported that student attitudes to science tend to decline with increasing form level (Johnson, 1981; Sullivan, 1979; Hadden & Johnstone, 1983). Hadden & Johnstone reported on a gradual erosion of initially favourable attitudes towards science during the first year of secondary school and found that this erosion was more pronounced in science than for other subjects. Baimba (1991) reported a similar decline in attitudes among Sierra Leonean students. He suggested that this may derive from dissatisfaction with the secondary school curriculum and that there is frequently a wide gap between student expectations of science and what is actually provided in the science curricula.

5.3.5.2 Scale Means by Form Level: Significance Tests

A MANOVA showed that form level was a significant main effect on scale mean differences. Table 5.10 gives the results of ANOVA applied on the scale means with form level taken as an independent factor.

Table 5.10: ANOVA on Scale Means with Form Level as Independent Factor

SCALE		Sum of Squares	Mean Square	F
SOCIMP	Between Groups	18.44	9.22	.25
	Within Groups	24823.50	36.50	
	Total	24841.95		
NORMSCI	Between Groups	397.63	198.81	**
	Within Groups	21321.98	31.35	
	Total	21719.61		
ATTINQ	Between Groups	46.72	23.36	.50
	Within Groups	31153.03	46.35	
	Total	31199.75		
ADOPTATT	Between Groups	33.43	16.71	.54
	Within Groups	20736.81	30.81	
	Total	20770.24		
ENJYLESS	Between Groups	1833.32	916.66	**
	Within Groups	61860.55	91.37	
	Total	63693.88		
LEISINTR	Between Groups	486.53	243.26	*
	Within Groups	45453.66	67.74	
	Total	45940.20		
CAREERIN	Between Groups	445.97	222.98	*
	Within Groups	46755.73	69.99	
	Total	47201.70		

The ANOVA analysis suggests significant differences between scale means for each form level group for four of the seven scales except for the *Social Implications of Science*, *Attitude to Scientific Inquiry* and the *Adoption of Scientific Attitudes* scales.

5.3.5.3 Scale Means by Form Level for Ethnic Groups

Johnson (1981) reported that in the USA the decline in interest with increasing form level was more pronounced among Caucasian students than coloured students. The idea that different ethnic groups might display different variations in attitude with increasing form level was tested in the present study by calculating scale means for each ethnic group at each of the three form levels concerned. Tables 5.11 to 5.14 give the scale means by form level for each of the four participant ethnic groups, and the numbers of students in each group whose responses were included in the calculations.

Table 5.11: Scale Means by Form Level for Maori Students

FORM	No'		socimp	normsci	attinq	adoptatt	enjoyless	leisintr	careerin	Mean
3	30	μ	27.4	26.3	22.0	27.4	30.0	36.9	33.2	29.0
		σ	5.3	5.4	6.5	5.8	10.5	7.7	8.1	
4	25	μ	27.2	28.2	24.1	27.5	31.8	37.9	34.0	30.1
		σ	6.3	4.7	7.3	7.1	9.3	8.8	8.1	
5	37	μ	29.2	27.8	25.1	25.7	30.5	35.7	32.8	29.5
		σ	5.4	5.1	6.7	5.4	9.2	7.9	7.7	

Table 5.12: Scale Means by Form Level for Pacific Island Students

FORM	No'		socimp	normsci	attinq	adoptatt	enjoyless	leisintr	careerin	Mean
3	33	μ	25.8	28.0	26.0	24.4	24.0	33.1	30.2	27.4
		σ	5.8	5.0	7.8	5.6	9.4	7.2	8.8	
4	28	μ	26.5	28.5	23.4	24.5	31.1	36.5	33.4	29.1
		σ	5.7	5.7	5.5	3.3	7.5	8.2	7.6	
5	28	μ	28.5	28.4	24.3	23.3	29.2	32.9	32.0	28.4
		σ	3.4	3.8	6.3	4.4	8.0	6.3	8.1	

Table 5.13: Scale Means by Form Level for European Students

FORM	No'		socimp	normsci	attinq	adoptatt	enjoyless	leisintr	careerin	Mean
3	131	μ	27.0	24.6	22.9	24.9	27.6	36.2	31.2	27.8
		σ	6.1	5.3	6.4	5.9	9.0	8.5	8.1	
4	103	μ	27.1	26.8	22.5	25.7	33.4	39.2	33.4	29.7
		σ	6.6	6.9	6.8	6.1	10.6	8.5	9.3	
5	100	μ	26.2	26.1	22.5	24.7	31.7	37.4	33.3	28.8
		σ	6.4	6.1	6.5	5.7	9.1	8.0	7.8	

Table 5.14: Scale Means by Form Level for Asian Students

FORM	No'		socimp	normsci	attinq	adoptatt	enjoyless	leisintr	careerin	Mean
3	12	μ	25.5	24.4	21.5	23.0	25.0	33.7	31.2	26.3
		σ	5.0	5.0	5.4	3.6	7.6	8.3	7.8	
4	23	μ	26.4	30.3	26.6	26.0	31.0	36.7	32.1	29.9
		σ	6.0	5.9	7.5	6.0	8.1	6.4	7.5	
5	4	μ	26.0	28.0	30.3	28.0	30.8	36.0	34.8	30.5
		σ	2.8	3.7	7.0	6.5	9.1	11.8	11.0	

Though there is variation in attitude with increasing form level, none of the ethnic groups displayed a decline in attitudes with increasing form level. In fact, for some groups interest in science actually appears to increase at the fourth form and decrease

slightly at the fifth form (possibly external examinations affect the means for Form 5). Further, One-way ANOVAs showed no significant differences in scale means by form level for Maori and Pacific Islanders, while most scales were significantly different for Europeans and Asians.

In summary, form level was a significant main effect on scale means, both for the entire target population, and for Europeans and Asians, though not for Maori or Pacific Islanders. Contrary to some prior studies, none of the participant ethnic groups showed a decline in attitudes towards science with increasing form level.

5.3.6 Mean Differences between Genders

5.3.6.1 Comparison of Scale Means by Gender

Table 5.15a gives the scale means by gender without regard to other factors. In all, responses from 294 male and 254 female students were included in the calculations of scale means by gender (questionnaire forms in which the gender of the respondent was not indicated were not included in this calculation).

Table 5.15a: Scale Means and Variations for the Male and Female Students

Gender		socimp	normsci	attinq	adoptatt	enjyless	leisintr	careerin	Mean
Male	μ	26.5	26.8	22.3	25.0	28.3	35.6	31.4	28.0
	σ	6.1	5.7	6.59	5.6	9.2	8.0	7.9	
Female	μ	27.0	26.3	24.7	25.4	32.3	38.1	33.8	29.6
	σ	5.9	6.0	6.7	5.9	9.6	8.2	8.6	

The results suggest that the females held slightly more positive attitudes towards science than the males. The mean of the scale means for females is 1.3 scale points greater than that for males, and females returned higher scale means on six of the seven scales. However, t-tests showed that the scale means for males and females are not significantly different for any but the *Attitude to Scientific Inquiry*, and the *Enjoyment of Science Lessons* scales. Additionally, as for the entire student cohort (see section 5.3.5), the *Attitude to Scientific Inquiry* scale displays the lowest scale mean, and the *Leisure Interest in Science* scale yields the greatest mean.

In order to take account of the possibility that student attitudes are influenced by school type, scale means by gender were calculated only for students of co-educational schools. Table 5.15b gives the scale means by gender for co-educational schools.

Table 5.15b: Scale Means and Variations for Males and Females from Co-educational Schools

Gender		socimp	normsci	attinq	adoptatt	enjoyless	leisintr	careerin	Mean
Male	μ	27.7	27.9	21.6	26.5	30.1	36.3	32.8	29.0
	σ	5.6	5.0	5.3	5.0	9.0	8.1	8.1	
Female	μ	29.2	26.4	24.7	27.1	34.0	39.2	36.1	31.0
	σ	6.0	5.1	6.4	5.9	9.7	7.7	8.2	

Again, females held slightly more positive attitudes towards science than the males. The mean of the scale means for females is 2.0 scale points greater than that for males, and females again returned higher scale means on six of the seven scales.

Previous studies have reported female students' lack of confidence, lack of encouragement from adults, and diminished belief in the value of science and mathematics, and have related these to under-representation of women in higher mathematics and science programs and in mathematics and science professions (Antony, 1994; Century, 1994). Waldrip (1995) (see 5.3.4.1 for the list of countries included) and Giddings & Waldrip (1996) found that male students from South Pacific countries (Cook Islands, Fiji, Papua New Guinea, Solomon Islands, Tuvalu and Vanuatu) held more favourable attitudes towards science than female students. In his study of attitudes towards science amongst Sierra Leonean students, Baimba (1991) found that junior secondary level girls exhibited significantly more positive attitudes towards science than boys, particularly for attributes relating to *Enjoyment of Science Lessons*, *Leisure Interest in Science* and *Career Interest in Science*. The present study corroborates Baimba's findings, but disagrees with other prior studies which found that boys exhibit significantly more positive attitudes towards science than girls (Gardner, 1975; Johnson, 1981; Menis, 1983; Wooley, 1978; Sjoberg, 1983; Ato & Wilkinson, 1983). By comparison, Ayers & Price (1975), Hoffman (1977) and Selim & Shringley (1983) found no significant gender differences in attitudes towards science. Perhaps, the variability of these findings underscores the context and cohort-dependent nature of educational research.

5.3.6.2 Scale Means by Gender: Significance Tests

A MANOVA showed that gender was a significant factor for scale mean differences in this study. Table 5.16 gives the results of an ANOVA with gender taken as an independent factor.

Table 5.16: ANOVA on Scale Means with Gender as Independent Factor

SCALE		Sum of Squares	Mean Square	F
SOCIMP	Between Groups	87.27	87.27	2.401
	Within Groups	24754.67	36.35	
	Total	24841.95		
NORMSCI	Between Groups	36.62	36.62	1.15
	Within Groups	21682.99	31.84	
	Total	21719.61		
ATTINQ	Between Groups	1278.55	1278.50	**
	Within Groups	29921.24	44.45	
	Total	31199.75		
ADOPTATT	Between Groups	24.624	24.62	.80
	Within Groups	20745.62	30.78	
	Total	20770.24		
ENJYLESS	Between Groups	1702.33	1702.33	**
	Within Groups	61991.54	91.43	
	Total	63693.88		
LEISINTR	Between Groups	971.87	971.87	**
	Within Groups	44968.32	66.91	
	Total	45940.20		
CAREERIN	Between Groups	820.06	820.06	**
	Within Groups	46381.64	69.33	
	Total	47201.70		

The ANOVA indicates significant differences in scale means for males and females for all but three of the seven scales. These are the *Social Implications of Science*, the *Normality of Scientists* and *Adoption of Scientific Attitudes* scales.

5.3.6.3 Scale Means for Males and Females by Ethnicity

Table 5.17 gives scale means for males and females for each of the participant ethnic groups.

Table 5.17: Scale Means for Males and Females by Ethnicity

GENDER		socimp	normsci	attinq	adoptatt	enjoyless	leisintr	careerin	Mean
Maori Males	μ	27.5	28.7	21.3	27.0	28.6	34.4	31.3	28.4
	σ	5.2	5.0	4.9	6.1	9.0	6.7	6.5	
Maori Females	μ	28.6	26.4	25.9	26.6	32.4	38.6	34.9	30.5
	σ	5.9	4.9	7.5	5.9	9.7	8.5	8.6	
Pacific Island Males	μ	26.9	28.3	25.0	24.0	26.6	33.8	31.4	28.0
	σ	5.3	4.8	7.2	4.4	8.7	7.4	8.2	
Pacific Island Females	μ	26.8	28.3	24.0	24.3	30.2	34.6	32.5	28.7
	σ	5.1	4.9	5.5	4.7	8.5	7.3	8.4	
Asian Males	μ	25.7	27.4	24.4	25.3	27.1	34.4	30.9	27.9
	σ	4.8	5.3	6.9	5.5	8.5	8.3	8.5	
Asian Females	μ	26.5	29.2	26.6	25.2	31.7	37.5	33.5	30.0
	σ	6.1	6.7	7.8	5.6	7.4	5.9	6.7	
European Males	μ	26.2	25.9	21.3	24.9	29.0	36.6	31.6	27.9
	σ	6.6	5.9	6.3	5.7	9.4	8.3	8.0	
European Females	μ	26.6	25.5	24.1	25.3	32.5	38.5	33.6	29.4
	σ	6.0	6.3	6.4	6.0	10.0	8.4	8.7	

The key finding of the above analysis is that, for each of the participant ethnic groups, females appear to hold more positive attitudes towards science than the males, a result at variance with Waldrip's (1995 & 1996) work on South Pacific students. The trends for low scale means for *Attitude to Scientific Inquiry* and *Adoption of Scientific Attitudes*, and high means for *Leisure Interest in Sciences*, are reflected across the subgroups discussed here.

In summary, gender was a significant main effect on scale means, both for the entire student population, and for each ethnic group. The female students displayed slightly more positive attitudes towards science than the males and this applied for each of the four ethnic groups.

5.3.7 Mean Differences Between Schools

5.3.7.1 Comparison of Scale Means for Each School

Scale means for each participant school were calculated in order to assess the contribution that each school cohort would make to the overall scale statistics, as well as to inform about the schools themselves. The results are given in Table 5.18.

Table 5.18: Scale Means for each Participant School

School		socimp	normsci	attinq	adoptatt	enjyless	leisintr	careerin	Mean
RO	μ	27.8	27.7	23.5	25.7	29.2	35.4	31.4	28.7
	σ	6.4	5.3	7.4	6.1	9.8	8.1	9.0	
TT	μ	28.7	27.2	23.2	27.1	31.8	37.3	33.8	29.9
	σ	6.3	5.5	6.7	5.8	11.1	9.3	8.8	
SP	μ	25.0	25.7	21.9	23.8	26.7	35.3	30.7	27.0
	σ	5.8	6.1	6.5	5.3	8.5	7.8	7.8	
MG	μ	26.1	29.8	25.1	25.2	32.2	35.9	32.0	29.5
	σ	5.2	5.8	5.8	5.1	8.9	8.3	8.0	
RT	μ	28.3	27.1	23.2	26.7	32.4	38.2	34.9	30.1
	σ	5.7	4.7	5.7	5.2	8.4	7.0	6.7	
SMW	μ	26.1	24.1	24.4	24.4	31.2	38.5	33.2	28.9
	σ	5.7	5.7	7.2	6.0	9.8	8.4	8.8	

The mean of the scale means varied from 27.0 for SP (a Roman Catholic boys' school in a working class catchment) to 30.1 for RT, a co-educational school and the only rural school of all of the participant schools. The significance of this finding is difficult to appraise and the possibility of significant attitudinal differences between urban and rural schools can only be determined in a separate study.

Additionally, as for the entire student cohort (see section 5.3.5) and the different ethnic groups (section 5.4.6), the *Attitude to Scientific Inquiry* scale generally yielded the lowest scale mean, and the *Leisure Interest in Science* yielded the greatest mean for each school.

5.3.7.2 Scale Means by School Attended: Significance Tests

A MANOVA showed that the factor school attended was a significant main effect on scale mean differences. Table 5.19 gives the results of ANOVA with school taken as an independent factor.

Table 5.19: ANOVA on Scale Means with School Attended as Independent Factor

SCALE		Sum of Squares	Mean Square	F
SOCIMP	Between Groups	1053.54	150.50	**
	Within Groups	23788.40	35.24	
	Total	24841.95		
NORMSCI	Between Groups	1767.76	252.53	**
	Within Groups	19951.84	29.55	
	Total	21719.61		
ATTINQ	Between Groups	1030.78	147.25	**
	Within Groups	30168.97	45.23	
	Total	31199.75		
ADOPTATT	Between Groups	775.586	110.79	**
	Within Groups	19994.66	29.93	
	Total	20770.24		
ENJYLESS	Between Groups	3746.95	535.27	**
	Within Groups	59946.92	89.20	
	Total	63693.88		
LEISINTR	Between Groups	1134.97	162.13	*
	Within Groups	44805.23	67.27	
	Total	45940.20		
CAREERIN	Between Groups	1926.51	275.21	4.03
	Within Groups	45275.19	68.28	
	Total	47201.70		

The ANOVA indicates significant differences in scale means between the six school cohorts for all scales at the 0.01 level of significance.

In summary, school attended was a significant main effect on scale means, and it is notable that the only rural school yielded the most positive attitudes towards science of all participant schools.

5.3.8 Mean Differences between Type of School

5.3.8.1 Comparison of Scale Means by School Type

All participant schools were classified as either single-sex (RC, SP, SMW and MG) or co-educational (TT and RT), without discriminating between single-sex boys' and single-sex girls' schools. In all, 404 students came from the single-sex participant schools and 146 came from the co-educational participant schools (questionnaire forms on which school type were not indicated by responses were not included). Table 5.20 gives the scale means for the single-sex and co-educational participant schools.

Table 5.20: Scale Means for the Single-sex and Co-educational Participant Schools.

School Type		socimp	normsci	attinq	adoptatt	enjoyless	leisintr	careerin	Mean
Single-sex	μ	26.1	26.4	23.5	24.6	29.4	36.3	31.8	28.3
	σ	5.9	6.1	6.9	5.7	9.5	8.2	8.4	
Co-educational	μ	28.5	27.1	23.2	26.9	32.1	37.8	34.5	30.0
	σ	5.9	5.0	6.1	5.4	9.6	8.0	8.2	

The scale means for six of the seven scales and the mean of scale means are higher for the co-educational schools than for the single-sex schools. As for the entire student cohort (see section 5.3.5), the *Attitude to Scientific Inquiry* scale displays the lowest scale mean for both single-sex and coeducational schools, and the *Leisure Interest in Science* scale also yields the greatest mean for both (it is recognised that a gender effect may have influenced scale means for single-sex and co-educational schools, but this is difficult to account for without calculation of means for males and females of each school type separately).

Most prior studies which have examined student attitudes towards science have found that students in single-sex schools display more positive attitudes towards science than students from coeducational schools (Commonwealth School Commission, 1984). Baimba's (1991) study of Sierra Leonean students was

exceptional in finding that coeducational students displayed more positive attitudes than single-sex school students. The present study agrees with Baimba's findings.

5.3.8.2 Scale Means by School Type: Significance Tests

A MANOVA showed that the factor school type was a significant main effect on scale mean differences. The results of a one-way ANOVA analysis of scale means with school type taken as an independent factor are given in Table 5.21.

Table 5.21: ANOVA on Scale Means with School Type as Independent Factor

SCALE		Sum of Squares	Mean Square	F
SOCIMP	Between Groups	294.09	294.09	**
	Within Groups	24547.85	36.04	
	Total	24841.95		
NORMSCI	Between Groups	174.99	174.99	*
	Within Groups	21544.62	31.63	
	Total	21719.61		
ATTINQ	Between Groups	120.40	120.40	2.60
	Within Groups	31079.34	46.18	
	Total	31199.75		
ADOPTATT	Between Groups	404.42	404.42	**
	Within Groups	20365.82	30.21	
	Total	20770.24		
ENJYLESS	Between Groups	1165.60	1165.60	**
	Within Groups	62528.27	92.22	
	Total	63693.88		
LEISINTR	Between Groups	320.44	320.44	*
	Within Groups	45619.75	67.88	
	Total	45940.20		
CAREERIN	Between Groups	1455.28	1455.28	**
	Within Groups	45746.42	68.38	
	Total	47201.70		

The ANOVA indicates that the scale means for the single-sex and coeducational schools are significantly different at the 0.01 level of significance, and only the *Attitudes to Scientific Inquiry* scale is similar at the 0.05 level of significance.

In summary, school type was a significant main effect on student attitudes and the co-educational schools yielded slightly more positive attitudes towards science than the single-sex schools.

5.3.9 Factor Interaction

Each TOSRA scale was analysed for interactions between the main factors – ethnicity, form level and gender. Multivariate tests of significance were performed to check for interactions. While significant main effects were detected between ethnicity and gender on the *Attitudes to Scientific Inquiry* scale (see Appendix 5.2a for the analysis), and between form level and gender on the *Leisure Interest in Science* scale (see Appendix 5.2b), significant three-way interaction effects between ethnicity, form level and gender were not found.

5.3.10 Conclusions on the TOSRA

The implementation of the TOSRA produced some unexpected findings, in particular, Maori and Pacific Island students returned more positive attitudes towards science than Europeans, and females returned more positive attitudes than males.

In fact, many students complained about the length of the test, the repetition inherent in some scales, particularly in items relating to ‘doing experiments’ (*Attitude to Scientific Inquiry*), and the complexity of the language used. For example, a number of students had to ask the meaning of the word ‘seldom’. The researcher recommends the development of a shorter version of the TOSRA survey using simpler language and reducing repetitive items. The low scores returned on the *Attitude to Scientific Inquiry* scale may partly reflect negativism on the part of some students towards the repetitiveness of the items concerned.

5.4 Associations between Student Attitudes towards Science and Achievement in Science

5.4.1 Correlations between Teacher Appraisals and Survey Scales

A simple correlation approach was adopted to determine whether or not there were any associations between ethnic minority group students' attitudes to science and their achievements in science (research question 5). Schibeci and Riley (1983) believe that attitudes influence achievement directly and several other studies have demonstrated a direct and strong relationship between student attitudes and achievement (Boulanger, 1981; Fraser, 1981; Malone & Fleming, 1983).

In the present study, this question was addressed by calculating correlations between the TOSRA survey scales and the *Standard of Academic Achievement* scale (see section 5.3.2.1) which comprises teacher appraisals of the academic achievement of selected students. Correlations (Pearsons Correlation Coefficient) between the seven TOSRA scales and the *Standard of Academic Achievement* scale (ACH) are given in Table 5.22.

Table 5.22: Correlations between the *Academic Achievement* and TOSRA Scales

	ACH	socimp	normsci	attinq	adoptatt	enjoyless	leisintr	careerin
ACH	1.00	-0.14	0.09	0.05	0.02	0.04	0.02	-0.09

It is immediate that the correlations are extremely weak and, in two cases, are even negative. Correlations were also calculated between the *Standard of Academic Achievement* scale and the 70 individual TOSRA scale items. Many of these correlations were negative or extremely weak, and the maximum correlation, returned for item 59 from the *Attitude to Scientific Inquiry* scale, was only 0.20. It is inferred that, for the target populations of the present study, there is no discernible association between attitudes towards science and achievements in science. By comparison, Fleming and Malone (1983) found that science attitudes showed a much

smaller relationship with student characteristics such as race, gender, ability and socio-economic status than cognitive and science achievement measures.

In summary, no associations between student attitudes towards science and achievements in science were found.

5.5 Summary of Findings of Chapter Five

This section presents the findings which have emerged from the analyses discussed in sections 5.3.4 to 5.4.1 of this chapter. The complete set of findings of this thesis is presented in Appendix 8.1.

(i) From section 5.3.4, which examined scale differences between the participant ethnic groups, it was found that Maori students returned more positive measures of attitude towards science than others.

Finding 1

Maori students displayed slightly more positive attitudes towards science than European and Asian students.

(ii) From section 5.3.5, which examined scale differences between form levels, no decline in attitude towards science, either for the entire target population or the individual ethnic groups, was found.

Finding 2

For the participant student population taken as a whole, there was no decline in student interest in science with increasing form level.

Finding 3

None of the participant ethnic groups showed a decline in attitudes towards science with increasing form level.

(iii) From section 5.3.6, which examined student attitudes by gender, it was shown that the female students returned more positive attitudes than the males, both for the entire target population and for the individual ethnic groups.

Finding 4

The female students displayed slightly more positive attitudes towards science than the males.

Finding 5

For each ethnic group, females held slightly more positive attitudes towards science than males.

(iv) From section 5.3.7, which examined student attitudes by participant school, it was found that the most positive attitudes were returned by the only rural school.

Finding 6

The only rural school yielded the most positive attitudes towards science of all participant schools.

(v) From section 5.3.8, which examined student attitudes by school type, it was found that students from co-educational schools returned more positive attitudes than those from single-sex schools (it is accepted that a gender effect may have influenced scale means by school type).

Finding 7

The co-educational schools yielded slightly more positive attitudes towards science than the single-sex schools.

(vi) From section 5.4.1, which examined correlations between student attitudes and teacher appraisals of student academic achievement, no discernible association between attitudes and achievement was found.

Finding 8

No associations between student attitudes towards science and achievements in science were found.

CHAPTER SIX

Nor can teachers often say with certainty at the close of a lesson whether it went well or whether the students 'got it'. A teacher may think that students were engaged, attentive, and learning on one day, only to discover the next day that they don't recall much at all from the day before. Mary Kennedy (1996, p. 6).

A SURVEY OF STUDENT PERCEPTIONS OF THEIR LEARNING ENVIRONMENTS

6.1 Introduction

The survey of student perceptions of their constructivist learning environments using the revised Constructivist Learning Environment Survey (CLES) questionnaire (Taylor, Fraser, & White, 1994) was implemented at the same time and on the same sample of students as was the TOSRA survey of student attitudes discussed in Chapter Five. The CLES survey was designed to enable teacher-researchers to monitor their development of constructivist approaches to teaching school science and mathematics (Taylor, Fraser, & White, 1994).

The CLES survey was adopted partly to address research questions 2, 3 and 4 (see section 4.1.2). These are:

2. Are there any differences in students' perceptions of their learning environments between ethnic minority groups and others?
3. Are there any associations between ethnic minority group students' perceptions of their learning environments and their attitudes to science?
4. Are there any associations between ethnic minority group students' perceptions of their learning environments and their achievements in science?

Critical Theory, which underpins the CLES survey, attempts to focus attention on the science classroom as a socio-cultural environment which sets the context for the learning environment by focusing on the ways in which the environment encourages

teachers and students to behave according to agendas which may be antithetical to effective meaning-making and ethical social interactions (Taylor, Dawson, & Fraser, 1995).

As for the TOSRA survey, the implementation and findings of the CLES survey are discussed in respect of the factors ethnicity (section 6.3.4) , form level (section 6.3.5), gender (section 6.3.6), school attended (section 6.3.7) and school type (section 6.3.8). In section 6.4, the relationships between the TOSRA scales and the CLES scales are investigated so that any associations between students' perceptions of their constructivist learning environments and their attitudes towards science can be determined. Firstly, in section 6.2, a pilot study is described in which the CLES survey was implemented in order to validate the CLES for use in the main study.

6.1.1 About the CLES Survey Instrument

6.1.1.1 The CLES Questionnaire Scales

The CLES survey variant used for the pilot study comprises five scales: the *Personal Relevance* scale; the *Student Negotiation* scale; the *Shared Control* scale; the *Critical Voice* scale, and the *Uncertainty* scale. Each scale comprises seven questions, each scored on a five point frequency response system which employs the categories: *almost always* (5 points); *often* (4 points); *sometimes* (3 points); *seldom* (2 points) and *almost never* (1 point). Each scale, therefore, has a maximum mean score of 35 and a minimum mean of 7, regardless of the numbers of students involved. This CLES variant was similar to that used in the main study (see section 6.3).

(i) The Personal Relevance Scale

The *Personal Relevance* scale concerns the perceived relevance of science to students' out-of-school lives, and is designed to assist teachers to make use of students' daily experiences as a context for the development of students' scientific knowledge (Taylor, Fraser, & White, 1994).

(ii) *The Student Negotiation Scale*

The *Student Negotiation* scale is concerned with facilitating opportunities for students to share with other students their newly developing ideas, to understand other students' ideas and reflect on their viability, and reflect on their own ideas (Taylor, Fraser, & White, 1994).

(iii) *The Shared Control Scale*

The *Shared Control* scale is concerned with facilitating opportunities for students to share control of the total learning environment, including the design and management of learning activities, determining and applying classroom assessment criteria, and participating in the negotiation of the social norms of the classroom (Taylor, Fraser, & White, 1994).

(iv) *The Critical Voice Scale*

The *Critical Voice* scale concerns the establishment of a social climate in which students feel that it is legitimate and beneficial to question the teacher's pedagogical plans and methods, and to express concerns about any impediments to their learning (Taylor, Fraser, & White, 1994).

(v) *The Uncertainty Scale*

The *Uncertainty* scale concerns the facilitation of opportunities for students to experience scientific and mathematical knowledge as arising from human experience and values, as evolving and insecure, and as culturally and socially determined (Taylor, Fraser, & White, 1994).

6.2 A Pilot Study: Validation of the CLES

6.2.1 Implementation of the Pilot Study

Prior to the main study, a pilot study was carried out using the CLES questionnaire with a fifth form class taught by a former teaching colleague of the researcher. This pilot study was carried out in order to validate the CLES for use in the main study, and to provide the researcher with experience in implementing the CLES survey. The selected class of 11 girls from a private girls' school in Wellington comprised a range of abilities, but was characterised by their teacher as generally of low-average ability with low enthusiasm for schoolwork. The survey was administered on Monday 9 September 1996. This pilot study was the first occasion on which the CLES was implemented in New Zealand. Thus, the findings of this, and particularly those of the main study, are of considerable importance.

6.2.2 The Pilot Study: Responses and Scale Means

The mean, standard deviation (variation) and Cronbach alpha were obtained for each scale and are given in Table 6.1, along with scale means from a prior implementation of the CLES carried out on three Year 8 classes in a high school in Perth (Taylor, Fraser, & White, 1994). For brevity, PERSREL denotes the *Personal Relevance* scale; UNCERTY denotes the *Uncertainty* scale; STUDNEG denotes the *Student Negotiation* scale; SHARCONT denotes the *Shared Control* scale, and CRITVOIC denotes the *Critical Voice* scale.

Table 6.1: Pilot Study and Perth Study (in brackets) Means and Variations

Student ID	PERSREL	STUDNEG	SHARCONT	CRITVOIC	UNCERTY
1	16	21	21	17	20
2	22	19	24	26	26
3	12	14	15	9	17
4	20	19	11	8	14
5	19	16	23	21	31
6	23	23	33	25	27
7	18	19	19	12	22
8	23	18	22	15	24
9	16	16	27	15	23
10	17	23	30	21	22
11	10	11	18	11	27
μ	17.8 (26.2)	18.1 (28.5)	22.1 (20.5)	16.4 (29.9)	23.0 (24.3)
σ	4.2	3.7	6.4	6.2	4.8
α	0.54	0.46	0.66	0.63	0.55

The scale means vary between 16.4 (*more than seldom*) and 23.0 (*more than sometimes*). The large standard deviations indicate considerable heterogeneity of perceptions of their learning environment, an effect perhaps exacerbated by the small sample size.

The Cronbach alphas vary from 0.46 to 0.66. Generally, these are low and may reflect the small sample size. Fraser (1986) has stated that, in learning environment research, alpha coefficients greater than 0.7 indicate satisfactory internal consistency. All of the scales, therefore, have low internal consistency.

Inter-scale correlations were also calculated. These were all less than 0.4, suggesting that the scales were usually measuring independent, if overlapping, attitudes.

6.2.3 Comparison with the Perth Study

It is clear that the means for the QMC class fall well below those of the Perth students for all but the *Shared Control* scale. In particular, the means for *Personal Relevance*, *Student Negotiation*, and the *Critical Voice* scales fall more than five scale points below the corresponding means for the Perth students. This is consistent with the teacher's assessment of the QMC class as of low-average ability and low motivation.

6.2.4 Conclusions on the Pilot Study

The pilot study yielded results consistent with the character of the class concerned, provided worthwhile practical experience, and supported the use of the CLES instrument for use in the main part of the study.

6.3 The Main Survey of Student Perceptions of their Constructivist Learning Environments

6.3.1 Introduction

The CLES main survey participant schools and students were the same as those used for the TOSRA survey (see section 5.3.1). The CLES variant used was a revised version of that used in the pilot study, but essentially identical, apart from a slight reordering of scales and a reduction in the number of scale items from seven to six in each scale. This variant is described in Taylor, Dawson, & Fraser (1995) and utilises the following scale ordering: *Personal Relevance* (items 1 to 6 of the questionnaire); *Uncertainty* (items 7 to 12 of the questionnaire); *Critical Voice* (items 13 to 18 of the questionnaire); *Shared Control* (items 19 to 24 of the questionnaire); *Student Negotiation* (items 25 to 30 of the questionnaire). Each item is scored on a range from 1 to 5 points, and therefore each scale can range between a minimum mean of 6 and a maximum of 30 scale points. Item 6, the only negatively-worded item, is reverse-scored.

6.3.2 Overall Scale Means for the Main Survey

6.3.2.1 The CLES Scales: Initial Results

Table 6.2 gives the CLES survey scale means and variations for the entire student cohort, along with the corresponding results for a prior study carried out on a randomly selected sample of 13-year-old Western Australian students (Years 8 and 9)

by the Australian Council for Educational Research (ACER) in 1994 using the same questionnaire (Taylor, Dawson, & Fraser, 1995).

Table 6.2: CLES Survey and ACER Survey (in brackets) Scale Means, Variations and Reliabilities

Scale	Mean	Standard Deviation	Alpha Reliability
Personal Relevance	20.1 (20.6)	3.8 (4.8)	0.66
Uncertainty	20.1 (18.7)	3.7 (4.3)	0.63
Critical Voice	21.7 (18.7)	5.1 (6.2)	0.80
Shared Control	12.7 (10.9)	5.3 (5.1)	0.85
Student Negotiation	20.8 (19.9)	5.4 (5.5)	0.84

All scale means are significantly greater than the ACER study scale means except for the *Personal Relevance* scale, for which the means are similar. The calculated Cronbach alpha reliabilities vary from 0.63 to 0.85. These are moderate to high, and indicate that three of the scales have good internal consistency except for *Personal Relevance* and *Uncertainty*, whose internal consistency is moderate. These mostly satisfy Fraser's (1986) criterion for satisfactory internal consistency. On this basis, it may be concluded that any findings based on the main survey scale means may be considered reliable, though somewhat less reliable for any based on *Personal Relevance* and *Uncertainty*.

A review of the individual item scores showed a high proportion of the response *sometimes*, to which attaches an item score of 3 scale points. Taylor, Fraser, and White (1994) explain this as a result of students averaging their experiences of different constructivist learning environments, thus frequently choosing the mid-range response.

6.3.2.2 Variability of the Scale Means

Scale means vary between 12.7 for the *Shared Control* scale (*seldom*) and 21.7 for the *Critical Voice* scale (*more than sometimes, but less than often*). The standard deviations are roughly comparable to those of the ACER study, although responses to

the *Personal Relevance*, *Uncertainty* and *Critical Voice* scales were more homogeneous than in the ACER study.

6.3.2.3 A Factor Analysis of the CLES Survey Responses

A factor analysis was carried out on the entire suite of responses to the CLES scale items (see section 5.3.3.2 for the corresponding analysis for the TOSRA survey) in order to determine whether the structure of scale item responses was consistent with the influence of five factors (the five CLES scales). As for the TOSRA survey, a principal components analysis direct obliminal approach was adopted for this analysis, assuming five factors and allowing 25 iterations for convergence. Table 6.3 gives the principal components matrix elements corresponding with individual CLES survey items (matrix elements less than 0.1 are not included in the table).

Table 6.3: Principal Components Matrix Elements for CLES Scale Items

	persrel	uncerty	critvoic	sharcont	studneg
Item	1	2	3	4	5
1				.41	
2				.36	
3				.35	
4				.49	
5				.44	
6				.15	
7					.37
8					.45
9					.24
10					.27
11					.48
12					.41
13			.63		
14			.66		
15			.63		
16			.45		
17			.35		
18			.43		
19	.48				
20	.50				
21	.50				
22	.46				
23	.44				
24	.48				
25		.29			
26		.34			
27		.31			
28		.24			
29		.16			
30		.23			

The matrix elements are generally of moderate magnitude, but are significantly larger than other matrix elements of the analysis which are not shown, suggesting moderate correspondence with the scale items. Because the most significant matrix elements correspond with particular scale items, component 3 is seen to correspond with the *Critical Voice* scale; component 4 with *Personal Relevance*; component 5 with *Uncertainty*. Component 2 could reasonably have corresponded with either *Critical Voice* or *Student Negotiation*, while component 1 could reasonably correspond with any of the CLES scales, yielding significant matrix elements for all 30 items of the survey.

The close correspondence of the five components found from the principal components analysis with the five CLES survey scales demonstrates that the factor structure of the item responses corresponds well with that of the original CLES questionnaire, and suggests that the meanings assumed by the respondents to the survey scales and items are largely congruent with those intended in the survey design.

6.3.3 Inter-scale Correlations

Table 6.4 gives the CLES inter-scale correlations and mean correlations with other scales for the entire student cohort.

Table 6.4: CLES Inter-scale Correlations and Mean Correlations

SCALE	PERSREL	UNCERTY	CRITVOIC	SHARCONT	STUDNEG	Mean Correlations
PERSREL	1.00	.35	.18	.24	.31	0.27
UNCERTY		1.00	.18	.25	.33	0.28
CRITVOIC			1.00	.10	.28	0.16
SHARCONT				1.00	.19	0.20
STUDNEG					1.00	0.28

The inter-scale correlations are all positive and low, and are similar in magnitude to those of the ACER study. The mean correlation varies from 0.16 to 0.28, indicating low overall correlation of any one scale with the other CLES scales, and that the survey is measuring relatively independent, if overlapping, aspects of student learning environments.

6.3.4 Mean Differences between Ethnic Groups

6.3.4.1 Comparison of Scale Means by Ethnicity

Table 6.5 gives the CLES scale means and variations for the four ethnic groups of the study. Also given are the means of each scale mean as an overall measure of the perceptions displayed by each group. In all, 92 Maori, 91 Pacific Islanders, 340 European and 41 Asian students were included in the calculation of scale means by ethnicity.

Table 6.5: CLES Scale Means with Variations for all Ethnic Groups

ETHNIC		PERSREL	UNCERTY	CRITVOIC	SHARCONT	STUDNEG	MEAN
Maori	μ	20.3	20.5	22.7	13.6	20.6	19.5
	σ	3.6	4.0	4.4	5.6	5.6	
Pacific Island	μ	20.1	21.3	21.4	13.7	22.0	19.6
	σ	3.6	3.3	5.3	5.9	5.0	
European	μ	19.9	19.7	21.7	12.1	21.0	18.9
	σ	3.8	3.7	5.2	4.4	4.6	
Asian	μ	21.2	19.9	20.3	13.7	21.0	19.2
	σ	3.8	3.6	4.8	4.4	4.6	

The variation of scale means for the four groups is small. The maximum variation of 2.4 scale points was returned for the *Critical Voice* scale. The *Shared Control* scale returned by far the lowest of the scale means.

The key finding of this analysis is that Maori and Pacific Island students returned scale means higher than the European students on three of the five scales – *Personal Relevance*, *Uncertainty*, and *Student Negotiation*. Correspondingly, the means of the scale means for Maori and Pacific Island students were higher than those of the Europeans and Asians. This finding suggests quite positive perceptions of constructivist learning environments on the part of Maori and Pacific Island students. Further, the means of scale means for the Maori and Pacific Island students concerned were very similar.

6.3.4.2 Scale Means by Ethnicity: Significance Tests

A MANOVA showed that ethnicity was a significant main effect on CLES scale mean differences ($p < 0.05$). The calculated F statistics were generally greater than 2.1 ($\alpha = 0.01$) and 2.8 ($\alpha = 0.05$) and when the F statistic was less than 2.1 and 2.8, the significance levels were very small. Appendix 6.1 gives as an example the results of a MANOVA with *Leisure Interest* as dependent variable and ethnicity as independent factor.

Table 6.6 gives the results of a one-way ANOVA applied on the survey scale means with ethnicity taken as a single independent factor.

Table 6.6: ANOVA on Scale Means with Ethnicity as Independent Factor

SCALE		Sum of Squares	Mean Square	F
PERSREL	Between Groups	86.47	21.61	1.43
	Within Groups	10192.19	15.14	
	Total	10278.66		
UNCERTY	Between Groups	179.82	44.95	*
	Within Groups	9698.51	14.71	
	Total	9878.33		
CRITVOIC	Between Groups	244.29	61.07	2.26
	Within Groups	18219.86	26.99	
	Total	18464.16		
SHARCONT	Between Groups	300.81	75.20	*
	Within Groups	18910.03	28.47	
	Total	19210.84		
STUDNEG	Between Groups	288.44	72.11	2.30
	Within Groups	20889.02	31.41	
	Total	21177.46		

The ANOVA showed that the factor ethnicity gave rise to significant differences between the four ethnic groups on all scales except *Personal Relevance* at the 0.01 level of significance.

In summary, ethnicity was a significant effect on CLES scale means. Interestingly, Maori and Pacific Island students displayed equivalent or more positive perceptions of their constructivist learning environments than either European or Asian students. Differences in perceptions of their constructivist learning environments between Maori and Pacific Island students were not significant.

6.3.5 Mean Differences between Form Levels

6.3.5.1 Comparison of Scale Means by Form Level

Table 6.7 gives the CLES scale means and variations by form level. Some 210 form 3 students, 186 form 4 and 169 form 5 students were included in the calculation of scale means by form level.

Table 6.7: CLES Scale Means and Variations by Form Level

FORM		PERSREL	UNCERTY	CRITVOIC	SHARCONT	STUDNEG	MEAN
3	μ	20.0	20.3	21.0	12.7	21.0	19.0
	σ	3.8	3.5	4.8	5.2	5.2	
4	μ	20.6	20.3	22.4	12.5	21.5	19.5
	σ	3.9	4.0	5.1	5.4	5.4	
5	μ	19.7	19.8	21.8	12.9	19.6	18.8
	σ	3.6	3.7	5.3	5.5	5.6	

A weak trend, also visible in the TOSRA survey, is a tendency for perceptions of constructivist learning environments to become more positive at the fourth form, and then decline at the fifth form. The trend is seen in three of the five scales (*Personal Relevance*, *Critical Voice* and *Student Negotiation*). Correspondingly, the mean of the scale means increases in the fourth form and then decreases at the fifth form. Possibly, the trend is not significant and may have arisen by chance, but further research is required to investigate the significance of this finding.

6.3.5.2 Scale Means by Form Level: Significance Tests

A MANOVA showed that form level was a significant main effect on scale differences. Table 6.8 gives the results of an ANOVA on the scale means with form level taken as an independent factor.

Table 6.8: ANOVA on Scale Means with Form Level as Independent Factor

SCALE		Sum of Squares	Mean Square	F
PERSREL	Between Groups	61.20	30.60	2.02
	Within Groups	10257.26	15.15	
	Total	10318.46		
UNCERTY	Between Groups	20.04	10.02	.67
	Within Groups	9877.79	14.90	
	Total	9897.83		
CRITVOIC	Between Groups	290.81	145.40	*
	Within Groups	18332.89	27.00	
	Total	18623.71		
SHARCONT	Between Groups	30.61	15.30	.53
	Within Groups	19228.16	28.78	
	Total	19258.78		
STUDNEG	Between Groups	371.03	185.51	**
	Within Groups	20978.38	31.35	
	Total	21349.41		

The ANOVA shows that the factor form level gave rise to significant differences between the three form level groups on the *Critical Voice* and the *Student Negotiation* scales at both the 0.01 and 0.05 levels of significance.

6.3.5.3 Scale Means by Form Level for each Ethnic Group

The idea that different ethnic groups might display different patterns of perceptions with increasing form level was tested by calculating scale means for each ethnic group at each of the three form levels concerned. Tables 6.9 to 6.12 give the scale means by form level for the four participant ethnic groups.

Table 6.9: Scale Means by Form Level for Maori Students

FORM		PERSREL	UNCERTY	CRITVOIC	SHARCONT	STUDNEG	MEAN
3	μ	20.3	20.7	22.8	13.5	21.5	19.9
	σ	3.7	3.4	4.0	4.7	4.7	
4	μ	21.4	20.9	23.4	13.8	19.4	19.8
	σ	3.8	4.7	4.9	6.4	7.0	
5	μ	19.7	20.3	21.8	12.8	20.2	19.0
	σ	3.4	4.1	4.8	5.6	5.6	

Table 6.10: Scale Means by Form Level for Pacific Island Students

FORM		PERSREL	UNCERTY	CRITVOIC	SHARCONT	STUDNEG	MEAN
3	μ	19.3	20.5	19.7	13.6	21.7	19.0
	σ	4.5	3.8	6.1	6.0	4.7	
4	μ	21.3	21.9	22.6	13.1	23.3	20.5
	σ	3.4	2.9	4.3	4.6	4.3	
5	μ	19.5	21.5	21.8	14.2	20.9	19.6
	σ	2.7	3.0	5.6	7.3	5.9	

Table 6.11: Scale Means by Form Level for European Students

FORM		PERSREL	UNCERTY	CRITVOIC	SHARCONT	STUDNEG	MEAN
3	μ	20.0	20.3	21.0	12.0	20.8	18.8
	σ	3.8	3.6	4.7	5.1	5.5	
4	μ	20.0	19.7	22.6	11.8	21.4	19.1
	σ	4.0	3.8	5.3	5.4	5.3	
5	μ	19.6	19.1	21.9	12.5	19.0	18.4
	σ	3.8	3.6	5.5	5.0	5.5	

Table 6.12: Scale Means by Form Level for Asian Students

FORM		PERSREL	UNCERTY	CRITVOIC	SHARCONT	STUDNEG	MEAN
3	μ	21.3	19.3	19.5	14.5	19.9	18.9
	σ	3.1	2.7	4.1	4.3	3.8	
4	μ	21.1	19.9	20.3	13.1	21.7	19.2
	σ	4.0	4.2	5.2	4.6	5.0	
5	μ	21.5	21.8	22.8	14.3	20.8	20.2
	σ	5.5	2.1	4.7	4.4	5.1	

No distinct trend has emerged from the results of Tables 6.9 to 6.12. However, fifth form Maori and Europeans were slightly less positive than third form, whereas for Pacific Island and Asian students, perceptions among fifth formers were slightly

more positive than those of the third form. ANOVAs showed that scale mean differences between form levels were not significant for Maori, Pacific Islanders, or Asians but were significant for Europeans, who comprised over 60% of the target population.

In summary, form level was a significant main effect on scale means. Perceptions of constructivist learning environments tended to become somewhat more positive at the fourth form and decline at fifth form.

6.3.5 Mean Differences between Genders

6.3.6.1 Comparison of Scale Means by Gender

Table 6.13 gives the CLES scale means and variations by gender. Single-sex schools were excluded from this analysis because of the possibility that school type influences student perceptions significantly. In all, the responses from 69 male and 77 female students from the participant coeducational schools were included in the calculations of scale means by gender.

Table 6.13: CLES Scale Means for Males and Females

GENDER		PERSREL	UNCERTY	CRITVOIC	SHARCONT	STUDNEG	MEAN
MALES	μ	19.9	20.7	22.4	13.2	21.3	19.5
	σ	4.0	3.5	4.0	5.0	5.4	
FEMALES	μ	19.0	19.6	22.4	11.8	20.5	18.7
	σ	3.2	3.5	5.2	5.0	5.8	

The variation of scale means is very small. The maximum variation of 0.9 scale points was returned for the *Uncertainty* scale, while males and females returned identical means for the *Critical Voice* scale. Again, the *Shared Control* scale returned the smallest scale mean. The mean of the scale means for males was slightly greater than that for females. However, individual scale means showed small but significant differences, particularly for the *Uncertainty* and *Shared Control* scales.

6.3.6.2 Scale Means by Gender: Significance Tests

A MANOVA showed that gender was a significant main effect on scale differences. Table 6.14 gives the results of an ANOVA on the scale means with gender taken as an independent factor.

Table 6.14: ANOVA on CLES Scale Means with Gender as Independent Factor

SCALE		Sum of Squares	Mean Square	F
PERSREL	Between Groups	45.54	45.54	3.01
	Within Groups	10272.92	15.15	
	Total	10318.46		
UNCERTY	Between Groups	85.66	85.66	*
	Within Groups	9812.16	14.77	
	Total	9897.83		
CRITVOIC	Between Groups	246.20	246.20	**
	Within Groups	18377.51	27.02	
	Total	18623.71		
SHARCONT	Between Groups	161.69	161.69	*
	Within Groups	19097.08	28.54	
	Total	19258.78		
STUDNEG	Between Groups	193.76	193.76	*
	Within Groups	21155.64	31.57	
	Total	21349.41		

The ANOVA showed that the factor gender gave rise to significant differences between males and females on all scales.

6.3.6.3 Scale Means for Males and Females by Ethnicity

Table 6.15 gives scale means for males and females for each ethnic group.

Table 6.15: Scale Means for Males and Females by Ethnicity

GENDER		PERSREL	UNCERTY	CRITVOIC	SHARCONT	STUDNEG	MEAN
Maori Males	μ	21.1	20.8	22.3	14.3	19.2	19.5
	σ	3.7	4.1	4.4	5.5	5.6	
Maori Females	μ	19.7	20.5	22.8	12.4	21.4	19.4
	σ	3.6	4.0	4.8	5.5	5.8	
Pacific Island Males	μ	20.3	21.5	20.4	13.1	20.8	19.2
	σ	4.0	3.4	5.7	5.4	5.3	
Pacific Island Females	μ	19.5	20.8	22.8	14.4	24.1	20.3
	σ	3.3	3.2	5.2	6.8	3.8	
Asian Males	μ	21.9	20.0	19.9	14.5	20.2	19.3
	σ	3.6	3.8	3.7	4.5	3.9	
Asian Females	μ	20.1	19.9	20.8	12.7	22.0	19.1
	σ	3.9	3.7	6.0	4.2	5.7	
European Males	μ	20.0	20.1	21.0	12.7	20.1	18.8
	σ	3.9	3.7	5.0	4.9	5.3	
European Females	μ	19.7	19.4	22.5	11.5	20.9	18.8
	σ	3.8	3.6	5.3	5.4	5.7	

From Table 6.15, it appears that Pacific Island and European females held, on average, slightly, but not significantly, more positive perceptions than the males. For the other ethnic groups, males and females held roughly equivalent perceptions. By comparison, in studies of South Pacific secondary schools, Waldrip (1995) and Giddings & Waldrip (1996) found no significant differences in learning environment perceptions between male and female students.

In summary, gender was a significant effect on scale means. Overall, males and females displayed similar perceptions of their constructivist learning environments.

6.3.7 Mean Differences between Schools

6.3.7.1 Comparison of CLES Scale Means by School Attended

Table 6.16 gives the CLES scale means and variations for each participant school.

Table 6.16: CLES Scale Means and Variations for each Participant School

SCHOOL		PERSREL	UNCERTY	CRITVOIC	SHARCONT	STUDNEG	MEAN
RO	μ	19.8	19.9	19.2	12.4	18.0	17.9
	σ	4.2	4.1	5.3	5.5	5.2	
TT	μ	20.5	21.1	23.8	12.5	22.3	20.0
	σ	3.2	3.4	4.4	5.4	5.5	
SP	μ	20.9	20.6	21.5	13.7	20.9	19.5
	σ	3.5	3.7	4.7	4.8	4.7	
MG	μ	19.1	19.2	22.0	11.6	21.4	18.7
	σ	3.7	4.1	5.5	5.3	4.9	
RT	μ	18.7	19.5	21.4	12.4	20.0	18.4
	σ	3.7	3.5	4.6	4.7	5.5	
SMW	μ	20.5	20.2	22.9	12.6	22.1	19.7
	σ	3.8	3.5	5.1	6.1	5.8	

The variation of the scale means is larger for this set than for means by ethnicity or gender. Again, the *Shared Control* scale returns the smallest means.

TT College, a small co-educational school, returned the most positive overall perceptions, while RO College, a large public boys' school returned the lowest. RT College, which had returned the most positive attitudes towards science (see Chapter Five), returned the lowest overall mean for perceptions of constructivist learning environments. This is an interesting finding, the significance of which is unclear.

6.3.7.2 Scale Means by School Attended: Significance Tests

A MANOVA showed that the factor school attended was a significant main effect on scale mean differences. Table 6.17 gives the results of an ANOVA on the scale means with school attended taken as an independent factor.

Table 6.17: ANOVA on Scale Means with School Attended as Independent Factor

SCALE		Sum of Squares	Mean Square	F
PERSREL	Between Groups	351.86	50.26	**
	Within Groups	9966.60	14.83	
	Total	10318.46		
UNCERTY	Between Groups	244.64	34.94	*
	Within Groups	9653.19	14.67	
	Total	9897.83		
CRITVOIC	Between Groups	1358.70	194.10	**
	Within Groups	17265.01	25.61	
	Total	18623.71		
SHARCONT	Between Groups	410.77	58.68	2.06
	Within Groups	18848.01	28.42	
	Total	19258.78		
STUDNEG	Between Groups	1491.65	213.09	**
	Within Groups	19857.76	29.90	
	Total	21349.41		

The ANOVA showed that the factor school attended gave rise to significant differences between the six school cohorts on all scales except *Shared Control* at the 0.01 level of significance.

In summary, school attended was a significant main effect on scale means and the school which returned the most positive attitudes towards science returned the least positive perceptions of constructivist learning environments.

6.3.8 Mean Differences between Type of School

6.3.8.1 Comparison of Scale Means by School Type

Table 6.18 gives the CLES scale means and variations by school type. In all, 404 students came from the single-sex participant schools and 146 came from the co-educational participant schools.

Table 6.18: CLES Scale Means by School Type

SCHOOL TYPE		PERSREL	UNCERTY	CRITVOIC	SHARCONT	STUDNEG	MEAN
Single-sex	μ	20.3	20.1	21.5	12.8	20.7	19.1
	σ	3.8	3.8	5.2	5.5	5.4	
Coeducational	μ	19.5	20.1	22.4	12.5	20.9	19.1
	σ	3.6	3.5	4.6	5.0	5.6	

The variation of scale means is small. The largest variation, that for the *Personal Relevance* scale, is only 0.8 scale points and the means of the scale means are identical.

Table 6.18 shows that students from the single-sex schools yielded slightly more positive perceptions on the *Personal Relevance*, *Uncertainty* and *Shared Control* scales than those from the coeducational schools, whereas the reverse was true for the *Critical Voice* and *Student Negotiation* scales.

6.3.8.2 Scale Means by School Type: Significance Tests

A MANOVA showed that the factor school type was a significant main effect on scale differences. Table 6.19 gives the results of an ANOVA on the scale means with school type taken as an independent factor.

Table 6.19: ANOVA on Scale Means with School Type as Independent Factor

SCALE		Sum of Squares	Mean Square	F
PERSREL	Between Groups	62.94	62.94	*
	Within Groups	10255.52	15.12	
	Total	10318.46		
UNCERTY	Between Groups	0.08	0.08	.01
	Within Groups	9897.74	14.90	
	Total	9897.83		
CRITVOIC	Between Groups	15.45	15.45	.57
	Within Groups	18608.26	27.36	
	Total	18623.71		
SHARCONT	Between Groups	90.28	90.28	3.15
	Within Groups	19168.49	28.65	
	Total	19258.78		
STUDNEG	Between Groups	112.61	112.61	3.55
	Within Groups	21236.79	31.69	
	Total	21349.41		

The ANOVA showed that the factor school type gave rise to significant differences between the single-sex and coeducational school groups for *Personal Relevance*, *Shared Control* and *Student Negotiation* at both the 0.01 and 0.05 levels of significance.

In summary, school type was a significant main effect on scale means and students from single-sex and coeducational schools displayed similarly positive perceptions of their constructivist learning environments.

6.3.9 Factor Interaction

Each CLES scale was analysed for interactions between the main factors – ethnicity, form level and gender. Multivariate tests of significance were performed to check for interactions (the results of these tests are presented in Appendix 6.2). While significant main effects were detected between the factors ethnicity and form level for the *Uncertainty* scale at the 0.01 level of significance (Appendix 6.2a), the only

three-way effect was that detected for the *Student Negotiation* scale at the 0.01 level (Appendix 6.2b). However, this effect was not significant at the 0.05 level of significance.

6.4 Associations between Student Perceptions of Constructivist Learning Environments and Achievements in Science

6.4.1 Correlation between Teacher Appraisals and Survey Scales

The extent of associations between student perceptions of their constructivist learning environments and achievements in science (research question 4) were appraised through examination of the direct correlation between the five CLES scales and the teacher-assessed scale *Standard of Academic Achievement*.

The calculated correlations are given in Table 6.20 for the subset of students whose standard of academic work had been appraised by their teachers.

Table 6.20: Correlations between Standard of Academic Achievement and CLES Scales

SCALE	PERSREL	UNCERTY	CRITVOIC	SHARCONT	STUDNEG
ACH	-0.03	-0.10	0.14	0.15	-0.04

It is clear that there is no correlation whatsoever between the *Standard of Academic Achievement* scale and any of the CLES scale means. However, the methodology used, that of correlating a teacher-assessed numerical scale with learning environments scales, may be inappropriate.

In summary, no association between student perceptions of their constructivist learning environments and their achievements in science was found.

6.5 Associations between Students' Perceptions of their Learning Environments and Attitudes to Science

6.5.1 Introduction

This section examines whether or not there is a relationship between student perceptions of their constructivist learning environments and their attitudes towards science (research question 3). This relationship was tested through correlation between TOSRA and CLES scales. It is accepted that the survey scales, especially those of the CLES scales, were designed to measure discrete, if overlapping, aspects of student attitudes towards science and perceptions of their learning environments. However, it is reasonable to suppose that there may exist underlying associations between student attitudes and learning environments.

6.5.2 Correlations between the CLES and TOSRA Surveys

The extent of associations between the multiple meanings relating to the term 'attitude towards science' and student perceptions of their constructivist learning environments were appraised through examination of the correlation between the seven TOSRA scales and the five scales of the CLES survey (the correlations are given in Table 6.21 below).

Table 6.21: Correlations between Scale Means for TOSRA and CLES Surveys

SCALE	PERSREL	UNCERTY	CRITVOIC	SHARCONT	STUDNEG
SOCIMP	-.38	-.22	-.08	-.11	-.25
NORMSCI	-.31	-.11	-.08	-.02	-.15
ATTINQ	-.26	-.18	-.01	-.02	-.12
ADOPTATT	-.44	-.22	-.00	-.16	-.32
ENJYLESS	-.41	-.24	.07	-.21	-.31
LEISINTR	-.37	-.20	.06	-.25	-.21
CAREERIN	-.38	-.23	.18	-.18	-.22

It is evident that there is no positive correlation between the scales of the TOSRA and CLES surveys. In fact, most of the inter-scale correlations are weak and negative, probably reflecting the fact that the two surveys are measuring independent factors.

Nevertheless, a positive correlation between perceptions of learning environments and student attitudes towards science was expected. The negative correlations between the two survey instrument scales, particularly between the CLES *Personal Relevance* scale and each of the TOSRA scales, are difficult to explain since both surveys are scored consistently on the basis that higher scores denote more positive attitudes or perceptions.

By comparison, Fisher and Waldrup (1997) investigated associations between classroom learning environments and student attitudes. They also used direct correlation between scales but, unlike the present study, found weak, positive correlations. Further research is required to investigate the associations between student attitudes and constructivist learning environments. Similarly, in a study of Singaporean and Papua New Guinean students, Waldrup and Wong (1996) found strong associations between learning environments and attitudes towards science.

In summary, no direct association between student attitudes towards science and perceptions of constructivist learning environments was found.

6.6 Summary of Findings of Chapter Six

[The complete set of findings of this thesis is presented in Appendix 8.1]

(i) From section 6.3.4, which examined scale differences between the participant ethnic groups, it was found that Maori and Pacific Island students displayed equally positive or more positive perceptions of their constructivist learning environments than Europeans or Asians. Maori and Pacific Islanders displayed similarly positive perceptions.

Finding 9

Maori and Pacific Island students displayed equivalent or more positive perceptions of their constructivist learning environments than European or Asian students.

Finding 10

Differences in perceptions of their constructivist learning environments between Maori and Pacific Island students were not significant.

(ii) From section 6.3.5, which examined scale differences according to form level, it was found that students' learning environments became more positive at fourth form and declined at fifth form.

Finding 11

Perceptions of constructivist learning environments became more positive at the fourth form level and declined again at fifth form level.

(iii) From section 6.3.6, which examined scale means by gender, it was found that males and females displayed equivalently positive perceptions of their learning environments.

Finding 12

Overall, males and females displayed similar perceptions of their constructivist learning environments.

(iv) From section 6.3.7, which examined scale means according to school type, it was found that students from single-sex and co-educational schools displayed similarly positive perceptions.

Finding 13

Students from single-sex and coeducational schools displayed similarly positive perceptions of their constructivist learning environments.

(v) From section 6.4, which looked for associations between learning environments and achievements in science, no association was found.

Finding 14

No association between student perceptions of their constructivist learning environments and their achievements in science was found.

(vi) From section 6.5, which looked for associations between constructivist learning environments and attitudes towards science, no such association was found.

Finding 15

No direct association between student attitudes towards science and perceptions of constructivist learning environments was found.

6.7 Conclusions on the CLES

This chapter has presented the results and findings of a survey of student learning environments using the CLES. Along with the TOSRA, the results and findings of which are discussed in Chapter Five, the CLES has generated information which will be used to develop recommendations for enhancement of student science education outcomes (see Chapter Eight). However, information complementary to that gathered during the surveys was gathered during a suite of interviews with teachers and students. These interviews are discussed in Chapter Seven.

CHAPTER SEVEN

I believe that the fundamental requirement of any inquiry which hopes to be consonant with the teachers' perspectives on teaching is that it must view human behaviour as reflexive. Bolster (1983, p.304)

IMPLEMENTATION AND RESULTS OF THE TEACHER AND STUDENT INTERVIEWS

7.1 Implementation of the Interviews

7.1.1 Interviews with Teachers and Students

The interviews were intended to sample teachers' and students' opinions which would help to address the research questions of the study, obtain information complementary to that obtained from the surveys reported in Chapters Five and Six, and gather other relevant information (Cohen & Manion, 1986; Tuckman, 1994; Wiersma, 1991; Mayher & Brause, 1991). The interviews were designed as *less formal* interviews (Cohen & Manion, p. 307) in which the interviewer accesses a suite of key issues which are raised in conversational style in order to minimise any effects on the behaviour of the subjects.

Interviews with both students and teachers were designed to address a set of interview research questions based on those developed and used by Baimba (1991). These interview questions were intended to address the five main research questions discussed in section 4.2.1, and comprised a suite of eight questions posed to teachers and students during the course of interviews (see 7.3.1). The same questions were posed to both teachers and students in order to obtain the differing and complementary viewpoints of these target groups on the issues concerned. These interview questions were intended to guide the course of discussion rather than to serve as an end in themselves.

7.1.2 The Interview Questions

The interview questions were based directly on the five research questions of 4.2.1, but included additional questions designed to elicit from teachers their philosophical perspectives on the nature of science, the appropriateness of curricula for Maori and Pacific Island students, and the religious and cultural beliefs of students which might mitigate against achievement in science.

The interview questions used with both teachers and students were:

- 1. What feelings do ethnic minority group students have towards science?**
- 2. Is teaching these students rewarding?**
- 3. What is the importance of science to these students?**
- 4. Why do few ethnic minority group students (Maori and Pacific Island especially) continue studies in science during their senior secondary and tertiary years?**
- 5. What is science?**
- 6. How appropriate is the present science curriculum for Maori and Pacific Island students?**
- 7. Should there be some Maori or Pacific Island science or medicine in the course?**
- 8. Do many Maori and Pacific Island students hold strong religious or cultural beliefs which mitigate against their acceptance and enjoyment of science?**

The only differences in the approach adopted with teachers and students lay in the precise wording used to frame these questions. For example, instead of the words 'these students' used with teachers, the word 'you' was used with students.

In sections 7.2 and 7.3 responses from teachers and students to these interview questions are discussed and findings drawn from these responses. A summary of all findings of this thesis is given in Appendix 8.1.

7.2 Key Responses from Interviews with Teachers

Preamble

In this section, a synopsis is presented of the discussions with teachers which ensued from the eight interview questions. Firstly, a brief biography of each of the participant teachers is given in order to provide contextual background for later discussion of student attitudes and perceptions.

1. DR (RO College)

DR is head of the department of science at RO College and has taught there for 25 years. He was born in Wellington and attended RO College and later Victoria University, graduating with an honours degree in geology. He coaches hockey and has extensive experience in teaching Maori and Pacific Island students.

2. JL (TT College)

JL has taught at TT College for ten years. He came to New Zealand about 20 years ago from England. JL read for a degree in Biology in England, and completed a Diploma in Horticulture in New Zealand before commencing his teaching career. JL teaches senior biology as well as junior science.

3. MR (MG School)

MR is 50 years of age. He was born in Auckland and has lived most of his life there. MR undertook a variety of occupations before deciding to read for a degree in physics at Auckland University which he completed in 1983. He then decided to enter the teaching profession and graduated with a Diploma in Teaching from Auckland Secondary Teachers College in 1985. Since then, MR has taught at several schools, including a well-known school for Maori boys in Auckland. He has taught for two years at MG School where he teaches senior physics as well as junior science.

4. RN (SP College)

RN is 40 years of age and has taught at SP College for three years following periods at several other schools in the Wellington region. RN holds a bachelor's degree in physics from Canterbury University.

5. GS (RT College)

GS, presently head of the department of science at the college, has taught at RT College for nearly twenty years. He holds a Master's degree with Honours in Biology from Victoria University in Wellington.

6. ST (SMW College)

ST is 31 years of age and holds a bachelors degree in biology which she gained in England. ST came to New Zealand in 1997 having married a New Zealander. SMW is the first New Zealand school at which she has taught, and at the time of the study, she had been teaching there for only five months.

Comment on the Participant Teachers and their Backgrounds

Of the six participant teachers, five were more than 40 years of age at the time of the study, and had more than 10 years of teaching experience as well as extensive experience in teaching Maori or Polynesian students. This lends credibility to opinions expressed by them about their students.

Key responses made by participant teachers to each of the interview questions are given in sections 7.2.1 - 7.2.7 of this chapter.

7.2.1 Student Feelings Towards Science

Q1. What Feelings do Ethnic Minority Students have towards Science?

Asians are motivated and see science as relevant and important, while Maori students mostly lack motivation and don't seem to regard science as relevant and important to them. Pacific Island students are similar to Maori. Of course, these are generalisations and there are many exceptions. (JL)

. . . the majority find it hard to relate to science and tend towards indifference or negative feelings. (MR)

The Chinese - positive. Polynesians - negative in older students; perhaps more positive in Year nines [third form], and perhaps improving? (DR)

For one teacher, language is at the heart of the problem, rather than cultural differences:

There is some confusion because of language, but otherwise [Maori and Pacific Island students have] the same [attitudes] as the majority group. (RN)

Some really like it, some hate it and some are indifferent. (ST)

Generally positive, I have found. However, it seems to depend entirely on how the teacher presents the subjects. In fact, I cannot really see any difference in feeling between different racial groups. It is the type of delivery that counts. (GS)

Summary of Teacher Responses to Question 1

The teachers consistently indicated that Maori and Pacific Island students experience problems with science education, are less motivated, that they hold less positive feelings towards science than others, and that they perceive science as less relevant to their needs. The teachers generally saw these problems as originating in cultural differences and language difficulties.

The teachers interviewed generally viewed Asian students as very different from Maori and Pacific Islanders. In particular, they viewed Asian students as having stronger work habits and educational and professional ambitions. The teachers clearly saw these differences as resulting from completely different cultural perspectives and values systems.

7.2.2 Rewarding for the Teacher?

Q2. Is teaching these students rewarding?

Overall it is rewarding, although it is hard work getting them motivated. Often poor attitudes and work habits are the main barrier to learning in science. (JL)

Those that are gaining something out of science make it [teaching them] worthwhile. (MR)

Chinese - yes! Polynesians - hard work. Some are keen, but peer pressure is that academic success is not for them. Almost a cult of failure! (DR)

Yes, because they can move ahead quickly if given some individual attention. (RN)

Teaching all students can be rewarding. (ST)

Yes, but all teaching is rewarding when you seem to be getting there. It is not when students are unmotivated and lacking home support. Unfortunately, some of our Maori students come into this category. (GS)

Summary of Teacher Responses to Question 2

The consensus among the teachers was that, while teaching Maori and Pacific Island students is generally rewarding, the task can be a particularly challenging one because of poor motivation and low interest in science. The reasons given for this low interest and motivation were varied, but frequently focussed on cultural differences and poor teaching at the junior levels.

7.2.3 The Importance of Science

Q3. What is the importance of science to these students?

Science is important to help them make better sense of their world and to offer them opportunities which may help them in a future career. (JL)

As they become more able to master the subject, so does the importance and relevance increase for these students. (MR)

Chinese - interested in physics and keen on learning generally. Polynesians see it as having little relevance. (DR)

Same as others - jobs in the future; understanding the world around them. (RN)

When science is an option, the balance of the group reflects the balance of the school. (ST).

Science appreciation and knowledge is important to all students, especially these days with such a high reliance on videos, films and science fiction. Science teachers have an important duty to uphold reality. Many students, including Maori, believe that everything they see on television is true. (GS)

Summary of Teacher Responses to Question 3

A common view amongst the teachers is that science is of importance to Maori and Pacific Island students and to their future career opportunities, just as it is for Asians and European students. However, in their opinion, Maori and Pacific Islanders more frequently do not appreciate this.

7.2.4 Continuation of Science Studies

Q4. Why do few ethnic minority group students (Maori and Pacific Island especially) continue studies in science during their senior secondary and tertiary years?

They don't wish to be scientists, so why study science? The notion that scientific understanding is useful in many everyday situations is hard to get across to them. (JL).

. . . a lack of relevance to their perceptions of where they have come from and what their expectations are for the future. (MR)

They generally don't [continue with senior science]. Year 11 [form five] junior science is a far as they tend to go. They are turned off by having to learn basics and they often never gain an understanding. Cultural problems? Scientific method is not known in these cultures which were in recent times based around the spoken word, so documentation does not come easily to many Polynesians. (DR)

[They are] . . . overwhelmed in the early years. (RN)

In our school, they do continue their studies. (ST)

Those who have a career or aim in sight keep to the sciences and usually do very well. Many give in to the tall poppy syndrome from their mates. It is not cool to want to succeed at school. (GS)

Summary of Teacher Responses to Question 4

The consensus among the teachers is that Maori and Pacific Island students relinquish science studies in great numbers at the senior high school level because they do not see science as relevant to their needs. Another opinion expressed is that these students come from cultures in which science is not strong and in which they are not encouraged in academic endeavours by either their families or peers. Hence, their motivation is low.

7.2.5 The Nature of Science

Q5. What is science?

Science is a method of investigation of natural phenomena. The emphasis should be placed on skills and processes with less emphasis on knowledge. Science contributes to students making better sense of life-world experiences. (JL)

To me, science is the study of all natural phenomena. (MR)

Science is understanding the world around us and how things work. (RN)

The nature of science at secondary school is to provide the student with the skills to investigate, observe, measure and describe phenomena in their world; to uncover the truth, to disprove fallacy, to encourage an open, inquiring mind; to provide an explanation of why things happen, or how they work. (GS)

Summary of Teacher Responses to Question 5

The teachers generally appeared to view science as an approach to understanding the natural world, rather than as a collection of facts or knowledge. One teacher, MR, also expressed the view that '*physics is the art and science of measurement*'. Such mature perspectives on science impressed the researcher as well considered systemic impressions of the nature of science rather than 'secondary school-level' world views. By comparison, scientism (see Chapter Three) is based on the ontological thesis which assumes the existence of real, isolated entities, independent of human perception (Eastman, 1969).

7.2.6 Appropriateness of Curricula

Q6. How appropriate is the present science curriculum for Maori and Pacific Island students?

The curriculum has been written to be inclusive, but it is hard to include Maori and Pacific Island perspectives on topics such as electricity. Even in earth science, where Maori legends are included with the best intentions, often the effect is to devalue the legends. The Science for All approach has to be made in the way that it is taught rather than in what is taught. A pragmatic approach needs to be taken in which the science which is taught is useful and relevant to the needs of all students. (JL)

It [the curriculum] should be appropriate, but is often not because these students have failed to be captured at an earlier age when their interests might have been aroused. They are unprepared! (MR)

The current curriculum does little for serious science students! If you mean a Maori or Pacific Island content, basic science was not strong in these cultures. There is a great deal of pseudo-science which is little more than a sop to attain a Polynesian science content. (DR)

It's as appropriate as you [the teacher] make it. It's appropriate to New Zealand and its people. (ST)

OK, I think. I'm afraid I do not see science as a cultural thing. It is a discipline. Sure you can relate science to ideas, beliefs, practices of other cultures, but the emphasis should still be on 'is it science?' as opposed to myths, folklore etc. (GS)

Summary of Teacher Responses to Question 6

The teachers appear to view the present science curriculum as well intentioned but not the best adapted to the needs of Maori and Pacific Island students. It was agreed by the teachers that extremely little of Maori or Polynesian science, medicine or folklore is promoted in western science education in New Zealand. However, few felt that this was a serious omission (see 7.2.7).

When constructivist ideas were explained to them, teachers were usually willing to accept such approaches as plausible mechanisms for transmitting and acquiring scientific knowledge. Several teachers agreed with the notion that students come to school with prior conceptions or beliefs about certain scientific phenomena and that these conceptions are often 'gut' or 'lay' ideas (Claxton, 1984). However, a more common perception is that most students arrive with no preconceived ideas about scientific concepts.

7.2.7 Indigenous Science?

Q7. Should there be some Maori or Pacific Science or medicine in the course?

No. There is a great deal of pseudo-science which is little more than a sop to attain a Polynesian science content. (DR)

There are not enough resources that deal appropriately with Maori science and even less [with] Pacific Island [science]. (RN)

Yes, where appropriate. However, the problem is that there is no such thing as Maori science or medicine. The whole thing varies throughout the country and, even within an area, a general consensus is never reached. Also, there is a lack of resources available to teachers to use with confidence. (GS)

Summary of Responses to Question 7

The majority of the teachers (four out of six) did not believe that more Maori and Pacific Island themes should be introduced. Several were quite negative about this suggestion, feeling that indigenous science is not appropriate for science curricula, either from the perspective of enhancement of students' scientific education, or from the perspective of the limited resources available. Several in fact remarked that token inclusion of such material could devalue indigenous beliefs. However, it was generally agreed that Maori and Pacific Island scientists should be promoted as role models. At present, famous scientists who become scientific 'heroes' are almost entirely European or American, and there are few credible famous role models for young Maori and Pacific Island students to emulate.

7.2.8 Religious or Cultural Beliefs Mitigating against Success

Q8. Do many Maori and Pacific Island students hold strong religious or cultural beliefs which mitigate against their acceptance and enjoyment of science?

No. Most of the families whose kids we see here have been in New Zealand for several generations. Beyond an attitudinal difference, their traditional backgrounds have been watered down and are no longer an issue. (DR)

Not that I have come across in our area. The only time this surfaced was with one student who was told by her parents not to participate in a family tree exercise in genetics to get the students to work out where they had inherited certain features from. They claimed that all this information was tapu [sacred]. (GS)

Summary of Teacher Responses to Q8

Conflicting difficulties between cultural beliefs, values and norms and standards promoted in the science laboratory were not recognised by any of the teachers. It was not accepted by any of the teachers that the 'traditional origin' of Maori and Pacific Island students presents significant conflictual difficulties because most of these

students come from families that have lived in western culture for one or more generations.

7.2.9 Summary of Teacher Interviews

Section 7.2 has presented key responses from interviews conducted with teachers. The considerable practical experience of these teachers enabled them to make worthwhile contributions to the study and their objectivity was a crucial factor in enhancing our understanding of the problems of ethnic minority students.

The teachers consistently identified problems in science education among Maori and Pacific Island students, but have varying perspectives on how they should be addressed. Thus, some of the teachers interviewed did not subscribe to the idea of including Maori and Pacific Island science in regular science curricula, whereas a 'culturally sensitive' approach might have been to do exactly this, and perhaps to make science courses more 'user friendly' for minority students.

7.3 Interviews with Students

Preamble

(i) Conducting the Student Interviews

Interviews with students were conducted in accordance with the interview technique used by Taylor, Fraser, and White (1994), with groups of three students from each class, lasting for approximately 30 minutes. The three students selected from each class were chosen to provide a representative coverage of ethnic groups and gender. Where possible, this meant that an interview group would comprise three of the following: one Maori student, a Pacific Island student, one Asian student, and one European student. The interviews were conducted in a vacant classroom and students sat in a semi-circle with the interviewer (the researcher of the present study).

Students were assured of the strict confidentiality of the process and their responses were recorded on dictaphone. These interview questions were nearly identical to those used with teachers so that similar but complementary information to that gained from teachers could be elicited.

(ii) Timing of Interviews

TT College Interviews

Interviews with students at TT College were conducted on Tuesday 19 May 1998. Third form students interviewed were AA (European), MI (Pacific Island, Cook Islands) and TA (European). Fourth form students interviewed were BR (European), CA (Maori) and OW (Pacific Island Samoan). Fifth formers included LI (European), RE (Maori) and JN (Pacific Island Tongan).

SMW College Interviews

SMW College was visited on Wednesday 10 June 1998. Third form students interviewed were SH (Pacific Island), JE (Maori) and VA (European). Fourth form students interviewed were HA (Maori), HE (European), and PA (Pacific Island, Samoan). Fifth form students interviewed were KA (European), KU (Pacific Island, Samoan) and AM (Maori).

MG School Interviews

Students at MG School were interviewed on Thursday 29 June 1998. Third form students interviewed were VI (Pacific Island), MR (Maori) and HE (European). The Fourth formers were JE (Maori), LE (Pacific Island) and PA (European). The Fifth formers were MG1 (Maori), MG2 (Pacific Island) and MG3 (European) respectively.

RT College Interviews

Interviews were conducted at RT College on Friday 11 September 1998. Two Maori and one European student from each of the three form levels were interviewed. These students preferred to remain anonymous to the researcher and are coded differently to those from other schools. The participant students from the third form were R3-1 (Maori), R3-2 (Maori), and R3-3 (European). Fourth form students were R4-1

(Maori), R4-2 (Maori), and R4-3 (European). Fifth form students were R5-1 (Maori), R5-2 (Maori), and R5-3 (European).

Interviews were not conducted with RO or SP College students because of academic and other commitments.

Sections 7.3.1 to 7.3.8 discuss students' responses to the eight interview questions. Only key responses are given, and not all schools or students are quoted for each interview question. The summaries of each suite of interviews for each interview question are based on the entire dialogue which occurred during each session, and reflect much that has not been recorded as key responses.

7.3.1 Feelings Towards Science

Q1. What feelings do you have towards science?

7.3.1.1 Third Form

TT College

MI (PACIFIC ISLAND): *It's OK. I like using the bunsen burner. I would prefer to do stuff like fossils.*

TA (EUROPEAN): *I really enjoy it, but the stuff I learn is not going to help me. It's all right. I enjoy learning about it and I know heaps more now. I enjoy doing the practicals, but you don't really know what they're for, you know, how you're going to use them. It would be quite interesting to learn more about fossils and palaeontology and I've always liked marine biology.*

CA(MAORI): *Stuff like geology and fossils would be more enjoyable than learning about making chemicals like carbon dioxide.*

SMW College

SH (PACIFIC ISLAND): *Sometimes its really boring; sometimes not. I just like experiments.*

JE (MAORI): *I like it. It's better than other things. One of my favourite subjects.*

VA (EUROPEAN): *I like experiments as well. It's laid back. Like - not so strict. But it wouldn't be one of my favourite subjects.*

MG School

VI (PACIFIC ISLAND): *I do enjoy learning about science although there are some sub-topics that are very boring. Some or most of science should be enjoyed learning.*

RT College

R3-1 (MAORI): *Chemistry is quite cool, but I think the rest is pretty boring except for energy.*

R3-3 (EUROPEAN): *Sometimes it is boring, but when we do experiments it's pretty cool. When the teacher talks too much you kind of get tired but I don't go to sleep.*

7.3.1.2 Fourth Form

TT College

CA (MAORI): *I don't like science, but I quite enjoy the practical side of the fourth form course.*

OW (PACIFIC ISLAND): *I really love this subject. This has a great deal to do with the positive attitude of my science teacher.*

MG School

JE (MAORI): *I find that science is very interesting - finding out new things. I like it when we do experiments and get chemical reactions.*

SMW College

HA (MAORI): *It's OK - not as boring as you would think. It can be quite interesting.*

HE (EUROPEAN): *It depends on what you are doing. Sometimes it's interesting; sometimes it's not. I like it.*

PA (PACIFIC ISLAND): *I like it. I thought it would be hard, but I understand it. Its better than other subjects and I like both the practicals and the writing.*

RT College

R4-1 (MAORI): *I only enjoy science when we do experiments.*

R4-2 (MAORI): *It's OK. Some things I don't understand.*

R4-3 (EUROPEAN): *Fun sometimes. Writing and doing activities out of books is boring.*

7.3.1.3 Fifth Form

SMW College

KA (EUROPEAN): *I enjoy it sometimes, but it's boring copying down notes.*

KU (PACIFIC ISLAND): *I like doing experiments, but not copying down notes.*

AM (MAORI): *I enjoy the experiments and finding out things I didn't know. I don't enjoy tests.*

MG School

MG1 (MAORI): *Hard! When science hasn't been taught to you properly in forms three and four, it is very difficult to understand it in fifth form.*

RT College

R5-1 (MAORI): *Can be fairly interesting, especially doing practicals.*

R5-2 (MAORI): *Science needs to be more exciting.*

R5-3 (EUROPEAN): *I enjoy science as I learn a lot from it.*

Summary of Student Responses to Question 1

On several occasions students would echo responses given previously by other participant students. This was exemplified by KA and KU's (SMW College) responses involving the tedium of 'copying down notes'. A few students admitted to having harboured negative preconceptions about science studies or the difficulty they might experience in science or that science was bound to be 'boring'. One comment echoed a common sense perception of the great importance of getting it right early on; ie. bad teaching or ineffectual learning in the early years makes for problems which are very difficult to remediate in later years. This comment by a MG College student echoes a comment made by her teacher, who opined that the motivation problems experienced by some Maori and Pacific Island students partly derives from poor capture of students' interest in the early years. Noticeably, Maori students were reluctant to speak and generally had little to say.

The small size of the sample made it impossible to discriminate between responses from different form levels, schools, genders or ethnicities. Some consistent points did

emerge, however, which include the positive attitude many students have towards practical work in science rather than lectures or bookwork. This point deserves notice among curriculum designers who aim to produce curricula which must motivate students and hold their interest. Other points noted include the great importance of the teacher's classroom personality and his or her interactions with students in shaping students' enjoyment and attitudes towards their science studies. For example, when questioned, OW, a Pacific Island student, indicated that his enjoyment of science and any other school subject relates both to the teacher and the subject.

7.3.2 Rewarding for the Teacher?

Q2. Is teaching you rewarding for your teacher?

7.3.2.1 Third Form

TT College

AA (EUROPEAN): *Yeah, some of the time. Our class has a bit of a habit of burning pens and so on.*

MI (PACIFIC ISLAND): *He [JL] doesn't like teaching me. He's always yelling and everything. I hassle him. It's all right. I get away with it.*

TA (EUROPEAN): *We get a lot of laughs. He laughs as well. We get along well. The whole class does.*

SMW College

SH (PACIFIC ISLAND): *It would [be rewarding for my teacher]. But I'm not cooperative in class.*

JE (MAORI): *It depends on the teacher. She [ST] makes it fun.*

MG School

MR (MAORI): *Of course! MR is a well-skilled teacher and has his own way of communicating with his students.*

RT College

R3-1 (MAORI): *Yes, because it is usually all taken in.*

R3-2 (MAORI): *It kind of is because they are helping you by preparing you to find a job when you leave school.*

R3-3 (EUROPEAN): *I think so because he gets to know that he has taught pupils some important facts.*

7.3.2.2 Fourth Form

TT College

CA (MAORI): *I try to be positive towards the subject most of the time, but other students disrupt the class frequently.*

OW (PACIFIC ISLAND): *Me and another student try to compensate for the kids who try to make the class a living hell for the teacher. Overall, teaching our class is probably a rewarding experience for him.*

SMW College

HA (MAORI): *We are good [well behaved] for our teacher. Better than in other classes.*

HE (EUROPEAN): *It's good for her. She gets to hear childrens' thoughts about how things work in science.*

PA (PACIFIC ISLAND): *She would [find it rewarding]. She's teaching but also learning - learning how to teach better. If you're getting better at it, you've done your job.*

MG School

JE (MAORI): *Yes. He is happy when we get good results, when we answer questions, when we get good results from experiments.*

RT College

R4-1 (MAORI): *No. Not me anyway!*

7.3.2.3 Fifth Form

SMW College

KA (EUROPEAN): *Sometimes. It depends on how you react - how she's teaching us - how we take it in.*

KU (PACIFIC ISLAND): *I don't usually listen. I talk in class. I sometimes feel guilty about it.*

AM (MAORI): *Our class is OK. It depends on what's happening.*

MG School

MG2 (PACIFIC ISLAND): *Depends on students and the respect they have for the teacher.*

RT College

R5-1 (MAORI): *Yes. He enjoys it quite a bit except when we play up.*

Summary of Student Responses to Question 2

Responses to this question were mixed, some indicating a belief that teaching them would be rewarding, others conceding that it might not be. Some interesting responses included several admissions of undesirable behaviour on the part of students, including inattention, talking in class, non-cooperation and ‘burning pens’. Some responses echoed those of the previous question in underscoring the importance of the teacher’s interaction with the class and, perhaps, the fickle nature of students’ reactions to teachers (*It depends on what’s happening and . . . how she’s teaching us.*).

7.3.3 The Importance of Science to Students

Q3. What is the importance of science to you?

7.3.3.1 Third Form

TT College

AA (EUROPEAN): *I look forward to two periods a week when we do practicals. The other two periods we copy off the board, usually. That’s really boring! But we do learn a lot. With practicals he tells us about the method we will use. He tells us what’s going to happen. I may be a scientist later on, but the main thing I want to do is [work with] computers.*

MI (PACIFIC ISLAND): *I don’t want a career later on in science. I want to be an engineer in the army.*

TA (EUROPEAN): *I love marine biology. I used to have my heart set on being a schoolteacher. I like working with children; maybe in intermediate years, say standard four. It’s important. You’re starting their education for them. I don’t think I’d be a very good teacher for that [science] because I have trouble understanding some of the ideas.*

SMW College

SH (PACIFIC ISLAND): *I don't know. I want to be an air hostess or a lawyer. Probably, science is relevant.*

JE (MAORI): *I don't think it will [be relevant]. I don't want to be a scientist. It wouldn't be that much fun.*

VA (EUROPEAN): *I want to be a lawyer. Science may play a bit of a part.*

MG School

HE (EUROPEAN): *Science is very important because it can help you in future jobs or opportunities. Science can help you decide what job you want.*

RT College

R3-1 (MAORI): *It's important to me because I'm really interested in some subjects of science.*

R3-2 (MAORI): *It's important when you leave school. Example – if you want to be in the navy.*

R3-3 (EUROPEAN): *Science isn't really that important to me because of the career option I have chosen. But I still think I need to learn about it.*

7.3.3.2 Fourth Form

TT College

CA (MAORI): *Science is important for me because it is worthwhile to know about the world.*

BR (EUROPEAN): *Science is quite important for my future career in volcanology and seismology. It is important to know what's out there - in the wilderness.*

OW (PACIFIC ISLAND): *Science is real important because I did not learn any science at my previous school and originally I did not want to learn science. I am interested in lava currents in the earth's mantle and crust.*

SMW College

HA (MAORI): *I want to be a physiotherapist. You've got to do science for that. Besides, it helps to understand everyday things like electricity.*

HE (EUROPEAN): *I don't know what I'll be. But it helps everybody. Science is there every day in your life.*

PA (PACIFIC ISLAND): *I might be a dietitian, or a physiotherapist or a doctor. I would not like to be a scientist, though. It's good to learn new things. People must work hard to understand them.*

MG School

JE (MAORI): *I want to be a vet or a chef when I grow up, so science is very important if I want to become a vet.*

RT College

R4-1 (MAORI): *It's fun doing experiments. If I learn about acids, I can make my own bomb!*

R4-2 (MAORI): *Nothing towards my career. Well, I don't think so anyway.*

7.3.3.3 Fifth Form

SMW College

KA (EUROPEAN): *I want to join the police force and maybe do forensic science. That would be pretty cool.*

KU (PACIFIC ISLAND): *No! I want to be in the army. I want to learn to drive a tank!*

AM (MAORI): *I don't know. I wouldn't mind teaching, but not [become] a science teacher.*

MG School

MG1 (MAORI): *It may provide wider options in the sixth form. Important if I need it in the future.*

MG2 (PACIFIC ISLAND): *It's important to know what's around. We need it for our careers, for example. I may be a navy officer. We should know why the things in this world happen and that helps us to understand the world, the living world, around us.*

RT College

R5-1 (MAORI): *You could need it for a number of careers, even hairdressing, and it could come in useful anyway in your life.*

R5-2 (MAORI): *It's important for me to pass science so I can do applied science next year.*

R5-3 (EUROPEAN): *I need to know how things react and their outcomes.*

Summary of Student Responses to Question 3

The requirement made of students to articulate the importance of science to them prompted two broadly differing interpretations of the question, one in terms of the level of interest and enjoyment they derive from their science studies, and the other in

terms of the practical importance science holds for their future careers. There was wide variation in the kinds of responses made, but only three students indicated that they would contemplate a science career. Several students, however, indicated interest in careers which might involve further scientific training such as physiotherapy, medicine, veterinary science, and forensic science. Thus, many students at the junior secondary level are aware of the importance of science to certain professions. The three TT College fourth formers were adamant that they would like to see more science topics such as astronomy and geology and palaeontology included in the science curriculum because these are more interesting subjects to them than the formal core sciences which, they also agreed, have their place.

7.3.4 Continuation of Science Studies

Q4. Why do few Maori and Pacific Island students continue studies in science?

7.3.4.1 Third Form

TT College

AA (EUROPEAN): *The low numbers of Maori and Pacific Island students continuing in science is historical because most scientists are European and so it's the right thing to do for many European students. They [Maori and Pacific Island students] are not as technologically advanced as we are. Europeans have the technology.*

MI (PACIFIC ISLAND): *Most of them drop out of school and go to gangs.*

SMW College

SH (PACIFIC ISLAND): *They probably don't like it. It could be boring to them.*

JE (MAORI): *Probably, teachers turn them off.*

VA (EUROPEAN): *Maybe they don't believe in it.*

MG School

VI (PACIFIC ISLAND): *I think because they feel as if there will be no need for science in their future and that the few that do continue think they need it, or [else] it interests them.*

RT College

R3-1 (MAORI): *Because they might not think it would be useful in life.*

R3-2 (MAORI): *Because they can't be bothered listening because they think they don't need to know the things you get taught.*

R3-3 (EUROPEAN): *Some Maoris have to leave school early anyway to work to put food on the table.*

7.3.4.2 Fourth Form

TT College

BR (EUROPEAN): *Pacific Island and Maori students drop out of senior science because it probably gets harder at that level. Maori and Pacific Island students probably mess around too much to be successful in senior science studies. In the Islands, they are not used to it [science].*

OW (PACIFIC ISLAND): *It's really up to the student. The teacher can't help you if you can't help yourself.*

SMW College

HA (MAORI): *They [Maori and Pacific Islanders] probably don't understand it. They probably aren't interested in it. They believe more in religion.*

HE (EUROPEAN): *It depends on what you are interested in. They are more interested in sports.*

PA (PACIFIC ISLAND): *They aren't interested.*

MG School

JE (MAORI): *They don't have enough motivation to encourage them to learn and be interested.*

RT College

R4-2 (MAORI): *Probably because they don't like it.*

R4-3 (EUROPEAN): *Because they feel they don't need science in the future.*

7.3.4.3 Fifth Form

SMW College

KA (EUROPEAN): *I don't know. It probably doesn't suit them. They don't want to take part.*

KU (PACIFIC ISLAND): *It depends on how our parents brought us up. I don't need it [science]. It depends on the student. Some people drop out because their friends drop out.*

AM (MAORI): *It's got to do with your family. Your upbringing.*

MG School

MG1 (MAORI): *It's because of their background. Some parents expect too much from their children and some parents don't care and [this] makes the kids rebel against their parents and, for example, drop out of school, get pregnant when young, smoke and become alcoholics.*

MG2 (PACIFIC ISLAND): *They find they do not get enough freedom and their parents want them to do everything they didn't get to do, laying a lot of pressure on the students. Soon, they just don't care about their lives because it's being run and controlled by someone else.*

RT College

R5-1 (MAORI): *The effects of racism changed Maori attitudes and they are not doing well at school because of it.*

R5-3 (EUROPEAN): *Maybe they don't see a use for it in their future.*

Summary of Student Responses to Q4

Students' perceptions of why ethnic minority students relinquish science studies appear to focus on the lack of enjoyment these students experience in science and the perception among them that science holds little relevance for their everyday lives or for their futures. Many of the students interviewed expressed the opinion that Maori and Pacific Island students may sometimes lack the discipline required to achieve in science, that their cultures and their families do not foster a strong respect for science, and that some drop out because science becomes more difficult at the higher levels. Such sentiments were articulated by Maori and Pacific Island interviewees as well as by European students.

7.3.5 Student Definitions of Science

Q5. What is science?

7.3.5.1 Third Form

TT College

AA (EUROPEAN): *Science is the study of everything. It isn't the study of the world, it is the world. Everything is science.*

MI (PACIFIC ISLAND): *Science is when you get taught a lot about atoms and matter and how to make stuff. It's like cooking.*

SMW College

SH (PACIFIC ISLAND): *I don't know.*

JE (MAORI): *Science is finding out things that haven't been found out yet and finding out more about things we know about already.*

VA (EUROPEAN): *The study of the world.*

MG School

MR (MAORI): *Science is helpful in the future and it opens a whole new world of science and technology.*

RT College

R3-1 (MAORI): *Science is life. Some science is just teaching about things we do every day like water you drink has lots of living things in it.*

R3-2 (MAORI): *I don't know!*

R3-3 (EUROPEAN): *Science is the study of everything.*

7.3.5.2 Fourth Form

TT College

CA (MAORI): *Science is stuff about the environment, I guess.*

BR (EUROPEAN): *How things are made and what they're about. Chemistry, Biology, Botany.*

OW (PACIFIC ISLAND): *Science is studying everyday life - getting the inside story of it.*

SMW College

HA (MAORI): *Understanding what to do every day and inventing.*

HE (EUROPEAN): *Finding out about the world and what's in it.*

PA (PACIFIC ISLAND): *How everything is made up and how we can make new things.*

MG School

JE (MAORI): *Learning about your surroundings.*

RT College

R4-1 (MAORI): *Another boring class at school!*

R4-3 (EUROPEAN): *Studying the world; learning about chemicals.*

7.3.5.3 Fifth Form

SMW College

KA (EUROPEAN): *The study of everything and reactions.*

KU (PACIFIC ISLAND): *It's the future and how this affects us.*

AM (MAORI): *Can't put this into words because it means so many things.*

MG School

MG1 (MAORI): *[Science is] making sense of our world.*

MG2 (PACIFIC ISLAND): *Matter. Understanding our world and everything around it.*

RT College

R5-1 (MAORI): *The study of the physical, chemicals and the living world around us; finding out how things work.*

R5-3 (EUROPEAN): *It's a study of what things are and how they were made.*

Summary of Student Responses to Q5

Student definitions of science were articulated both in terms of the science process and its scope. Students frequently perceived science as an active human process involving 'studying', 'learning', 'getting taught', 'finding out', and 'making sense'. These perceptions are of interest because they reflect those of teachers who also frequently explained science as a man-made activity. Other responses articulated conceptions of the nature of science in terms of the nature of issues and subject matter addressed. Such responses portrayed science as 'about the world', about 'surroundings', about 'reactions', and one response ran: *It's the future!*

7.3.6 Appropriateness of the Curriculum

Q6. How appropriate is the present science curriculum for you?

7.3.6.1 Third Form

TT College

AA (EUROPEAN): *The safe stuff is appropriate. Last term, we used some dry ice and some people were trying to make explosions which is dangerous.*

TA (EUROPEAN): *I think it's all right. We're taught how to handle acids. Our class learned about the dangers of some of the chemicals used in our science studies when one student was nearly blinded in an accident at the laboratory.*

SMW College

SH (PACIFIC ISLAND): *Yes. It is appropriate. Nothing should be taken out. Just, it should be made more interesting.*

JE (MAORI): *Many of the words are not relevant. Like 'chlorophyll'. We shouldn't have to remember them.*

VA (EUROPEAN): *It's not so interesting at third form. Maybe we need it as basic background.*

RT College

R3-1 (MAORI): *Fine. I think it is at just the right level.*

R3-2 (MAORI): *I think it's but some of it is hard.*

R3-3 (EUROPEAN): *I think that what we are currently learning is appropriate for us to be learning.*

7.3.6.2 Fourth Form

TT College

CA (MAORI): *Science is pretty well the way it should be.*

OW (PACIFIC ISLAND): *I like it the way it is. But we should have more topics such as volcanoes, astronomy and electronics.*

SMW College

HA (MAORI): *Some things you have to know, like electricity. People get bored. It's OK for me.*

HE (EUROPEAN): *We should do the same stuff even though it's not interesting.*

PA (EUROPEAN): *It depends on what you are better at. You should learn everything.*

MG School

JE (MAORI): *It depends. If you want to learn it is easy, but if you don't read your notes and look over what you did then you make it harder for yourself.*

RT College

R4-1 (MAORI): *We are learning about teeth. Hey! This is a science class, not a dental clinic!*

R4-2 (MAORI): *It sucks! We should make bombs!*

7.3.6.3 Fifth Form

SMW College

KA (EUROPEAN): *Some topics are reasonable. They're trying to give us a rounded education.*

KU (PACIFIC ISLAND): *There's too much. You can't remember everything.*

AM (MAORI): *What we do in biology is helpful. She [the teacher] gives us a variety. Overall, it's OK.*

MG School

MG2 (PACIFIC ISLAND): *Easy if you have studied. Hard if you don't.*

RT College

R5-1 (MAORI): *Fairly good, especially with the current teachers.*

R5-3 (EUROPEAN): *It is good because it gives you a good look at a wide range of things to do with science.*

Summary of Student Responses to Q6

The students interviewed generally appeared to feel that the curriculum is appropriate. Such criticisms levelled at the present New Zealand junior science curriculum concerned the general interest of the material taught to students and the lack of more stimulating special interest topics such as 'astronomy' or 'dinosaurs', high workloads, and the requirement to remember numerous scientific terms. There were some inappropriate responses to this question, such as those pertaining to the relationship between the ease or difficulty of the science experience and students' work habits. Many of the students appear to appreciate the need for a broad

introductory science education, even if not all of the taught subject matter is enjoyed by them.

7.3.7 Maori and Pacific Island Science

Q7. Should there be some Maori or Pacific Science or medicine in the course?

7.3.7.1 Third Form

TT College

AA (EUROPEAN): *It would be good to know how they navigated 600 years ago and how they prepared their food. But now we learn some of these things in social studies.*

MI (PACIFIC ISLAND): *I'm not keen on the idea of having Maori and Pacific Island science in the school curriculum because when we hit the twenty-first century they're still a hundred years back. They haven't got flush toilets! They have to use hoses!*

TA (EUROPEAN): *Maori and Pacific Island science topics should be included, but not in the regular science curriculum. That could be included in the present 'science badge' system. However, the students would have to pay for this and some parents wouldn't pay it.*

SMW College

SH (PACIFIC ISLAND): *Yes. It would make it more interesting.*

JE (MAORI): *We already do that in social studies. I don't reckon it would make any improvement.*

VA (EUROPEAN): *It would be good - an advantage in learning about different aspects of science from different cultures.*

MG School

MR (MAORI): *Yes - big time! It would be really nice if we could learn how our Pacific science and technology work.*

VI (PACIFIC ISLAND): *Yes. I think there should be some so that we understand what the doctors are talking about. Also, if we are sick we know how to cure ourselves.*

RT College

R3-2 (MAORI): *Yeah, because it would be kind of a privilege to Maoris.*

R3-3 (EUROPEAN): *Yes, because then Maori would be learning about their own culture as well.*

7.3.7.2 Fourth Form

TT College

BR (EUROPEAN): *It would be quite fun to learn about indigenous science such as navigation and herbal remedies.*

OW (PACIFIC ISLAND): *It's [traditional science] really for survival. You've got to know what fruits to eat and what are poisonous berries.*

CA (MAORI): *[Maori and Pacific Island science] could be good for teenagers going out tramping.*

SMW College

HA (MAORI): *We already did Maori astronomy. We can tell when to harvest using the moon. It's good, but I wouldn't want to do a big study.*

PA (PACIFIC ISLAND): *It's good to learn different ways of thinking about the world. You can choose which suits you.*

MG School

JE (MAORI): *Yes. It would mean that if you are Maori or Pacific Island you would relate to it more and be more interested.*

RT College

R4-1 (MAORI): *Yeah. It must be better than what we are learning now.*

R4-2 (MAORI): *Yes. I think it would be quite interesting.*

R4-3 (EUROPEAN): *No. We do similar work in social studies.*

7.3.7.3 Fifth Form

SMW College

KA (EUROPEAN): *Yes. Because you can learn how different cultures think.*

KU (PACIFIC ISLAND): *Yes, because you can pass it on.*

AM (MAORI): *Yes. You could get more people from different cultures interested. We'd like to know about Maori medicine, for example.*

MG School

MG1 (MAORI): *No, because what if the scientific world finds out that the Pacific Island medicine is a fake and so members of the minority feel ashamed? I also feel that any changes which may be made will not make a difference. It depends on how the person finds the subject.*

MG2 (PACIFIC ISLAND): *Yes and no. Other students might not fit in; and yes, because some Maori and Pacific Islanders feel confident in sharing their experience about medicine.*

RT College

R5-1 (MAORI): *If it is applicable and relates to it [science], yes!*

R5-3 (EUROPEAN): *Yes. I think that would be a good idea.*

Summary of Student Responses to Q7

The majority of student interviewees felt that the inclusion of Maori and Pacific Island science would be worthwhile. Interestingly, the few students who argued against this idea were mostly Maori or Pacific Islanders, one of whom felt that Maori and Pacific Island people might become embarrassed if their science and medicine were found to be inadequate. The student responses bear marked contrast with teachers' responses to the same question. Most teachers interviewed believed that there would be little value to students in presenting such material at the secondary level.

7.3.8 Student Religious or Cultural Beliefs

Q8. Do you have religious or cultural beliefs which go against what you learn in science?

7.3.8.1 Third Form

TT College

TA (EUROPEAN): *Where did the first trees come from? Scientists may be right, but each individual is entitled to his or her own opinion. I don't believe that an animal can turn into another animal and into yet another animal.*

SMW College

SH (PACIFIC ISLAND): *I have religious beliefs, but it doesn't make things difficult. God could have created the world and then the dinosaurs came!*

JE (MAORI): *I'm not religious.*

VA (EUROPEAN): *I don't know. There's no proof. Even scientists have no proof. And I don't care what happened [about creation].*

MG School

VI (PACIFIC ISLAND): *Yes. Some scientists believe people originated from apes, but Christians believe God made us and was the creator of the world.*

MR (MAORI): *I believe that in this world today there are many scientists who believe miracles are all made up and always have a solution for problems. I believe their solutions are fake!*

7.3.8.2 Fourth Form

TT College

OW (PACIFIC ISLAND): *I'm Christian, but I don't have any problems with science. Christianity clashes more strongly with science than Pacific Island beliefs. It would be fun if we could have more 'god stuff' as well as evolution.*

BR (EUROPEAN): *I also have a belief in Christianity, but there is much evidence to support science, but none at all to support the existence of god.*

SMW College

HA (MAORI): *I believe in god and I go to church. I also believe in [scientific] facts. I've got to believe it [science]. It's no problem. I can believe in both [Christianity and science].*

HE (EUROPEAN): *You can't believe in both. I have no religious beliefs.*

PA (EUROPEAN): *Even scientists are guessing. It's [creation] is too hard a question to answer. Everyone has a different opinion. You don't know.*

MG School

JE (MAORI): *I only believe no animals, no matter what, should be harmed or tested on.*

7.3.8.3 Fifth Form

SMW College

KA (EUROPEAN): *I'm religious, but it doesn't mean I follow everything blindly. You can choose what to believe.*

KU (PACIFIC ISLAND): *No. But it is a problem for some of my relatives.*

AM (MAORI): *Not really.*

MG School

MG1 (MAORI): *No. Religion is important to me, but science is fact and I don't really mix them up.*

RT College

R5-1 (MAORI): *Yes. Evolution. Fine as long as it is only the theory of evolution, not forced on us.*

Summary of Student Responses to Q8

The majority of students interviewed appeared to prefer modern scientific ideas to traditional or religious ideas. Some felt that it is legitimate to hold religious beliefs and accept science simultaneously. Five students identified as Christians, but did not express particular difficulties in accepting scientific tenets. One student declared doubts about the veracity of science, and two believed that creation and the origin of life are questions which are too difficult even for scientists to answer.

The TT college third formers were unanimous in preferring modern scientific ideas and believe that Maori and Pacific Island cultures simply have to accept what science has to say about the world. MI, a Pacific Islander, has family members who still adhere to traditional beliefs and superstition, nevertheless feels that western education and school science need pose no problems for Pacific Island students. He accepted that other Pacific Island students may have some problems and cited the case of his aunt who holds strongly felt cultural traditional beliefs and who is unable to accept scientific ideas. TA is Christian and stated an acceptance of the creation of the universe by god. She has some acceptance of evolution, but is puzzled by such questions as *What was the first organism and how did it come to be?*

Some of the non-Christian students believe that there may be a problem for Christians when they encounter teachings which conflict with the teachings of the bible. The most obvious example is the tension between literal belief in the creation myth and the theory of evolution as taught in science classes. For example, for OW, a Samoan Pacific Islander brought up with Samoan traditions and legends, theories about the formation of rocks and the 'big bang' event run contrary to Samoan cultural beliefs. He indicated that he no longer has time for the traditional beliefs of his culture. He stated that a choice of beliefs may be a bad thing and may leave students confused about what to finally believe in.

7.4 Summary of Findings of Chapter Seven

[The complete set of findings of this thesis is presented in Appendix 8.1]

(i) From section 7.2.1, which examined students' feelings towards science, it was found that teachers perceived Maori and Pacific Island students as having less positive feelings towards science than other students.

Finding 16

The teachers generally perceived that Maori and Pacific Island students hold less positive feelings towards science than others.

(ii) In section 7.2.2 it was found that teachers generally found teaching Maori and Pacific Island students rewarding.

Finding 17

The teachers found teaching Maori and Pacific Island students rewarding, but felt that motivating them can present particular difficulties.

(iii) In section 7.2.3, which examined the importance of science to Maori and Pacific Island students, it was found that teachers perceived science as of equal importance to these students as to others.

Finding 18

The teachers believed that Maori and Pacific Island students generally perceive science as having little relevance to their everyday lives or to their futures.

(iv) From section 7.2.4, which examined reasons why Maori and Pacific Island students relinquish science studies earlier than others, it was found that teachers perceived that Maori and Pacific Island students give up science studies earlier than others because they see it as irrelevant and because they receive no peer encouragement in science.

Finding 19

The teachers believed that Maori and Pacific Island students often relinquish their science studies earlier than others because they do not see science as relevant to their needs and because they are not encouraged to pursue science by their peers.

(v) In section 7.2.5 it was found that the teachers generally saw science as a human activity embodying methods and processes.

Finding 20

The teachers usually held mature views of the nature of science and typically saw science as man's active attempt to study and understand the natural world, with various methods and research processes integral to it.

(vi) Section 7.2.6 discussed teachers' opinions of the appropriateness of science curricula for Maori and Pacific Island students. The teachers generally felt that the

present junior science curriculum is not entirely appropriate for Maori and Pacific Island students and some disagreed with the notion that students build sophisticated concepts upon prior concepts.

Finding 21

The teachers generally viewed the present science curriculum as well intentioned but not the best adapted for the needs of Maori and Pacific Islanders.

Finding 22

The teachers generally believed that, contrary to the constructivist ideal, many students do not hold prior conceptions about scientific phenomena which can later be built upon. Rather, the first concepts are initially acquired at school.

(vii) In section 7.2.7 it was found that teachers were divided about the merit of including Maori and Pacific Island science in science curricula. However, they believed that Maori and Pacific Island role models in science should be promoted.

Finding 23

The teachers were divided about whether more Maori and Pacific Island themes should be introduced.

Finding 24

All of the teachers believed that a useful purpose would be served if Maori and Pacific Island scientists were promoted as role models.

(viii) In section 7.2.8 it was found that teachers did not believe that students' religious or cultural beliefs cause significant conflict with their science studies.

Finding 25

The teachers did not believe that dislocations between cultural beliefs, values and norms, and tenets of modern science present significant conflictual difficulties for Maori and Pacific Island students.

Finding 26

The teachers believed that the traditional (pseudo-traditional) origin of Maori and Pacific Island students does not present significant conflictual problems of integration into the education system because most such students come from westernised families. Rather, the problems are attitudinal.

(ix) In section 7.3.1 it was found that the students interviewed were generally positive about their science studies and were usually more enthusiastic about practical and experimental work than written work.

Finding 27

The students interviewed were generally positive about their enjoyment of science and indicated a greater enjoyment of practical work than written work.

(x) In section 7.3.2 it was found that students generally believed that their teachers would find teaching them rewarding. It was also found that students were aware of their own behavioural shortcomings and that students perceive that the mood of the class depends heavily on the personality and mood of the teacher.

Finding 28

Students interviewed were aware of, and frequently open about, their own imperfect behaviour in class.

Finding 29

The students interviewed perceived that class reactions to their learning environment depend heavily on the teacher and vary sensitively according to the ‘mood of the moment’.

(xi) In section 7.3.3 it was found that students held varying views as to the importance of science to their lives. Some held strong opinions as to possible future careers and some were aware that science might play a part in their careers.

Finding 30

Many of the students interviewed had strongly held views as to possible future careers and some were aware of the importance of science to some professions.

(xii) In section 7.3.4 it was found that the students interviewed generally believed that Maori and Pacific Island students relinquish science studies earlier than others because they lack the required discipline to achieve in science and because their cultures do not value science.

Finding 31

Many of the students interviewed expressed the opinion that Maori and Pacific Island students do not continue with senior science studies because they lack the discipline required to achieve in science, that their cultures and their families do not foster a strong respect for science, and because science becomes difficult at the higher levels.

(xiii) In section 7.3.5, which discussed student definitions of science, it was found that students thought of science both as a human activity and in terms of the subject matter addressed in science curricula.

Finding 32

The students interviewed gave definitions of science encompassing both the notions of a human activity and the scope of subject matter and issues addressed.

(xiv) In section 7.3.6 it was found that the majority of Maori, Pacific Island and other students interviewed believed that current science curricula are generally appropriate but could be made more interesting.

Finding 33

The majority of students interviewed believed that present curricula are appropriate but could be made more interesting.

(xv) In section 7.3.7 it was found that students were generally enthusiastic about the idea of incorporating a greater Maori and Pacific Island science content in junior science curricula.

Finding 34

The students interviewed generally felt that the inclusion of Maori and Pacific Island science topics in junior secondary science curricula is desirable both as general interest and as a way of learning about other cultures.

(xvi) In section 7.3.8 it was found that the Maori, Pacific Island and other students interviewed did not hold religious or cultural beliefs which pose difficulties in science education.

Finding 35

For the majority of students interviewed, cultural or religious beliefs do not pose conflictual problems with their education in science.

7.5 Conclusions on Teacher and Student Interviews

Interviews with teachers and students were designed to:

1. Investigate the cultural beliefs which characterise those groups and which create preconditioned attitudes which mitigate against success in high school science.
2. Investigate the relationship (if any) between the holding of strong traditional cultural beliefs and the fostering of negative attitudes towards education generally, and science education in particular.
3. Investigate the development of students' scientific conceptions and attitudes towards science from a perspective based on constructivist theory.

The interviews were carried out on a small subsection of the ethnic minority student population and a small subset of the teachers who teach them. The small size of the samples concerned made it impossible to discriminate between responses from different form levels, schools, genders or ethnicities. However, the interviews were nevertheless successful in allowing the researcher to appraise the significance of cultural beliefs in giving rise to conflictual problems for students.

It was found that, for the students interviewed, such cultural values, beliefs and norms do not generally give rise to conflicting problems in respect to scientific teachings. Further, the constructivist approach to the interviews adopted enabled the researcher to focus his classroom observations on the relationship between students' cultural backgrounds, prior knowledge and attitudes towards science. The interviews generated sufficient feedback from both teachers and students to underpin the development of recommendations for enhancement of curricula and teaching practice. These recommendations are discussed in Chapter Eight.

CHAPTER EIGHT

Significant knowledge of any social situation consists of an awareness of the emerging meanings that participants are developing, and the specific ways that these meanings are functioning to shape their endeavours and thus the characteristics of the situation itself. (Bolster, 1983, p. 303)

DISCUSSION OF RESEARCH FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

8.1 Discussion of the Research Findings

8.1.1 Introduction

In this research study, quantitative and qualitative research approaches were adopted in order to shed light on the experiences of Maori and Pacific Island students in secondary-level science. The adoption of multiple research methodologies was intended to achieve complementarity in research findings and corroboration of those findings through triangulation.

In the following sections, a summary of the findings accruing from each of the research methodologies is presented. Some of the research findings of this thesis relate solely to the ethnic minority groups of the study – Maori and Pacific Islanders. Others relate to the entire student cohort which participated in the study. Those relating solely to the ethnic minority students directly inform educationalists and policy-makers about those students. Findings relating to the wider student body help to establish the broad context in which ethnic minority students carry out their learning activities, and provide useful information about non-ethnic minority students.

8.1.2 The Key Findings of the Study

The 35 findings of Chapters Five, Six and Seven are summarised in Appendix 8.1. They cover a wide range of issues pertaining to the science education of Maori and Pacific Island students. This suite of findings will be used to underpin the development of a set of recommendations for enhancement of science education outcomes for Maori and Pacific Island students. These recommendations are discussed in section 8.2.

The key findings from those of Chapters Five, Six and Seven, of particular interest to educators and policy-makers, are given in this section (it is accepted that findings relating to student achievement may be due to the type of achievement measure used).

8.1.2.1 Key Findings of the TOSRA Survey

- Maori and Pacific Island students returned slightly more positive attitudes towards science than others.
- Female students returned slightly more positive attitudes towards science than males.
- No decline in interest in science with increasing form level was found.
- Students from coeducational schools held slightly more positive attitudes towards science than those from single-sex schools.
- No association between student attitudes towards science and achievement in science was found.

8.1.2.2 Key Findings of the CLES Survey

- Maori and Pacific Island students returned slightly more positive perceptions of their constructivist learning environments than others.
- Perceptions of constructivist learning environments became slightly more positive at form 4 and declined again at form 5.
- Males and females held equally positive overall perceptions of their constructivist learning environments, though there were differences in particular aspects of their perceptions.

- Students from single-sex schools held slightly more positive perceptions of their constructivist learning environments than those from coeducational schools.
- No associations between student perceptions of their constructivist learning environments and achievements in science were found.
- No associations between student perceptions of their constructivist learning environments and attitudes towards science were found.

8.1.2.3 *Key Findings of Interviews with Teachers*

- The teachers perceived Maori and Pacific Island students as generally experiencing less positive feelings about science than others.
- The teachers believed that science is of importance to Maori, Pacific Island students in relation to academic and professional advancement, but that these students rarely realise this fact.
- The teachers believed that ethnic minority students drop out of advanced science courses because they do not regard science as relevant to their lives or needs.
- The teachers believed that the present curriculum is not ideally adapted for Maori or Pacific Island students.
- Few teachers believed that Maori and Pacific Island themes should be introduced.
- The teachers believed that Maori and Pacific Island scientists should be promoted as role models.

8.1.2.4 *Key Findings of the Interviews with Students*

- The ethnic minority students interviewed generally viewed science as having little relevance or importance to their lives.
- The ethnic minority students interviewed generally believed that other ethnic minority students drop out of science because it has little relevance, is intellectually demanding and carries unfavourable perceptions with others.
- The students interviewed generally believed that Maori and Pacific Island science should be taught at school.

8.2 Recommendations

Changes need to be made in all areas of education, both within the current mainstream education system and in the continuing development of Maori education initiatives, and at all levels from early childhood to tertiary.
(Waiti, 1995, p. 8)

In this section, a set of recommendations for enhancing the quality and uptake of science education for Maori and Pacific Island students is developed and justified. Rationales for each recommendation are discussed in terms of theoretical perspectives (generic rationales) and in terms of the findings of this study (specific rationales). It is conceded that these recommendations are developed on the basis of findings of a study of a small subset of the ethnic student populations concerned, and it is assumed that these findings can be proposed and extrapolated credibly for the wider ethnic student populations. These recommendations have been developed with the explicit intention of assisting ethnic minority students to achieve in modern science education. It is accepted that this approach may not be fully acceptable to all Māori and other ethnic minorities who may view the approach adopted as reinforcing the dominance of 'western science' and failing to recognise pervasive influences such as mono-cultural classroom environments, culturally-biased teacher expectations and biased curriculum, and instead prefer to assume autonomy in educational choice. However, the recommendations of this thesis are predicated on the author's strongly held view that students of all backgrounds and ethnicities deserve the opportunity to participate in science which is 'owned' by all people and which does not recognise either nationality or ethnicity. Indeed, the author contends that failure to encourage all students to have access to modern science education may severely disadvantage those concerned educationally and economically, as well as denying them an experience of great social importance. All recommendations arising from this study are summarised in Appendix 8.2.

Recommendation 1

Continue to group Maori and Pacific Island students with others.

Generic Rationale

In Chapter One the term '*pseudo-traditional*' was used to describe present day urban Maori and Pacific Islanders, embodying the notions that traditional norms, values and beliefs retain a profound, if not dominant, role in their societies, but that western society has also exerted a profound influence on their thinking and lifestyles. Although Thaman (1992, 1993) argued that exposure to the educational norms and values of a culture alien to the learner will inevitably result in teaching and learning difficulties the prime cause of which Serpell (1993) believes to be dislocation between the goals of the curriculum and the cultural goals of the group to which learners belong, nevertheless ethnic minorities will always be faced with the problem of integration with the greater society. Ethnic minorities must mix together and with others successfully, just as others must learn tolerance and accept difference. This should begin at an early age so that children grow, develop together, and share their lives without prejudice or misunderstanding.

Changes need to be made in terms of the expectations of both Maori and non-Maori in the participation and achievement of Maori in science, mathematics and technology, and an holistic and strategic approach is required. (Waiti, 1995, p. 8)

Changes in expectations of Maori and Pacific Islanders regarding achievement in science and any other educational endeavour can only come about through active participation. These ends cannot be brought about through segregation.

Specific Rationale

Contrary to the findings of previous studies, and despite the articulations of several ethnic minority students during interviews about the low relevance of science to their lives, the slightly more positive measures of attitudes towards science (Finding 1) and perceptions of constructivist learning environments than others (Finding 9) returned by Maori and Pacific Island students during the surveys suggest that these groups may not react greatly differently from others in science class, despite historic thinking to the contrary.

As a result of their different backgrounds, we were told, Maori children will react very differently to certain situations than Pakeha children, and teachers have to know how to handle it. (Mutu, 1995, p. 55)

Like others, their attitudes towards science did not change greatly with increasing form level, there was no decline in attitudes (see Finding 3), and differences in perceptions of their constructivist learning environments between these ethnic groups and with others were not great (Finding 10). Further, the study suggested that neither cultural nor religious beliefs, nor the traditional origin of Maori and Pacific Island cultures, create undue conflictual problems for Maori and Pacific Island students (Findings 25, 26 & 35). These findings suggest that the reasons for the educational under-performance of these groups may lie elsewhere, perhaps in their attitudes towards achievement, a suggestion made by several student interviewees (Finding 31). In this regard, the study suggested that student attitudes towards science or perceptions of constructivist learning environments and their achievement in science may not be associated (Finding 8). Thus, it may be incorrect to blame the immediate school environment as the main determinant of educational failure for these groups.

Further, the study provided no clear justification for segregating males and females. Previous studies showed that gender differences appear to play a significant role in shaping attitudinal differences towards education between ethnic groups (Straub, 1987; Taub & McEwan, 1991), but in the present study females returned slightly more positive measures of attitudes towards science than males (Finding 4) and nearly equivalent perceptions of constructivist learning environments to males (Finding 12). Further, students of coeducational schools returned more positive attitudes towards science than those from single-sex schools (Finding 7). If the attitudes and perceptions displayed by females and ethnic minorities had been found greatly more negative than for others, and if a causal connection between negative student attitudes and perceptions and scholastic achievement had been established, this might have provided support for segregated education. However, these were not found.

Recommendation 2

Find and develop ways of making classroom environments more sharing and cooperative.

Generic Rationale

Formerly, in curriculum development little account was taken of the experiential world of children (Young, 1973). Today, the constructivist view of curriculum development recognises both the pre-school and out-of-school dispositions (Driver & Oldham, 1985; Bell, 1990). Additionally, little account was taken of the differences in psychosocial needs of children which largely relate to their out of school lives. Thus, whereas western society values competition and achievement, this is not necessarily true for many indigenous peoples and ethnic minority groups. For example, Pacific Island culture encourages sameness and frowns upon individualism and western notions of success (John Fiso, pers comm.), and Maori culture values behaviours which are principally directed towards the common good (Patterson, 1998).

Jegede and Fraser (1989) reported a correlation between socio-cultural factors and attitudes towards science and they proposed the idea that the less positive attitudes which generally characterise students of non-western backgrounds, contrary to the findings of the present study, may result from an inhibitory consequence of those socio-cultural factors. Wilson (1981) suggested that negative attitudes towards science may derive from the alienating nature of school science. Additionally, Ford (1983) has reported that, for ethnic minority students, allegiance to the goals and preferences of the group may be viewed as more important to the student than individualised thinking. These findings underscore the great importance of establishing supportive environments for ethnic minority students.

Further, Hewson (1986) argued that western science curricula do not encourage students in traditional societies to think scientifically in the contexts of their own cultures. Copying of western competitive educational paradigms in non-western countries was noted by Cole (1975), who suggested that in traditional societies science was not being taught for the purposes of gaining knowledge and skills, but in order to prepare students for public examinations. However, many of the tenets of

western education are alien to the thinking of ethnic minorities such as Pacific Islanders, including gradation of schooling, projection of grading into child development, the stigmatisation of the unschooled, condescension in teacher-pupil relationships, and the concept of educational expertise (Thaman, 1995).

Classroom environments must be able to accommodate the kinds of differences in thought style between traditional, 'pseudo-traditional' (people deriving from traditional cultures but who have adopted western values and life-styles through exposure to western culture) and western people. For traditional societies education is conducted through participation rather than the western approach of skills training. For traditional societies, the emphasis is placed on cooperation - the 'We' rather than the western 'I', and for traditional societies traditional techniques assume the importance which the 'search for new solutions' has in western thinking. Additionally, notions such as the anthropocentric view of the universe (see Chapter Three, section 3.2.3), quantification and demystification of the world, faith in the progress of science and the analytic ideal (Smoliez and Nunan, 1975), though seminal to the scientific method, run counter to the holistic spiritual and reverential view of the universe held by Maori and Pacific Island cultures in which nature is not to be divided into parts for the sake of analysis, but is treasured as a giver of life.

Secondary education could account for psychosocial differences in minority students better than at present by de-emphasising competition and promoting cooperative approaches to learning which countervail the alienating nature of science (Holmes, 1977; Wilson, 1981). To this end, group learning and a reduced emphasis on assessment (see Recommendation 4) could be promoted at the junior levels. Later, at the senior secondary levels, greater self-reliance could be encouraged among students, and greater emphasis placed on individual assessment.

Specific Rationale

The problem of alienation in the school and classroom may be addressed partly by establishing classroom environments in which the emotional and psychosocial needs of young people, particularly those from groups experiencing a high degree of social stress, are met successfully. The great importance of the classroom environment was

underscored in the observations made by several student interviewees that student reactions to their constructivist learning environments depend heavily on the teacher and vary with the 'mood of the moment' (Finding 29). Emphasis should be placed in teacher training on the great importance of establishing cooperative and friendly classroom environments. Although the study showed no association between perceptions of constructivist learning environments and achievement (Finding 14), it is possible that this has resulted from the research method used and further research into this association is required.

Recommendation 3

Promote technology education as a core subject equivalent in status to the core sciences.

Generic Rationale

Today's world is a technological knowledge-based one. Familiarity and ease with technology is a prerequisite for all. This includes ethnic minorities who, in addition to wishing to retain the essential features which characterise their native cultures, also must integrate successfully into the greater global culture. The need for integration applies even to the primary and secondary school levels, although the assimilation of ethnic minority groups into the predominant culture may sometimes be viewed as an unwanted necessity by ethnic minority students (Ford, 1983).

Effective technology education as a planned process designed to develop students' competence and confidence in understanding and using existing technologies is therefore vital as a guide to the intellectual and practical development of students as individuals and as informed members of a technological society. Biotechnology, electronics, food technology, information and communication technology, materials technology, production and process technology are central and topical components of present day global technological trends with which people need to become

familiar. Understanding today's emergent technology may also enable students to see the relevance in their science studies more clearly. In tandem, through technology education, ethnic minority students will have many opportunities to perceive clearly the value of education as a means to achieving economic success (Emina, 1983).

. . . in ten years time, 72% of the fishing resource will be in the hands of Maori, and a lot of the resource rental we are paid is paid for scientific management of that resource. If it belongs to us but we are not part of the management or maintenance of that resource, then we really have no control over it. (Tamahori, 1995, p. 11)

Clearly, management and control of their resources by ethnic minorities can only be truly effective if their people possess the necessary skills and knowledge.

Specific Rationale

In attempting to devise a scientific education for young people, attention must be paid to feedback provided by them on aspects of science which they find interesting and enjoyable, and those which they find less so. Note should be taken of their greater enjoyment of practical work than written work, repeatedly expressed by students in interviews (Finding 27), consistent with student expectations of science as activity-based (Finding 32). Further, if ethnic minority students discontinue science studies because of attitudinal factors (Finding 31) and perceptions that science holds little relevance to their lives (Finding 19), it is reasonable to address this by finding ways of making science more enjoyable and relevant. Placing greater emphasis on practical work and technology education than at present may help to address both student enjoyment and relevance to their future professional lives (Finding 33) by providing greater opportunity for hands-on, practical experience and by encouraging students to engage in activities the relevance of which is clearer to them.

Recommendation 4

Reduce emphasis on examinations and competition and retain a strong component of internal assessment.

Generic Rationale

Forbes (1995) believes that there is no justification for insisting that the written examination in mathematics is the most appropriate for any student, and argued that a large number of different types of assessment methods should be used. In a study of student performance in the New Zealand national examinations, she found that, on average, girls tend to achieve lower positions in class in examinations by comparison with project work, and boys tend to achieve higher positions. Forbes found this to be true for both Maori and non-Maori, and it seems probable that these findings apply for science studies as well as for mathematics. She advocates a mix of many different assessment approaches which should be used as diagnostic tools to inform the student and teacher about learning rather than to sort and stream students.

The present New Zealand science curriculum embodies a Science for All approach, for those students whose learning in science will cease when they leave school, as well as for those who will later choose a science-related career.

Quality science education for all students requires the removal of barriers to achievement and encourages continuing participation in science. Accordingly, the curriculum in science should recognise, respect, and respond to the educational needs, experiences, achievements, and perspectives of all students: both female and male; of all races and ethnic groups; and of differing abilities and disabilities. (Science in the New Zealand Curriculum, 1993, p. 11)

Clearly, any mode of assessment should not of itself pose insurmountable barriers or unduly disadvantage certain students over others. However, assessment is a part of the ongoing suite of educational routines which diverts attention from the substantive meaning of academic work to procedures, schedules and products (Doyle, 1986). Thus, the need to assign grades focuses teachers' attention on product standards and completion deadlines rather than on the intellectual content of the work.

Fensham (1985), in discussing the desirable qualities in a Science for All approach to teaching and learning, stressed that learning should embody achievement objectives and criteria within the capabilities of the majority of learners while allowing for different levels of achievement. The related constructivist perspective is that appraisal of learning and methods used for assessment of learning should take into

account the prior beliefs and experiences of learners. Thus, a constructivist science education should account for socio-cultural differences between students. Account should be taken of the great cultural importance of cooperation in Maori and Pacific Island cultures and the problems faced by these students in an isolating, competitive environment. Students, particularly ethnic minority students, should be led into a discovery-based approach to science learning in which cooperation is emphasised over individualism, thus addressing not only alienation, but also preparing students for the cooperation which will later be required in the workplace.

This cooperative approach should also be reflected in the assessment process, wherever possible, without significantly reducing the ability of teachers to appraise the learning of individuals. Examinations, which have an important place as a mechanism for encouraging effective learning as well as in appraisal, should be retained but de-emphasised in favour of internal assessment at the junior secondary levels. Group projects should be promoted as models of how people should harmonise in the workplace.

Specific Rationale

Curriculum designers and designers of assessment processes should note students' expressed enjoyment of practical work rather than written work (Finding 27) and the expectations they hold of science as activity-oriented (Finding 32). These factors suggest the development of assessment criteria which also focus on practical work and experimentation, group projects and internal assessment rather than solely on written examinations which, nevertheless, should still play a significant role in focussing learning and in assessment.

Recommendation 5

Give prominence in curriculum design to the constructivist paradigm of conceptual change which recognises the role of prior conceptions which must be built upon and developed during the course of the learning experience.

Generic Rationale

In discussing Science for All, Fensham (1985) argued that curriculum content should be chosen which has demonstrable personal and social relevance to learners and considers students' prior conceptions and experiences as a starting referent. Driver and Oldham (1985) also recognised the importance of building upon prior conceptions and argued that humans construct knowledge through social interactions and experience with the physical environment, that knowledge and beliefs of individuals influence constructed meaning, that constructing meaning is an active process, and that the learning of scientific ideas involves conceptual change.

For Driver and Oldham, and for Wittrock (1974), the curriculum is the total set of learning experiences which enables the learner to develop understanding. Hodson (1986) advised science teachers and curriculum designers to take account of students' existing conceptual frameworks and he suggested a discovery learning approach. Wittrock (1974) indicated the importance of meaning as constructed by individuals in attempting to make sense of their world and argued that learning is dependent on the prior beliefs, experiences and emotions of the learner.

For ethnic minority students who encounter novel and abstract ideas in school science which may conflict with their prior conceptions and beliefs, the work of Fensham, Driver and Oldham, Hodson, and Wittrock has special relevance in recognising those differences in thinking which relate to the different cultural backgrounds of these students, and in encouraging progressive development of scientific ideas of increasing sophistication. If it is accepted that learners build upon prior beliefs and experiences, constructivist curriculum frameworks should be developed so that the needs of students can be met.

Specific Rationale

Curriculum design must be predicated on some well-grounded conceptual framework which provides defensible rationalisations for student learning activities and which accounts for the real needs of students at different levels. Despite the beliefs of several teachers that students frequently do not hold prior conceptions about scientific phenomena which can later be built upon (Finding 22), constructivism

observes the self-evident reality that maturity of thinking arrives with experience. This was partly corroborated in the definitions of 'science' provided by students (Finding 32), which, not unexpectedly, were clearly less mature and less well-articulated than those provided by teachers (Finding 20).

Recommendation 6

Introduce carefully chosen examples of credible Maori and Pacific Island traditional science such as medicine, navigation, food and food preparation, and hygiene in order to underscore the importance of indigenous science to ethnic minority students and add cultural interest to the curriculum.

Generic Rationale

Ogunniyi (1986) suggested that, for many African countries, science curricula should include topics such as mechanised farming, disease control, the production of food and the provision of drinking water. Vielfaure (1980), working with rural students in Zambia adopted an approach which involved leading students to elicit the scientific principles which underlie many of the traditional activities of their cultures, including traditional home-building, medicine and bellow-making. Knamiller (1983), working with rural students in Ghana developed issue-based topics of immediate relevance and usefulness to rural communities there. These include agricultural topics and topics relating to crop pests and small industries.

Kelly (1980) has suggested an issue-based approach to curriculum design, the objective of which is to make school science more congruent with community needs. However, it has become increasingly accepted that science education must accommodate the cultural context and those whose needs it exists to serve (Maddock, 1981). Thus, Seng (1979) believed that science and technology education should be compatible with cultural heritage, that curricula must be compatible with the cultural environment and that teaching and learning practice should harmonise with cultural concepts and values. Further, Knamiller (1984) has underscored the potential of indigenous technologies in developing science curriculum content; and so it must for non-western students and ethnic minorities. For these students, topics for learning

should be chosen so as to be relevant and meaningful to learners so that the acquisition of cognitive and practical skills should develop naturally from them (Fensham, 1985). The introduction of credible examples of indigenous science would encourage respect for the learning of non-western societies and may help ethnic minority students to feel less alienated in the science classroom. Munn (1995) has given examples which demonstrate that Maori had access to sophisticated and credible scientific knowledge. These included Maori circumnavigation of the Pacific, cultivation of at least 72 species of plants, and the use of many plants for healing.

Traditional science has a category of its own, its own context and functions, but it is not helpful for Maori to argue that it is scientific by the Western definition of science. (Howe, 1995, p. 63)

Dart and Pradham (1967) reported that schoolchildren from traditional cultures often describe the natural world in two types of explanation - mythological and scientific. Gilbert, Watts and Osborne (1985) have also discussed the possibility that students may have different kinds of knowledge of the same topic. Perhaps, it is possible, and even desirable, for students to hold differing conceptions about the world which might include the purely scientific and rational, as well as ethnocentric conceptions which are partly based on survival science and closely intertwined with cultural values and norms. Perhaps, different conceptions are, in fact, related. For example, in Maori culture each individual has a responsibility to respect and care for the natural world (*kaikitanga*). Central to this concept is the recognition that members of the present generation have responsibilities which were passed on to them by preceding generations to care for nature and to oversee and sustain a balance between human need and resources. This concept has a counterpart in western science where it is known as 'environmental sustainability'.

Such approaches as those of Vielfaure, Knamiller and Kelly could be adapted to develop or modify curricula for New Zealand students with particular needs such as rural students and those from ethnic minority backgrounds. However, the need to accommodate a student population from diverse ethnic backgrounds poses difficulties which may result in bland curricula. In discussing ethnic heterogeneity in the United States in the early twentieth century, Waller (1938) observed that cultural

heterogeneity exerted a conservative influence on the curriculum, because agreement could frequently only be reached on mundane points.

Science education needs to make science more accessible to Maori students. It must make use of teaching strategies which are effective with Maori students and must be responsive to the diversity of their cultural and language backgrounds. Acknowledging Tikanga Maori, and valuing the use of Maori language and the experiences of Maori students, affirms their identity and creates a positive learning environment.

(Science in the New Zealand Curriculum, 1993, p. 12)

Driver and Oldham (1985) developed a constructivist science curriculum model predicated on constructivist views on content, consideration of pupils' prior understanding and experiences in each topic, constructivist views on the learning process, and knowledge of teachers' knowledge and experiences of learning. This model was adapted specifically for the traditional students of Sierra Leone by Baimba (1991). An appropriate modification of the Driver and Oldham science curriculum model, similar to that of Baimba, by focusing on issues which relate closely to students' ethnic cultures, has considerable potential to enhance science educational outcomes for New Zealand ethnic minorities and could be trialed at the secondary level.

Maori and Pacific Island students derive from traditional cultures whose values are very different to western values and which are founded strongly on the importance of the extended family (the Aiga), love of nature, the importance of love and respect for each other, and Christianity. These cultures retain a residual, though declining, belief in spiritualism, ghosts, myths and legends. A fundamental part of many ethnic minority cultures is their traditional 'science', which frequently comprises learning about herbal medicine, navigation, foods and their preparation, hygiene etc. This was termed by one student interviewee 'the science of survival'.

To seek only a traditional interpretation would be to deny the impact of time, while to disregard the importance of traditional culture in favour of widespread western concepts would be to deny the reality in which Maori people live. (Baker, 1995, p. 82)

Western views of what is worthwhile in science education have never given much credence to ethnic or traditional science. Indeed, Hodson (1986) has argued that science is not completely value-free and Mead (1995) has stated that the scientific community is intimidating to Maori because it does not respect traditional views. It is probably true that professional scientists do not greatly esteem indigenous science. However, their viewpoint fails to recognise that the motives for indigenous science and modern western science are very different. Whereas western science is concerned with objective truths, indigenous science is frequently concerned with matters relating to group survival, and comprises a lore of knowledge about what is safe to eat, how to survive in the wild and ways of using nature's resources. In achieving the aim of fitting in people for survival in their environment, indigenous science has perhaps demonstrated great intrinsic worth.

Kirkwood (1988) described five kinds of science knowledge: *Scientists' Science*, in which meaning is agreed by professional scientists; *Curriculum Science*, which includes aspects of scientists' science; *Teachers' Science*, or teachers' versions of curriculum science; *Childrens' Science*, which consists of conceptualisations made by children, and *Students' Science*, or the fusion of teachers' science and childrens' science. Perhaps, to these could be added a sixth kind of scientific knowledge: *Indigenous Science*, or the science of survival as evolved by indigenous societies, and which could have a place in junior science education.

Emphasising the difference between Maori science and Western science overlooks the extensive common ground. (Durie, 1995, p. 12)

Similarly, many other branches of indigenous science have direct counterparts in western science.

Specific Rationale

Although several of the participant teachers felt that there would be little value in incorporating examples of ethnic science into science curricula (Finding 23), it is interesting that the students interviewed were nearly unanimous in believing this to be a worthwhile step (Finding 34). Certainly, most of the teachers interviewed felt that the present curricula are not ideal for Maori and Pacific Islanders and that some

improvement is necessary (Finding 21). The present New Zealand Science Curriculum Framework (1993) recognises the value of indigenous knowledge.

Students will develop their understanding of the changing nature of science, and the values and assumptions on which it rests. They will recognise the contribution that different perspectives make to the evolution of understanding in science. In New Zealand, the curriculum will recognise Maori and Pacific Islands knowledge about the natural and physical worlds.
(NZ Curriculum Framework, 1993, p. 12).

However, the present study suggested that current recognition of the knowledge of non-western people, and the current availability of non-core science topics, may guarantee failure to convince students of the relevance of science to their daily lives and to their futures. Incorporating more examples of indigenous science and developing associated practical work would be consistent with students' professed enjoyment of practical work (Finding 27) and with student expectations of science as a human activity (Finding 32). Further, an indigenous science curriculum component may help to address discontinuation of senior science studies by ethnic minorities because of a lack of respect for 'western' science (Finding 31) by encouraging the survival of traditional knowledge of which they have direct ownership.

Recommendation 7

Retain the core sciences, physics, chemistry and biology, in the curriculum for all students during the first three years of secondary school.

Generic Rationale

This study concerns the attitudes and perceptions of ethnic minorities in the course of their science education. Many of the conclusions reached and recommendations made concern approaches to enhancing outcomes for these students through carefully designed curricula, enhanced teacher education, and research into student learning and the world views of ethnic minority students. Hyde (1994) has articulated the fear that encouraging Maori perspectives in science education could relegate Maori students to a scientific ghetto by discouraging critical thinking and encouraging the use of ideas that cannot be accepted scientifically. However, such imperatives need

not degrade the quality of the science education that students receive. Degrading of the purely scientific content can be avoided by retaining current emphasis and standards in the core science curricula. Science is part of an international culture which is not and should not be captured or owned by any culture or ethnic group, and should remain independent of notions of culture and ethnicity, grounded firmly in notions of truth and truth-seeking. This independence from culture should hold as true for junior and secondary level science as for professional science. Thus, all students, regardless of background, should be introduced to fundamental scientific learning in addition to interest-driven scientific learning and ethnic science, both as part of their overall education, and in order to serve as a platform for further scientific studies which for some will lead ultimately to careers involving science.

Hodson (1985) believed that science provides factual truths about the world through detached observation, that scientific knowledge flows directly from observation of nature, that scientific hypotheses are tested through reliable empirical methods, and that science is unaffected by socio-historic and economic factors. Popper (1959) believed that science derives from theories or propositions which scientists construct in order to understand nature, rather than from passive observations. He contended that the seminal feature of scientific method is that it should seek to falsify hypotheses and conjectures about the natural world, and not merely to validate theories by citing particular instances which happen to accord with those theories. These goals and objectives of science hold for all people in all cultures.

Hodson (1986) argued that techniques of scientific observation have to be learned, without which intellectual scientific rigour will never be acquired. It can also be argued that a fundamental motive for education is to nurture competence. In discussing the development of competence, Chickering (1969) used the analogy of a three-tined pitchfork in which the tines denote intellectual competence, physical and manual skills, and social and interpersonal competence. A central part of academic competence which should be imparted at the secondary level are the competencies of detached observation, considered deduction, and the articulation of those deductions. These competencies are basic to scientific method and must therefore be passed on to students regardless of background. Failure to encourage students to acquire a solid

scientific foundation at the secondary level puts at risk the necessary competencies which many, if not all, students will need in later life.

Specific Rationale

In the present study, Maori and Pacific Island students displayed more positive attitudes towards science and perceptions of their constructivist learning environments than others. Therefore, it may be deduced that, though it is worthwhile to look for ways of making science lessons and curriculum content more interesting for students, the kind of subject matter taught and learned is not the sole determinant of the low academic achievement of these groups. Though teachers viewed the present science curriculum as not ideal for the needs of Maori and Pacific Islanders (Finding 21), and student interviewees believed that present curricula could be more interesting (Finding 33), both teachers and some students (generally not Maori or Pacific Islanders) believed that science has relevance for students' futures. This must be accommodated early in the educative process and requires that, in addition to general interest topics, concepts in the core sciences must be acquired effectively at the junior levels.

Recommendation 8

Include other non-core sciences in the curriculum such as earth science, environmental science, astronomy etc, both to stimulate general interest, and to broaden students' scientific perspectives.

Generic Rationale

Posner (1982) has argued that the constructivist view on learning has great relevance to curriculum design. In this paradigm, the curriculum is viewed as the set of learning experiences which enable learners to develop understanding (Driver & Oldham, 1985). Fensham (1986) believed that the best approach is one which focuses 'about and from science', particularly for those who are non-scientists, and that inductive elitist science education is appropriate only for the upper levels of schooling. Instead, Fensham argued, Science for All should promote everyday topics easily recognised by students. These, he argued, should include topics such as measurement, the human

body, health, nutrition, sanitation, food, population, pollution and energy. Thus, junior science education for ethnic minorities and others might advantageously be pitched more broadly than on the core sciences alone if the enthusiasm of students is awakened by their new learning. Munby and Russell (1987) believe that this approach will inevitably de-emphasise the intellectual component of science, but this should not occur if due attention is paid to the core sciences.

Specific Rationale

In designing future science curricula, account must be taken, not only of the requirement to promote science as a discipline, but also of the need to promote science as an adventure of great excitement. In the present study, teachers generally agreed that change is desirable (Finding 21) and students that, while largely appropriate, present curricula could be made more interesting (Finding 33). Several themes quoted by students as being of particular interest included the study of dinosaurs, astronomy, seismology and vulcanology. It seems reasonable to incorporate these topics, more effectively than at present, as catalysts of student interest and motivation. Inclusion of this material might perform a complementary function to the inclusion of indigenous science in stimulating the interest of students at the junior levels.

It is contended that a careful juxtaposition of core science, interest-driven science and ethnic science can be devised and implemented successfully at the junior levels of secondary school for all students, particularly for those schools with significant fractions of Maori and Pacific Islanders. This combination would serve the multiple purposes of providing students with the basic scientific knowledge and skills necessary for further progress in their science studies, the stimulation of students' interest in science, the fostering of ethnic minority students' sense of belonging in the world of science, as well as fostering general respect for the scientific learning of other cultures.

Recommendation 9

Establish school subjects such as agricultural science and home economics as valid and equal in importance to the mainstream sciences.

Generic Rationale

Chaplin (1964) noted that in many African countries the physical sciences had high status for the purposes of gaining entrance to universities, whereas subjects such as home economics, craft and agriculture have much lower status. In New Zealand, the core sciences similarly hold high status, perhaps because of the perception that tertiary science studies are critically dependent on the quality of education in the core sciences at the secondary level. The strong economic performance of several technologically advanced countries such as Japan, Sweden and the United States has indeed frequently been linked to their strong science base and their high ratios of professional scientists and technologists relative to other professions. However, in New Zealand the core sciences are currently failing to attract students generally, particularly ethnic minority students, at the senior secondary and tertiary levels (see section 1.1.2).

Eastman (1969) believed that an elitist academic image of science is promulgated through a school's curriculum through 'scientism', which he described as based on the notion of real, isolated entities, independent of human perception. However, scientism may fail to recognise the varied interests and motivations of students, and may also underplay the immense contributions which disciplines such as agriculture and technology have made for society.

Many students who give up on science were not given time and space to reflect on what the subject was really trying to do to people. What has happened is that the objective detail has gained prominence at the expense of the subjective feelings . . . Scientists and technologists need to understand that, without injecting humanity into the subject, they run the risk of turning off generations of scientists, technologists and mathematicians. (Howe, 1995, p. 62)

In fact, there are compelling economic reasons for raising the educational profile of subjects such as agriculture. The agriculture industry is an extremely valuable contributor to the economies of many countries, of which New Zealand is just one example. The horticulture export industry returned \$1,400 million to the New

Zealand economy in 1995, with an accompanying growth in employment from around 9,700 to around 37,300. The farming sector also contributes very significantly to the New Zealand economy, averaging 6% of Gross Domestic Product between 1992 and 1997 (FRST, 1998). Indeed, Johnson (1997) argued that increased agricultural and manufacturing productivity leads to the increased discretionary income which enables other sectors such as health, recreation and tourism to flourish, in addition to freeing up time for their consumption. A second economic sector underpinned by a strong science and technology base is the manufacturing sector, comprising more than 16,000 companies employing approximately 145,000 people, from which some 40% or more of New Zealand's exports now derive. Similar arguments could be advanced for other New Zealand economic sectors.

Clearly, there are compelling economic reasons for recognising the worth of sectors such as agriculture and manufacturing and raising the academic status of agricultural and technical education on a par with the basic sciences. In this way, a valuable secondary outcome may be achieved in addition to accommodating the diverse interests of students; viz. the fostering of the enthusiasm of new cohorts of students who will later as professional scientists and technologists carry out the underpinning research which will maintain the competitiveness of the New Zealand economy.

Specific Rationale

The present study suggested that many teachers view the present science curriculum as inadequate for the needs of Maori and Pacific Islanders (Finding 21) and that Maori and Pacific Island students often relinquish science studies earlier than others because they do not see science as relevant to their needs (Finding 19).

The early promotion of clearly vocation-oriented subject material may enable students to apprehend the importance of science and technology education, many of whom are aware of the potential importance of science to their careers (Finding 30), and that academic success in science may bring future professional rewards.

Recommendation 10

Vary the pedagogical styles used and incorporate as much practical work and group learning as possible.

Generic Rationale

Many New Zealand teachers are faced with the problem of capturing the interest and enthusiasm of ethnic minority students in science, a task which often poses greater challenges than for other students. Wilson (1981) believed that inquiry-based styles of teaching in which students may question teachers' assertions and test for truth are not necessarily appropriate for traditional societies. School science may then represent a system imposed on students who already have a belief system about the natural world. Fensham (1985), in articulating the desirable characteristics of the Science for All movement, argued that topics for study should always be in evidence so as to elucidate the component parts of learning and that teaching practice should utilise demonstration and practical themes as much as possible.

In addition to a varied curriculum, student interest, enthusiasm and educational outcomes may be served by introducing more varied tasks and teaching and learning styles. A varied pedagogical style which includes group learning and projects, as well as practical work which elucidates themes of relevance to students, must be achieved if the interest of ethnic minorities is to be captured. School science should attempt to instil wonder and reverence for nature, rather than solely to analyse and describe. Otherwise, for all students, but for ethnic minority students especially, science runs the risk of becoming an abstract academic exercise of little importance to their lives.

Specific Rationale

Students' belief that present curricula could be more interesting (Finding 33) may partly reflect the style of teaching they experience. A varied pedagogical style which includes practical and experimental work which students generally enjoy (Finding 27) may help teachers, whose approach is an important factor in students' feelings about their constructivist learning environments (Finding 29), to promote more positive learning environments.

Recommendation 11

Introduce ethnic minority role models in a credible and meaningful way.

Generic Rationale

Although few Maori or Pacific Islanders choose careers in science, nevertheless, there are some notable Maori and Pacific Islanders presently working as professional scientists in New Zealand (McKinnon, 1998, pers comm.). McKinnon is presently writing a doctoral thesis on Maori women in science in which she has case studied eighteen (18) female Maori scientists. McKinnon is aware of others who are not included in her study and estimates the number of men who identify as Maori and work as professional scientists as of the order of several hundred. The researcher of the present study personally knows both Maori and Pacific Islanders who work as scientists and mathematicians. It is important to promote some of these people as role models for young Maori and Pacific Island students. For example, brief biographies could be included in text books and some could be invited to appear at schools and talk to students. However, Durie (1995) has stated:

Simply having more scientists who are Maori will not necessarily advantage Maori. What is needed are Maori scientists who will be able to understand the Maori situation, work comfortably alongside whanau [family] and iwi [tribe], and appreciate the Maori preference towards integrated development.
(Durie, 1995, p. 12)

The importance of role models for students has been underscored in the work of Gardner et al. (1989) and Antony (1994), who examined the effect that a lack of role models may have on female students in science and mathematics. Antony (1993) and Kahle (1991) reported that as girls reach higher grades in school, they are more likely than boys to demonstrate lack of confidence in their ability to achieve in science and mathematics activities and are less likely to participate in upper-level science and mathematics classes. Perhaps, ethnic minority groups face a similar problem. Promoting Maori and Pacific Island scientists as role models would send clear messages to ethnic minority students that it is possible for them to pursue rewarding careers in science and that science is relevant and of interest to them even if they choose not to pursue scientific careers.

Specific Rationale

The lack of credible scientific role models for ethnic minorities was noted by several students during interviews. These students generally agreed that the inclusion of Maori and Pacific Island science topics in junior secondary science curricula would be a positive step (Finding 34), enhancing general interest and encouraging learning about other cultures. A natural extension of this would be to promote ethnic minority scientists as role models, a notion with which all of teachers agreed (Finding 24). During interviews, several Maori and Pacific Island students independently observed the dearth of scientist role models from their own cultures, but also cautioned against tokenism. Thus, those promoted as role models should be genuinely well regarded within their own fields.

Recommendation 12

Provide greater funding for teacher education, particularly for ethnic minority teachers who teach ethnic minority students, and for research into best learning approaches for ethnic minority students.

Generic Rationale

Hodson (1988) has argued that scientific knowledge may never be applied because science curricula embody a confused philosophical basis and because many teachers have inadequate views on the nature of science. Constructivism is one approach to providing a theoretical and practical framework to assist teachers to enhance their teaching practice, and is based on the notion that children construct interpretations of, and explanations for, the natural world long before formal science education begins. Fensham (1985) stated that the secondary curriculum in science and mathematics in many countries was characterised by rote recall of facts not socially useful, little familiarity with concepts to enable usefulness to be experienced, and the involvement of life experiences as exemplars rather than as the essence of science learning. However, these objections could be identified as resulting from inadequate teaching practice. For effective science education, it is important that not only are well designed curricula available for students, but that students are taught by teachers competent not only in their own subject matter, but also skilled in the art of imparting that knowledge while exciting the curiosity and interest of students.

Sutton (1981) and Gilbert, Osborne and Fensham (1982) have argued that the more which is known about learners' alternative conceptions, the more easily can teachers promote effective learning experiences in order to modify those conceptions. This requires teachers to have a profound understanding of the cultural perspectives of students and an understanding of how students learn. This in turn requires both research into the ways in which students learn and acquire skills, and into ways of enhancing teachers' skills. Additionally, ethnic minority students should have as much exposure to teachers from their own cultural groups as possible, not only to act as role models, but also because these teachers will most easily understand the psychosocial needs of their students. Kagan (1992) and Hollingsworth (1989) have underscored the importance of the prior beliefs of teachers in influencing the receptivity of teachers to new research ideas. Their research suggests that changing teaching and learning practice cannot be brought about simply by informing teachers. Further, it is not sufficient to place research within physical reach of teachers, but it is also necessary to frame research within their conceptual reach.

Although our training commits us to the practices of the modern school curriculum, our personal identities are often rooted in indigenous norms of socialisation. (Thaman, 1988, p. 56)

Further, the overall quality and relevance of teacher education must be improved, and research into ways of enhancing the effectiveness of teachers college courses is urgently needed. In particular, research into ways of enhancing teacher awareness of and responsiveness to the differentiated needs of students of many cultural backgrounds is required. It is the researcher's experience that many teachers retrospectively regard teacher training as unhelpful for the experience of beginning a teaching career, and regard multicultural education as promulgated in some New Zealand teachers' colleges as mere tokenism. Thaman (1993) argued that since teachers can use practices which conflict with students' previous learning patterns, home environments, mores and values, there is an increasing need for sensitivity towards the cultural milieu in which their teaching is placed. Delgado-Gaiten and Trueba (1991) reported that teachers experience difficulties in understanding the nature, causes and consequences of cultural conflicts in minority populations.

Fisher and Waldrup (1997) argue that if it is possible to identify the dimensions of culturally sensitive learning environments of students in science classrooms, then this presents opportunities to teachers to develop teaching strategies consistent with these cultural dimensions. Further, teachers need to consider how different learning conditions are utilised given students' different learning environments, and can use new information to match the teaching strategies they select with the cultural expectations of their students.

In addition to purely educational and humanitarian reasons for researching better modes of imparting knowledge and improving teaching and learning, there are strong economic reasons for initiatives for enhancing teacher effectiveness. Not only does it cost greatly more to support remedial education in later life (Commonwealth Government's response to the National Review of Education for Aboriginal and Torres Strait Islander Peoples, 1994), but society must also bear the opportunity costs and the costs of undesirable outcomes relating directly or indirectly to failure in education, such as unemployment, increased crime, and poor health levels.

Specific Rationale

No consideration of mechanisms for enhancing educational outcomes for students can ignore the contribution made by individual teachers. This was corroborated in the present study (see Finding 29). Clearly, an increase in the average level of teacher skills may result in enhanced outcomes for students and, in areas in which shortages in resources and teacher skills have been identified such as the area of ethnic minority science education, it is economically rational and expedient to direct greater levels of financial resources to these areas in order to effect improved outcomes.

Recommendation 13

At senior secondary levels, decrease the emphasis on traditional science and general interest science in favour of a modern discipline-based approach.

Generic Rationale

At the senior secondary school levels, once a proper respect for the cultures of indigenous and ethnic people and indigenous science, and the capture of ethnic minority students' interest in science has been achieved, recognition must increasingly be given to a seminal motive for senior science education. This is the provision of a platform for further scientific education.

Knowledge of the curriculum needs to be relevant for a wide range of people in different situations at different times. At the same time, it needs to be non-alienating for the wide range of students and provide a sound foundation for the development of new knowledge and for the critical evaluation of it. (McKinley, 1995, p. 43)

Further scientific education must be predicated on a staged sequence of educational steps at the secondary and tertiary levels, each of which must bear comparison with the equivalent educational stages internationally. For some, this will ultimately lead to scientific careers or to careers which require a high level of scientific training. Thus, senior curricula must focus on the core sciences and provide the necessary platforms for further studies.

Specific Rationale

The present study showed that many junior secondary students already recognise the possible connection which science and technology have to their future professional lives (Finding 30) and sense the importance that science plays in their lives generally. In order to accommodate the needs of students who will continue academic and professional studies in science, higher secondary level science studies must lead directly to tertiary level science. This requires increased emphasis on the core sciences in the senior secondary school years.

8.3 Implementing the Recommendations?

The disillusionment many of us feel, and that many of our audiences feel, probably stems from false expectations. (Kennedy, 1997, p. 10)

8.3.1 Introduction

Substantive educational change requires the approval and buy-in of many parties, including the general public, schools and teachers, as well as from school authorities, policy agencies and ministries of education. Change is seldom easy to induce and many school authorities are constrained by traditional public examination system requirements. The great importance placed on academic qualifications and attainment in today's world, particularly by employers, can sometimes erode the effectiveness of policy changes which aim to empower disadvantaged students in any way which might be seen to degrade expected standards. Kennedy (1997) has argued that the education system is vulnerable to innovations promulgated for the wrong reasons and justified by exaggerated claims, theoretical virtues and anecdotes.

Proposals for change are justified as moral imperatives rather than as proven ideas, and persuasion occurs through publicity rather than through reasoned argument.
(Kennedy, 1997, p. 8)

Chinn and Brewer (1993) have shown the importance of prior beliefs of teachers in determining their receptivity to new ideas, and demonstrated that all people, including teachers, can reject research findings which are not consonant with prior beliefs. Further, Cohen (1988) has argued that it may be wrong to expect substantial change in teaching practice and that the stability of practice derives from the nature of teaching itself. Others (Coleman, 1975; Richardson-Koehler, 1987) have argued that research has already exerted too great an influence and that research is responsible for many of the problems which beset the education system.

The major contribution of this thesis is the provision of a set of recommendations for the enhancement of science education outcomes for ethnic minority students. These recommendations represent the culmination of an extended period of research and reflection on the part of the researcher. However, having developed this set of recommendations, it is worthwhile to consider some of the key issues which drive policy-making which in turn enables educational change to be brought about. In section 8.3, a discussion of educational policy-making as it pertains to Maori and Pacific Island students, is presented.

8.3.2 Perspectives in Education Policy-Making

8.3.2.1 The Consultative Process

Decision-making in education often involves complex consultative processes. Gortner (1981) outlined the nature of the process which may have to be undertaken if, for example, the decision to be made is whether or not to integrate the school system of a metropolitan area. The decision may have to be made by a school board and account taken of the attitudes and activities of a variety of citizen groups as well as of quantifiable information about demographic characteristics and the availability of facilities, special educational programmes and finances. In reality, a great many groups become involved in the decision-making process, of which school administrators and consultants represent but a few of the more important members. Ultimately, a decision is accepted by or imposed upon the community and the board operates under that decision until new demands develop. The process to be undertaken, for example, when implementing policy initiatives designed to address ethnic minority group issues can be more complex still, involving planning and decision-making on a national rather than regional level, and consultation with a range of groups, each with its own cultural values.

House (1996) has discussed a framework for appraising suggested educational reforms *ex-ante*, based on transaction cost economics. His framework identifies reform as a contract between reformers and stakeholders (teachers, students and parents) and the transactions are characterised by bounded rationality (man's inability

to know everything), opportunism (self-interested behaviours) and the protection of specific assets (knowledge and skills). House believes that many suggested reforms fail to take account of the basic features of schools as organisations and institutions.

Many of the recommendations made in this thesis are intended to address precisely the activities of the classroom and school. They do not take the form of extreme measures such as the elimination of grading, a suggestion which usually results in a strong backlash (House, 1996), but rather are common sense suggestions made on the basis of dialogue with students in the classroom. Indeed, Hanuchek (1994) contended that research and policy should focus more on the classroom than on governance and other issues.

If a single, glaring lesson is to be learned from past attempts at school reform, it is that the ability to improve academic performance using standard, uniformly applied policy is limited. . . . The most appropriate, indeed, the only place to begin promoting diversity is at the basic unit of the school: the individual teacher in an individual classroom.

(Hanuchek, 1994, p. 4)

8.3.2.2 *Informed Practice and Policy-making*

Kennedy (1997) has reviewed several factors which may account for a lack of connection between research and practice. She argues that the research itself may not be sufficiently authoritative or of sufficient quality; the research may lack relevance to the classroom and may not have addressed teachers' and students' questions or constraints; the research may be neither physically nor conceptually within reach of teachers; and that the education system may be either too stable or too unstable to react coherently to new research.

McCullough (1990) asserts that historical analysis has played too small a role in guiding education policy-making in New Zealand. In this regard, the parallel views of Vinovskis (1996) on educational change in the United States are of interest. She sees much of educational development there as a series of ever-changing, but often short-lived, reforms responding to crises and stimulating apparently promising solutions but the results of which often prove disappointing retrospectively. In fact, certain

themes which drive educational processes and decision-making recur in many countries at different times. These include prevailing difficult economic conditions such as recession, inequalities in the distribution of wealth; social considerations such as ethnic unrest or class divisions, and purely political considerations which include the preferred educational paradigms of presiding governments or education ministers. McCullough (1990) stated:

. . . an awareness of the historic dimension should be of major importance in guiding the construction of new policies, as well as in suggesting alternatives. (McCullough, p. 23)

It can be argued that public policy in any area of government activity, and equally for education as for health, defence or social welfare, is an organic system capable of admitting change either through radical overhaul or by incrementation, both in response to prevailing ideology or to socio-economic and political pressures. It is such an awareness of the factual history of academic and socio-economic underachievement on the part of Maori and Pacific Islanders which should motivate policy change in response to clear needs.

8.3.2.3 Education Policy and Socioeconomic Considerations

Boyd (1978) has observed that the political process remains hidden from view inside a 'black box model'. He stated that lacking a conception of the process by which inputs are translated into outputs, the model is static, correlation can masquerade as causation, and the significance of political processes and political structures remains unknown.

In this connection, Davies (1981) goes further, and asserts that an overriding concern with stability coincides with the power interests of the dominant and is careless of the welfare of the powerless. Thus, to avoid situations where policy-makers repeat the mistakes of the past, they must be well informed, not only of contemporary society, but also about society as it has been in the past. Davies quotes the popular view of the 1950s and 1960s that third world countries merely have to adopt the educational processes of developed countries in order to emulate their political stability, democracy and economic growth. Davies reminds us that the economic recessions

and social instability which have beset the west in recent decades have shown up the fallaciousness of that view. Wirt and Kirst (1975) have also pointed out the contempt of policy-makers for the historic, the descriptive and for normative evaluations. They assert that the politics of education, therefore, tend to:

. . . look at the wrong things, confining attention to agents and actors rather than the social structure. (p. 7)

Davies believes that human capital theory, which claims that educational reform leads to economic growth, has lost some of its former credibility, as it has now been realised that educational reform often makes little real contribution in the nation's classrooms. If this is true, then policy must change the classroom and the curriculum directly and not simply provide remediation. It must do this in a way that arouses students' enthusiasm and encourages more positive attitudes and perceptions in all students, particularly in those at risk of failure who stand to be saved by appropriate intervention.

8.3.2.4 *The Relevant Political Issues in New Zealand*

In a briefing paper to the incoming government of New Zealand (New Zealand Treasury, 1987), underscored the close connection between the education system and the greater society:

The pressures on it are cultural, social, economic and political. It is linked in a complex way to the process of economic and social development and high expectations are placed on it.

The paper then cautions that the existing New Zealand education system displays little sense of historic contexts and operates as though only consideration of society of the day were necessary. Thus, little account is taken of the way in which society and the demands placed on it change, frequently quite rapidly. Patterns of immigration change from year to year and there is the danger that existing policy becomes unresponsive to the needs of a system which suddenly is faced with the problems, for example, presented by immigrant children from a variety of cultural and ethnic backgrounds and whose command of the English language may be

marginal. This is true for many eastern European and Pacific Island immigrants to New Zealand.

In a sense, if all politics is believed to arise from class struggle (the Marxist paradigm), then so is education partly an issue of class struggle. Young and Whitty (1977) were among the first to attempt to establish linkages between the politics of the classroom and the politics of class struggle. In New Zealand, this struggle can be seen to be largely the struggle of the educationally and socio-economically disadvantaged underclasses, of which Maori and Pacific Islanders form a significant fraction. While it is crucial that policy-makers recognise the difficulties of the educationally disadvantaged, it is perhaps even more crucial that governments also recognise the problems and articulate their preparedness to provide resources to rectify them.

The New Zealand Government has given notice of its awareness of the educationally disadvantaged. It has articulated this awareness as follows:

Issues affecting the education of students who face the huge personal, social and economic waste of not achieving to their full potential at school are a priority (New Zealand Government Online, 1998).

Further, ways of dealing with the major problems in today's education system were given.

1. Continuing to develop policies to address truancy. Some 500 students of compulsory school age are currently being catered for by church, Iwi and community groups in settings which are not registered schools. Policy initiatives to deal with truancy are designed to return to the education system many students who have been alienated by the traditional school setting, and also to ensure that schools can focus on providing for the learning needs of such students.
2. Improving the effectiveness of assistance to schools at risk of failure or poor performance in educational delivery, or schools that are struggling to provide an effective learning environment. Some South Auckland schools provide one example, although problems are not limited to one area. The Government is developing a range of initiatives, including alternative administrative arrangements in clusters of small schools, to reduce the workload of principals and boards of trustees.

3. Raising achievement levels for specific groups of students such as Maori students.
4. Pacific Islands students: the Ministry of Education recently launched a strategic plan for action to support Pacific Islands student education (New Zealand Government Online, 1998).

Such imperatives demonstrate a genuine desire on the part of the New Zealand government to address the major educational problems. However, few, if any, of these imperatives directly influence classroom environments or question the appropriateness of curricula. Hence, initiatives such as those recommended in the present study could be implemented in a way complementary to those of government.

In New Zealand there have been moves by Maori activists to promote compulsory teaching of Maori language and culture for primary school children. Such moves have met with considerable opposition from certain middle-class groups, fearful that these initiatives will lead to falling standards in the basic skills. Such fears may also be expressed in respect of recommendations arising from this study which propose to amend curricula and reshape classroom environments. However, after several generations of academic and socio-economic failure on the part of ethnic minorities, can New Zealand afford to ignore measures alternative to the purely remedial?

8.3.2.5 *Education, Human Capital and Economics*

The notion of human capital as enunciated by Vaizey, that is, 'the stock of the means of production embodying past and present know-how', has been a major consideration in the shaping of the education systems of Britain, Australia and New Zealand (White, 1994). In New Zealand, the reforms implemented in the 1980s were driven largely by a recession in which unemployment reached its highest levels ever (White, 1994). Both public and private schools, as well as the technical colleges, saw gradual but persistent improvement in response, not only to humanitarian considerations, but also to an increasing demand for workers with basic literacy and numeracy skills.

It is evident that in any modern economy, the stock of skilled human capital must be maintained through schools and universities. There is no other effective mechanism whereby young people leaving education for the workforce to take up semi-skilled jobs can be brought up to the required skill-levels, or young adults prepared for the skilled work of the professions. It is here that the prosperous middle classes of contemporary New Zealand enjoy a persistent advantage over other groups, particularly ethnic minorities. Minorities such as Maori and Pacific Islanders have for several generations languished at the bottom of the socio-economic scale, have under-performed educationally, and have been under-represented in the professions. Thus, more frequently than others they lack the resources to enable their children to acquire advanced education. In fact, it was a growing realisation of the inequality of educational opportunity, similar to that which emerged in New Zealand, which stimulated Systemic Reform in the United States in the 1980s (Vinovskis, 1996).

The correlation between length of schooling and future earnings noted by Fleisher and Kneiser (1984) demonstrates a greater likelihood of future affluence for those groups able to afford to undergo education to the highest levels. Additionally, if those groups are also characterised by higher intelligence or ability, then this advantage is increased. It could be added that the rapid expansion of industrialisation and increase in levels of technology have both demanded and driven increases in human capital stock. The consumption aspect of education noted by Vaizey (1972) probably has been strongest in the relatively affluent countries such as New Zealand, Australia, the United States, Great Britain and in other western countries (Peter Winsley, pers. comm.). In New Zealand education as consumption may be a preserve solely of the professional middle classes, while education for its own sake may hold little value for many disadvantaged minority groups such as Maori and Pacific Islanders. If the length of schooling and future earnings are positively correlated, then ways of encouraging further education for economically under-performing groups must be found. This must begin by making curricula more stimulating and classrooms more enjoyable.

8.3.2.6 *Education and Economic Growth*

Denison (1962) has discussed the role of education in promoting economic growth. Clearly, the role of education in enhancing the economies of nations varies from country to country and from year to year. However, many of the historic iterative steps taken in the course of promoting or enhancing education can be seen as short term responses to local demands for the provision of labour, defined by Vaizey as incorporating both the aptitudes and skills necessary for economic growth, rather than as imperatives for enhancing educational outcomes for young people. For example, raising the school leaving age has been a frequent response for restricting youth access to the workforce, implemented in order to reduce pressure on the labour market rather than because this would enhance the educative process. Vaizey's observation that the overall levels of educational attainment and income rise from year to year may well hold true on a nationwide or international macroeconomic scale. It certainly holds for today's western economies in which there is simultaneous gradual modernisation of curricula and educational management and a general increase in income and standard of living. However, this increase in standard of living should be within reach of all members of society, achievable only through enhanced educational outcomes for all.

8.3.2.7 *Education, Class and the Role of the State*

Scientific development, a key driving force in the shaping of education in 18th and 19th century Britain, remains a key driver in shaping education today. The recognition that new educative processes were required to prepare people for a new industrialised, technological workplace still applies. Neither have the wishes of the 18th century middle class for sound education and parity of educational and professional opportunity with the children of the upper classes changed fundamentally since those years.

A persistent question is that of the role of the State in the provision of education. Both Adam Smith and Bentham saw the State as having a vital role to play, and the various public inquiries into education in New Zealand over the last century have partly been motivated to provide guidance on this very question. In particular, the

American reforms of the 1980s and the New Zealand reforms of 1987 centred largely on this issue. The solution adopted in New Zealand was to devolve power to a central ministry, and much of the decision-making to the individual institutions. Perhaps, New Zealand is fortunate in that class divisions have largely been broken down by comparison with many other countries, though some residual racism remains. Full advantage must be taken of this fact and, through effective education, all New Zealanders given equal opportunities to lead successful lives.

8.3.2.8 *Planning for the Future*

Today's world is becoming increasingly dependent on science and technology and the rate of change is becoming increasingly rapid.

80 per cent of the systems, processes, services and products that today's five-year olds will experience and use as adults have not yet been thought of.
(MIT Media Laboratories; pers. comm.)

New Zealand, like other Western industrialised nations, is evolving to become a 'knowledge society'. In a knowledge society, individuals who are well-educated, self-motivated, and linked into information networks, are the most likely to live prosperous and fulfilling lives. Enterprises that are attuned to their customers' requirements, employ educated workers, encourage innovation through their workplace organisation, know more and learn faster than their competitors, are the most likely to succeed and grow. At the national level, societies that maximise opportunities for individuals and enterprises to develop knowledge-age skills and access knowledge-age services, and that enable people to share a common sense of national identity and belonging, are the most likely to be cohesive (MoRST, 1998). Robert Solow, a Nobel prizewinner in economics, has stated:

87% of the growth in the US economy this century arises from new knowledge and technological change, not economic efficiency or capital investment.
(Solow, cited in MoRST, 1998)

Technology is a key driver for knowledge societies, and will have wide-ranging implications for the structure of society and the way economic, social and environmental goals are addressed. Knowledge is one of the main drivers of

prosperity and well-being and includes information in any form, know-how and know-why. It involves the way we interact, both as individuals and as a community. Knowledge can be embodied in people, as human capital, and in technology. And knowledge can be embodied in all people, irrespective of race or gender.

. . . we need more Maori in science and more Maori contribution to science.
(Kirikiri, 1995, p. 80)

Educational imperatives, therefore, must encourage all young people to acquire the knowledge and skills which will not only contribute to a more prosperous society, but will also enable them to become more prosperous as individuals and lead fulfilling lives.

8.3.2.9 *The Knowledge Revolution*

The world economy is undergoing significant change, and far greater emphasis is now placed on the ability to create, store, distribute and apply knowledge. Globalisation of the world's economies has fuelled competition and, increasingly, competitiveness is achieved through knowledge-based technological innovation. Knowledge differs from physical resources; each new discovery provides a platform for further discoveries, thus generating the potential for rising rates of technological change. This principle has given rise to the idea of the 'knowledge revolution'. The increasing rate of knowledge-based innovation means that mankind is on the threshold of fundamental societal change (MoRST, 1998).

The Knowledge Revolution will be as profound for us as the Industrial Revolution was to the 19th Century. It will change the nature of every organisation and every job.
(Drucker; cited in MoRST, 1998)

Knowledge societies will exploit the enormous potential of new knowledge-intensive technologies in areas such as information and communications, biotechnology, medical systems, and nanotechnology. For New Zealand, the successful development of a knowledge society will involve moving towards systems, services and products with higher levels of value added by knowledge. This in turn will involve better and more rapid identification of the needs of stakeholders, customers, clients or

beneficiaries, and better satisfaction of those needs through more intelligent production, distribution and service delivery, underpinned by science and technology.

I believe we live in a time of great opportunity for us all. As young Maori interested in mathematics, science and technology, the world is close to being your scientific oyster. The funding opportunities you can wield because you walk in the Maori world and the Pakeha world, and the benefit you can bring both Maori and Pakeha society is enormous. What a time to be alive!
(Watson, 1995, p. 93)

8.4 Limitations of the Study

The main limitations of this study and its research design included those inherent in the school and student sampling procedures adopted; the cross-sectional experimental design; the possibility that some surveys were completed incorrectly; the inability to measure acculturation of ethnic minority students to the predominant culture; the limited time available to the researcher for carrying out the qualitative parts of the study, and possible cultural bias of the investigator (a European male).

Other possible factors which might constrain the validity of the research findings include:

(i) Acculturation

Acculturation was not assessed because of the lack of an appropriate measurement instrument and because it was deemed beyond the scope of the present study to address this effect. The term *cultural bias* refers to the notion that an investigator's observations are unavoidably influenced by his or her own world view (Casas & Atkinson, 1981). It is, of course, impossible for any researcher to completely avoid such influence, but the researcher was sensitive to this issue.

(ii) Representativeness of the Samples

The samples for this study came from particular available groups and may not be representative of the Maori and Pacific Island student populations as a whole.

(iii) The Sample Size

The sample size of 579 students, including 93 Maori, 92 Pacific Island, 44 Asian and 350 European students was large enough to validate the statistical procedures used and enable comparison to be made between the four ethnic groups. However, a larger sample size would have formed a more normal sample, possibly with improved homogeneity of variance. This would have broadened the generalizability of the findings.

(iv) The Number of Participant Schools

The study involved a small number of schools (6). Though this contributed to controlling for variance due to school, the small number of participant students and schools limits the generalizability of the findings to other schools. The ethnic minority students in the study sample probably derived disproportionately from lower socio-economic backgrounds. This was unavoidable given the number and location of the participant schools.

(v) The Working Class Socio-economic Catchments of the Schools

The socio-economics of the target groups was not considered in the study, but may have influenced findings such as the more positive attitudes displayed by Maoris and Pacific Islanders than others, and by females than males. Gottfried (1985) and Luzzo (1992) believe that socioeconomic status should be considered as a separate variable of psychological research.

(vi) The Design of the Study

The cross-sectional design of this study also rendered it difficult to draw compelling comparisons between form levels. For example, attrition of low scorers might have affected measurement of student attitudes on survey scales at the upper form levels, and not from other causes such as psychosocial development.

(vii) *Lack of Participant Observation*

Participant observation was not possible in the present study because of the commitments of the teachers and students involved. Implementation of the survey questionnaires, and interviews with teachers and students had already taken up a considerable amount of time for the participants and it was decided not to pressure the schools any further. Participant observation would, for example, have allowed information on non-verbal behaviour to be collected. Such contributions to the present study could not be made.

8.5 Suggestions for Further Research and Concluding Remarks

8.5.1 Suggestions for Further Research

Further research involving samples from a broader range of schools, students and teachers than considered in the present study could be conducted usefully. Future studies should involve schools from a wider geographic and socioeconomic range across both New Zealand than was achieved here. Further research should be undertaken to investigate the relationship between student attitudes towards science and achievement, perceptions of their constructivist learning environments and achievement, and how socio-economic factors such as family background, parental profession and religious background impact on attitudes and achievement. Research into the prior conceptions of Maori and Pacific Island students should be conducted in order to understand how best to frame Constructivist teaching methods which take account of the existence of such conceptions. The findings of such research would clarify some of the complex factors which affect these students and would assist in the design of responsive school environments and effective curricula for the future.

Additionally, many students complained about the length of the TOSRA survey, the repetition inherent in some scales, particularly those items relating to 'doing experiments' (*Attitude to Scientific Inquiry*), and the complexity of the language used. For example, a number of students had to inquire the meaning of the word

'seldom'. The researcher therefore recommends the development of a shorter version of the TOSRA survey using simplified language and reduced repetition.

8.5.2 Concluding Remarks

The present research study involving ethnic minority high school students in New Zealand arose from a review of the researcher's own teaching career following a decision to terminate that career in favour of a career in science policy with the New Zealand government. The researcher found much initial stimulation, and gained many useful ideas in reading a doctoral thesis by Andrew Baimba in which a trial of a Science for All approach to teaching and learning science was described. Other useful ideas were gleaned as the research progressed and from other literature read and assimilated during the course of the study.

The study produced some unexpected findings, such as the more positive attitudes towards science than others returned by the Maori and Pacific Island students, and the more positive attitudes held by females than males. Perhaps, the enthusiasm and care displayed by the participant teachers during interviews partly explains these findings.

The author hopes that the findings of this study will provide a clearer understanding of the experiences of ethnic minorities and others in science education in New Zealand and will stimulate the development of ways of enhancing their educational and life outcomes.

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APPENDICES

APPENDIX 1

The New Zealand Education System

1. Primary and Secondary Levels

The New Zealand education system provides for primary level education from age five (Junior 1) to age 12 (Form two). Secondary level education begins at form three and continues to form seven. The national school certificate examinations are taken at form five, the sixth form certificate examinations at the end of the sixth form year, and the University bursaries and scholarships examinations at the end of the seventh form year.

2. Tertiary Education in New Zealand

At the tertiary level, there are 25 polytechnics and many private tertiary institutions providing courses in English language, bridging courses and business courses. Seven universities offer Bachelors degrees, postgraduate diplomas, masters degrees and doctorates. A government agency, the New Zealand Qualifications Authority (NZQA), has responsibilities for setting and reviewing education qualification standards. The NZQA ensures that New Zealand education and qualifications are recognised internationally and that appropriate overseas qualifications are recognised in New Zealand. A central role of the NZQA is to assure the quality of education programmes offered by state institutions and private training establishments to international students. It is responsible for the registration of private training establishments offering courses of study for three months or longer and the approval of courses and accreditation of colleges of education, polytechnics and private providers.

3. Overseas Demand for New Zealand Education

As in Australia, there is growing overseas demand for education in New Zealand, particularly from Asian countries. Several colleges for Japanese students have opened since the 1980s and many Asian students come to New Zealand to study in secondary schools and the universities.

APPENDIX 2.1

A Recent History of New Zealand Education

1. Government Inquiries and Reviews

The seminal developments in recent New Zealand education policy have, like many of those of England in the 18th and 19th centuries and Australia during the depression decades, been driven by unfavourable socio-economic conditions. The year 1987 was a landmark year in New Zealand education. Several inquiries into the state of education were held, including the Curriculum Review, the culmination of which was the Picot Report (Picot, 1987) which Codd (1990) observes 'presented a cynical and highly negative image of a system which is alleged to be inflexible, unresponsive and weighed down with unnecessary rules and regulations', and government's response, *Tomorrow's Schools*, effectively a blueprint for administrative reform, devolving much decision-making to the boards of polytechnics and schools.

Codd (ibid.) asserts that the New Zealand State had been undergoing a 'legitimation crisis' since the election of the fourth Labour government in 1984. He defines 'legitimation crisis' as the tendency of State institutions to lose popular support and provoke opposition and resistance. In many capitalist economies, people may become depoliticised because decision-making becomes increasingly carried out by bureaucracies and democracy can become reduced to occasional choices between one administrative oligarchy and another. During this period, the New Zealand Treasury assumed ever greater power and eventually its policy advice took precedence over that of other government departments (Codd, ibid.).

2. Economic Pressures on New Zealand Education

Towards the end of 1984, Treasury published its blueprint, *Economic Management*, for the Labour government's plan of comprehensive economic reforms according to a process of strict economic analysis. In this document, it was asserted that 'with central planning, mistakes tend to be excessively costly and impact on everyone, with

few alternatives being available when things go wrong'. This monetarist plan took as its guiding ethos the notion that a market-place free from government intervention will work to the betterment of all and that most of the ills which had beset the New Zealand economy in the previous decade had derived from excessive spending. Therefore, it was assumed, economic problems were solvable through austerity and through an admittedly unpopular increase in unemployment which would lead eventually to prosperity. To support this contention, the 1987 Treasury document, *Government Management*, cited the increase of net government expenditure as a share of GDP from 31.1% in 1973/74 to 43.6% in 1986/87 and stated that this increase reflected the growing costs of debt-servicing, unemployment benefits and national superannuation rather than increased demand for goods and services. Continued overseas borrowing had by 1987 led New Zealand to become the fourth most indebted country in the OECD (Codd, *ibid.*) and there was both fiscal and political pressure to reduce educational spending.

3. The Picot and Earlier Reports

In August 1988, the Minister of Education, David Lange, endorsed the Picot Report and *Tomorrow's Schools* by appealing to the notion that reform, already advocated in the Currie Report of 1962 (Currie, 1962) and reaffirmed by Nordmeyer in the 1970s, was now long overdue and had been delayed for over thirty years. In fact, the Currie Report may have had cogency in the 1960s, a decade of economic growth, general prosperity and little racial or other political unrest. The Currie Commission had accepted as a reasonable working premise Peter Fraser's statement of intent as education minister 'that every person, whatever his level of academic ability, whether he be rich or poor, whether he live in town or country, has a right, as a citizen, to a free education of the kind for which he is best fitted and to the fullest extent of his powers'.

Although indeed recommending change, the tone of the Currie report was in fact supportive of existing administrative procedures and concluded that the calibre of New Zealand's education system was high by international standards, 'reflecting credit on those who have contributed to its development over the years'. The report promoted the role of the State as benevolent and, if anything, the instruments of State

control, the Department of Education and the New Zealand Council for Educational Research, had been too mild in pursuing corrective action on existing imbalances. State welfare reform promoting social equality was accepted as a characteristic feature of New Zealand's national identity, a view articulated by the historian, Keith Sinclair, in his work *A History of New Zealand* (Sinclair, 1957). As an extension of this ideology, the Currie Report tended to overlook or marginalise issues of the effect of education on different social groups, the wide spectrum of views on the role of education and the implications of such devices as zoning.

4. Criticism of State Control

The 1970s was characterised by an escalation in economic, social and political problems, including Maori unrest, gender issues and the beginnings of economic recession and the education system began to come under closer scrutiny. A 'new sociology' gained increasing credence in which it was promulgated that certain aspects of the educative process encourage the persistence of social and cultural inequalities. Shaker (1987), amongst others, levelled criticism at State control and the reproduction of social and economic divisions. In reaction, the Educational Development Conference Report of 1973-74 represented an attempt to retain continuity of administration while parrying or accommodating outside criticisms. By the early 1980s, there was a well established left wing critique of education and a challenge from the 'New Right' also emerged, seeking, as did the left wing, to explicate New Zealand's educational deficiencies in the context of international developments. The 'Great Debate' on British education, led by Labour Prime Minister, James Callaghan, had some years earlier initiated a review of standards, parental choice and productivity.

In 1987, the Picot Report and Tomorrow's Schools were espousing much more radical reforms than had been recommended by Currie. The terms of reference of the Picot Review demanded examination and appraisal of devolution and efficiency. David Lange, prime minister and self-appointed minister of education, was searching for a new 'myth' which could capture the popular imagination. Shallcrass (1985) commented that without such a myth 'we will inevitably stagger on from one expedient to another without direction or purpose'. The newly found myth espoused

'equality of results, equality of outcome' to replace that of the previous three decades, 'equality of opportunity'. In the Picot Report it was contended that the education system had not resulted from an overall plan, but had assumed its present form through successive increments and by accretion. Now, the report concluded that the basic units of educational administration are the individual colleges or technical institutes and that devolution of decision-making to those units could have positive and beneficial social consequences. Picot took as guiding ethics the notions that every learner should gain the maximum benefit from educational spending and that education should be fair to all learners irrespective of gender and cultural affiliation. By this common-sense and humanistic paradigm it was hoped to counter criticism from both left and right and eventually to gain consensus. What Picot marginalised was the real practical import of bureaucratic change in the classroom. As Codd observes, success in education really lies with the teaching body.

At one level, policy changes brought about during this period may be viewed as representative of a change of education minister but, more fundamentally, can also be seen as logical extensions to a more comprehensive reshaping of the role of the State which had been carried out in other areas of government policy (Codd, *ibid.*). Under the new devolved system, it is now more difficult to pressure for increased spending in education or for other qualitative improvements. Codd notes, for example, that teachers can no longer lobby for reductions in class size, inservice training or increases in resources.

5. Devolution in New Zealand Education

This recent New Zealand tendency towards devolution parallels similar reform in the United States, there referred to as Systemic Reform (Vinovskis, 1996) which has the objectives of the creation of a coherent, curriculum-driven reform and the provision of comprehensive educational and social services for school-aged children (Vinovskis, *ibid.*). Pressures to devolve power in the United States largely arose from a general disappointment in the performance of American students in international assessments, a realisation that the current system did not provide adequately for the needs of poor and minority groups, and from research demonstrating the importance of local commitment in the successful implementation of reforms.

A movement towards devolution then gained momentum from the active participation of governors and business leaders. As in New Zealand, these objectives were to be implemented through decentralisation and site-based management where local educators and administrators are given greater control over the management of their institutions. Three major changes were sought - the establishment of curriculum frameworks which delineate clearly what students should know and be able to do, the alignment of state education policies and the creation of a restructured governance system capable of giving schools the resources and flexibility required to encourage learning. The question of the role of the State(s) became as central here as it was in 18th and 19th century England, Australia during the depressions and contemporary New Zealand. In particular, the Consortium for Policy Research in Education, a research and development centre funded in 1985, had as a major goal the examination of the role of the states in fostering local educational improvements.

6. New Zealand Education Today

The New Zealand education system of 1997 comprises five distinct but interrelated strata. Parliament has ultimate control and the Minister, a member of Parliament, is answerable to it. Answerable to the Minister are four administrative agencies - the Ministry of Education, the New Zealand Qualifications Authority, the Education Review Office and the Teacher Registration Board (Education in New Zealand: The Central Education Agencies, Ministry of Education Report, 1993). These agencies control the individual educational institutions which are answerable to them through their Management Committees and Boards of Trustees or Councils. In turn, parents and the community at large provide input and are responsible to these committees and boards.

In parallel with this layered administrative system is a set of five Service Providers which have special support roles in the provision of specialist advice and assistance with a range of activities including early childhood education, education for the disabled, careers advice and general educational resources. These are the Early Childhood Development Unit, the Special Education Service, the Careers Service, the Education and Training Support Agency and Learning Media Limited. The first four of these have documents of accountability with the Minister of Education, while

the last has official contact with the Secretary of Education. How this bureaucratic system resulting from the Picot reforms and the implementation of *Tomorrow's Schools* will enhance New Zealand education will only become known in the next decade.

APPENDIX 2.2

TECHNOLOGY EDUCATION IN NEW ZEALAND

1. The Scope of Technology Education

Technology education is designed to be a planned process designed to develop students' competence and confidence in understanding using existing technologies and in creating solutions to technological problems (NZ Ministry of Education). The main aim of technology education is to enable students to achieve technological literacy through the development of technological knowledge and understanding, technological capability and understanding and awareness of the relationship between technology and society (NZ Ministry of Education).

The Technology curriculum is intended to contribute to the intellectual and practical development of students, both as individuals and as informed members of a technological society. Topics which fall within the compass of technology education in New Zealand include biotechnology, electronics and control technology, food technology, information and communication technology, materials technology, production and process technology, and structures and mechanisms.

2. Topics in Technology Education

Examples of projects or topics recommended in the New Zealand technology curriculum include:

1. Sensor Instrumentation
2. Quality Control Systems in Food Products
3. Home Security Systems
4. Protective Coverings and Coatings
5. Biosensors
6. Developments in Information and Communications Technology
7. Horticultural Exporting
8. Technology and Health
9. Robotics
10. Reproductive Technology
11. Waste Disposal Systems
12. An Information System for an Historical Site.

Technology education for Maori students is also carried out through the medium of te reo Maori (Maori language) and by including technological activities based on Maori developments and applications (NZ Ministry of Education).

APPENDIX 4.1

ANALYSIS OF VARIANCE (ANOVA)

1.1 General

Analysis of variance uses a statistic called F (just like the t-test used a statistic called t) to test for differences between the means of groups. For all F tests, the numerator consists of a measure of differences between groups (generally referred to as a Mean Square Between Groups (MSBG)), while the denominator is a measure of variation within those groups, usually referred to as the Mean Square Within Groups (MSWG), also known as the Mean Square Error. Explicitly:

$$F = \text{MSBG} / \text{MSWG}$$

As with the t, the larger the differences between the groups, and the smaller the differences within those groups, the larger the computed value of the F statistic. The larger the value of F, the more likely it is that the null hypothesis will be rejected. In the simple case where there are just two groups, the F statistic gives exactly the same information as the t-Test. However, the F test - ANOVA is able to handle more complex situations such as when there is more than one group or more than one independent variable.

As with all such tests, if the number obtained from calculations (the calculated F value) is greater than the tabulated number (the critical F value), then the null hypothesis is rejected. In this case, at least one of the groups examined is significantly different from at least one of the other groups. To determine exactly which groups are different requires post hoc tests such as the Tukey or Scheffe tests.

When the null hypothesis is rejected using ANOVA, there is a difference between the groups. However, where that difference is may not be known. A significant F statistic indicates that at least two of the groups were different, but not which ones. Multiple comparison tests can then be used to discover which groups are different. There are many multiple comparison tests, but the Scheffé test is among the most popular.

Scheffé Test

To conduct a Scheffé test, the means of any two groups for which it is hoped to detect a difference between are subtracted. If the difference between the means is larger than the critical difference (CD), then those two groups are different from one another. However, it is possible to find a significant ANOVA and not be able to find which two groups are different using the Scheffé test.

3. The Two-Way ANOVA

Two-way ANOVA is used in situations in which there is more than one independent variable. Two-way ANOVA analyses the total amount of variance in the dependent variable and breaks it down into parts accounted for by a number of different sources:

1. The main effect for the first independent variable
2. The main effect for the second independent variable
3. The interaction between the two independent variables
4. Error variance, or variance within groups associated with equivalent levels of the independent variables

These account for all of the variance in a given data set (assuming only two independent variables; naturally if there are three independent variables the analysis is more complicated, although the principle remains the same). As with the one-way ANOVA, F statistics are calculated for ratios of variance.

APPENDIX 5.1: MANOVA ON ETHNICITY AS INDEPENDENT FACTOR

DEPENDENT VARIABLE: NORMSCI

Source	Type III Sum of Squares	Mean Square	F	Sig.
Corrected Model	554.03	138.51	4.43	.00
Intercept	148300.14	148300.14	4741.21	.00
ETHNIC	554.03	138.51	4.43	.00
Error	21144.59	31.28		
Total	509920.00			
Corrected Total	21698.63			

MANOVA with Ethnicity as Independent Factor and NORMSCI as Dependent Variable

APPENDIX 5.2: INTERACTION EFFECTS

Appendix 5.2a

Tests of Between-Subjects Effects
Dependent Variable: ATTINQ

Source	Type III Sum of Squares	Mean Square	F	Sig.
Corrected Model	3809.63	131.37	3.10	.00
Intercept	99354.21	99354.22	2340.69	.00
ETHNIC	491.37	122.85	2.89	.02
FORM	54.10	27.05	.64	.53
GENDER	302.02	302.02	7.12	.01
ETHNIC * FORM	450.70	56.34	1.33	.23
ETHNIC * GENDER	472.11	118.03	2.78	.03
FORM * GENDER	7.47	3.74	.09	.92
ETHNIC * FORM * GENDER	472.83	59.11	1.39	.20
Error	27293.09	42.45		
Total	390116.00			
Corrected Total	31102.72			

Interaction Effects on ATTINQ indicating significant interaction between ETHNICITY and GENDER

Appendix 5.2b

Tests of Between-Subjects Effects Dependent Variable: LEISINTR

Source	Type III Sum of Squares	Mean Square	F	Sig.
Corrected Model	4439.22	153.07	2.38	.00
Intercept	217925.47	217925.47	3381.84	.00
ETHNIC	1596.58	399.14	6.19	.00
FORM	281.74	140.87	2.19	.11
GENDER	224.01	224.01	3.48	.06
ETHNIC * FORM	591.72	73.96	1.15	.33
ETHNIC * GENDER	220.69	55.17	.86	.49
FORM * GENDER	334.54	167.27	2.60	.08
ETHNIC * FORM * GENDER	566.78	70.84	1.10	.36
Error	41370.48	64.44		
Total	959941.00			
Corrected Total	45809.71			

Interaction Effects on LEISINTR: significant interaction between FORM LEVEL and GENDER

APPENDIX 6.1: MANOVA ON ETHNICITY AS INDEPENDENT FACTOR

DEPENDENT VARIABLE: LEISINTR

Source	Type III Sum of Squares	Mean Square	F	Sig.
Corrected Model	1420.28	355.07	5.34	.00
Intercept	252319.38	252319.38	3791.38	.00
ETHNIC	1420.28	355.07	5.34	.00
Error	44389.43	66.55		
Total	959941.00			
Corrected Total	45809.71			

MANOVA with Ethnicity as Independent Factor and LEISINTR as Dependent Variable

APPENDIX 6.2: INTERACTION EFFECTS

Appendix 6.2a

Dependent Variable: UNCERTY

Source	Type III Sum of Squares	Mean Square	F	Sig.
Corrected Model	836.20	28.83	2.02	.00
Intercept	58679.66	58679.66	4114.39	.00
ETHNIC	183.90	45.97	3.22	.01
FORM	98.61	49.31	3.46	.03
GENDER	21.26	21.26	1.49	.22
ETHNIC * FORM	246.72	30.84	2.16	.03
ETHNIC * GENDER	106.01	26.50	1.86	.12
FORM * GENDER	32.99	16.49	1.16	.32
ETHNIC * FORM * GENDER	78.57	9.82	.69	.70
Error	9042.13	14.26		
Total	279010.00			
Corrected Total	9878.33			

Interaction Effects on **UNCERTY**: significant interactions between **ETHNICITY** and **FORM LEVEL**

Appendix 6.2b

Dependent Variable: STUDNEG

Source	Type III Sum of Squares	Mean Square	F	Sig.
Corrected Model	2296.29	79.18	2.68	.00
Intercept	69161.97	69161.97	2344.33	.00
ETHNIC	403.07	100.76	3.42	.01
FORM	15.60	7.80	.26	.77
GENDER	118.31	118.31	4.01	.05
ETHNIC * FORM	187.65	23.45	.80	.61
ETHNIC * GENDER	227.15	56.79	1.93	.11
FORM * GENDER	82.89	41.44	1.41	.25
ETHNIC * FORM * GENDER	516.43	64.55	2.19	.03
Error	18881.16	29.50		
Total	299393.00			
Corrected Total	21177.46			

Interaction Effects on STUDNEG: significant interactions between
ETHNICITY, FORM LEVEL and GENDER

APPENDIX 8.1

SUMMARY OF STUDY FINDINGS

Finding 1

Maori students displayed slightly more positive attitudes towards science than European and Asian students.

Finding 2

For the participant student population taken as a whole, there was no decline in student interest in science with increasing form level.

Finding 3

None of the participant ethnic groups showed a decline in attitudes towards science with increasing form level.

Finding 4

The female students displayed slightly more positive attitudes towards science than the males.

Finding 5

For each ethnic group, females held slightly more positive attitudes towards science than males.

Finding 6

The only rural school yielded the most positive attitudes towards science of all participant schools.

Finding 7

The co-educational schools yielded slightly more positive attitudes towards science than the single-sex schools.

Finding 8

No associations between student attitudes towards science and achievements in science were found.

Finding 9

Maori and Pacific Island students displayed equivalent or more positive perceptions of their constructivist learning environments than European or Asian students.

Finding 10

Differences in perceptions of their constructivist learning environments between Maori and Pacific Island students were not significant.

Finding 11

Perceptions of constructivist learning environments became more positive at the fourth form level and declined again at fifth form level.

Finding 12

Overall, males and females displayed similar perceptions of their constructivist learning environments.

Finding 13

Students from single-sex and coeducational schools displayed similarly positive perceptions of their constructivist learning environments.

Finding 14

No association between student perceptions of their constructivist learning environments and their achievements in science was found.

Finding 15

No direct association between student attitudes towards science and perceptions of constructivist learning environments was found.

Finding 16

The teachers generally perceived that Maori and Pacific Island students hold less positive feelings towards science than others.

Finding 17

The teachers found teaching Maori and Pacific Island students rewarding, but felt that motivating them can present particular difficulties.

Finding 18

The teachers believed that Maori and Pacific Island students generally perceive science as having little relevance to their everyday lives or to their futures.

Finding 19

The teachers believed that Maori and Pacific Island students often relinquish their science studies earlier than others because they do not see science as relevant to their needs and because they are not encouraged to pursue science by their peers.

Finding 20

The teachers usually held mature views of the nature of science and typically saw science as man's active attempt to study and understand the natural world, with various methods and research processes integral to it.

Finding 21

The teachers generally viewed the present science curriculum as well intentioned but not the best adapted for the needs of Maori and Pacific Islanders.

Finding 22

The teachers generally believed that, contrary to the constructivist ideal, many students do not hold prior conceptions about scientific phenomena which can later be built upon. Rather, the first concepts are initially acquired at school.

Finding 23

The teachers were divided about whether more Maori and Pacific Island themes should be introduced.

Finding 24

All of the teachers believed that a useful purpose would be served if Maori and Pacific Island scientists were promoted as role models.

Finding 25

The teachers did not believe that dislocations between cultural beliefs, values and norms, and tenets of modern science present significant conflictual difficulties for Maori and Pacific Island students.

Finding 26

The teachers believed that the traditional (pseudo-traditional) origin of Maori and Pacific Island students does not present significant conflictual problems of integration into the education system because most such students come from westernised families. Rather, the problems are attitudinal.

Finding 27

The students interviewed were generally positive about their enjoyment of science and indicated a greater enjoyment of practical work than written work.

Finding 28

Students interviewed were aware of, and frequently open about, their own imperfect behaviour in class.

Finding 29

The students interviewed perceived that class reactions to their learning environment depend heavily on the teacher and vary sensitively according to the 'mood of the moment'.

Finding 30

Many of the students interviewed had strongly held views as to possible future careers and some were aware of the importance of science to some professions.

Finding 31

Many of the students interviewed expressed the opinion that Maori and Pacific Island students do not continue with senior science studies because they lack the discipline required to achieve in science, that their cultures and their families do not foster a strong respect for science, and because science becomes difficult at the higher levels.

Finding 32

The students interviewed gave definitions of science encompassing both the notions of a human activity and the scope of subject matter and issues addressed.

Finding 33

The majority of students interviewed believed that present curricula are appropriate but could be made more interesting.

Finding 34

The students interviewed generally felt that the inclusion of Maori and Pacific Island science topics in junior secondary science curricula is desirable both as general interest and as a way of learning about other cultures.

Finding 35

For the majority of students interviewed, cultural or religious beliefs do not pose conflictual problems with their education in science.

APPENDIX 8.2

Summary of Recommendations

Recommendation 1

Continue to group Maori and Pacific Island students with others.

Recommendation 2

Find and develop ways of making classroom environments more sharing and cooperative.

Recommendation 3

Promote technology education as a core subject equivalent in status to the core sciences.

Recommendation 4

Reduce emphasis on examinations and competition and retain a strong component of internal assessment.

Recommendation 5

Give prominence in curriculum design to the constructivist paradigm of conceptual change which recognises the role of prior conceptions which must be built upon and developed during the course of the learning experience.

Recommendation 6

Introduce carefully chosen examples of credible Maori and Pacific Island traditional science such as medicine, navigation, food and food preparation, and hygiene in order to underscore the importance of indigenous science to ethnic minority students and add cultural interest to the curriculum.

Recommendation 7

Retain the core sciences, physics, chemistry and biology, in the science curriculum for all students during the first three years of secondary school.

Recommendation 8

Include other non-core sciences in the curriculum such as earth science, environmental science, astronomy etc, both to stimulate general interest and to broaden students' scientific perspectives.

Recommendation 9

Establish school subjects such as agricultural science and home economics as valid and equal in importance to the mainstream sciences.

Recommendation 10

Vary the pedagogical styles used and incorporate as much practical work and group learning as possible.

Recommendation 11

Introduce ethnic minority role models in a credible and meaningful way.

Recommendation 12

Provide greater funding for teacher education, particularly for ethnic minority teachers who teach ethnic minority students, and for research into best learning approaches for ethnic minority students.

Recommendation 13

At senior secondary levels, decrease the emphasis on traditional science and general interest science in favour of a modern discipline-based approach.