Professional Science Knowledge and its Impact on Confidence in the Teaching of Earth Science

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By

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ABSTRACT

This study focused on the nature and parameters of the relationships between the professional science knowledge of primary and intermediate teachers and their confidence in teaching in the *Making Sense of Planet Earth and Beyond* strand of *Science in the New Zealand Curriculum* (earth science). The study was divided into two phases of data collection. The first phase used a questionnaire survey of 18 teachers from the Taranaki, Wanganui, Manawatu, Palmerston North and Horowhenua districts of the western and central North Island of New Zealand. The survey identified the influence of the relationships between the participants' backgrounds in earth science, their professional knowledge frameworks and their efficacy to teach earth science. The second phase of data collection builds on the trends and common themes identified in phase one. Data were collected in the second phase through interviews of four teachers selected from phase one participants.

Analyses of the data collected revealed the importance of maintaining a well-developed understanding of the subject matter when teaching earth science. Subject matter knowledge has a notable impact in teachers' efficacy beliefs and ability to translate content into teachable material. Findings support pervious researchers' conclusion that teachers with high self-efficacy have had a long interest in science and a relatively strong background of formal science studies with opportunities for exploring science in informal settings. Results indicate that effective earth science teachers possess a genuine interest and enthusiasm for earth science. Conversely, teachers with relatively little earth science background display less developed knowledge frameworks and weaker efficacy beliefs. Common indicators of these weaknesses include avoidance of earth science topics in general or use of 'shallow' teaching strategies such as transmission approaches or 'resource based' units. In some cases it appears that teachers' confidence in their ability to teach earth science may be misplaced. Results indicate that in some cases, teachers can use their considerable classroom skills to avoid confronting earth science concepts where their knowledge is inadequate. The implications for these findings are considered.

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I am indebted to the participants of this study, their willingness to participate and continue with the study. I continue to be impressed by their commitment and enthusiasm as members of the teaching profession.

TABLE OF CONTENTS

APPENDICIES

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

The study described in this thesis made an examination of the influences of primary and intermediate teachers' professional science knowledge frameworks on their confidence to teach earth science. The overall aim of this study is to investigate whether the knowledge teachers possess about earth science concepts and the teaching of earth science[1] has any influence on their feelings of efficacy in teaching earth science.

The current 'best practice' in science teaching is generally regarded as the use of constructivist teaching approaches with an emphasis on fostering students' conceptual development (Skamp, 1997). Such approaches place a great demand on teachers' professional knowledge frameworks. Also, the use of use these techniques requires a high level of belief that one can do so effectively.

Personal experiences, informal observations and anecdotal evidence suggest that in an effort to teach constructively, primary and intermediate teachers, often resort to watering down the content of science programmes. Such an occurrence is tragic from the science educator's perspective, but it is also understandable. Many primary and intermediate teachers are not science specialists and possess neither the knowledge, the confidence or the inclination to teach earth science when they would be far more comfortable teaching other subjects (Tilgner, 1990). Of these personal attributes, teachers' confidence has received the greatest amount of research attention.

Pre-service teacher education programmes generally address this lack of confidence by providing positive teaching experiences. However, in the personal experiences of the author these experiences rarely address earth science topics and often take place in artificial contexts that may actually trivialise the efficacy-building potential of these

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[1] For the purpose of this study, all material associated with the *Making Sense of Planet Earth and Beyond* strand of *Science in the New Zealand Curriculum* will be referred to as Earth science.

experiences. It is the author's belief that by bringing meaningful content back into primary science, and providing teachers with this content, or the means to access it, teachers will have more confidence to teach earth science effectively.

Background to the Study

Teacher confidence and competence in teaching science has long been an issue in New Zealand. After the first review of the implementation of *Science in the New Zealand Curriculum,* a report from the Education Review Office (1996) noted that many schools were identified as not covering all four of the contextual strands and the two integrating strands. The report also identified a tendency for primary schools to place greater emphasis on the contextual strand *Making Sense of the Living World,* while other strands, especially *Making Sense of the Physical World* and *Making Sense of the Material World* received much less attention.

"Expertise in teaching science" (Education Review Office, 1996, p. 22) and teacher confidence were reported to be "the most significant barriers to the successful implementation of *Science in the New Zealand Curriculum*" (ibid). Teachers cite "lack of knowledge, confidence and support" as a major factor.

The findings of the *Third International Mathematics and Science Study* (TIMSS) in 1994 revealed a disturbingly low level of science achievement by intermediate (Year 7 and 8) students as well as revealing concerns with the science programme level in general. The TIMMS data identified a wide variety of complex factors that could inhibit effective science programme implementation in New Zealand schools. Although many of these forces included external, system related components, it was inferred that the chief influencing factors related to teachers' knowledge, confidence and skill in implementing the science curriculum at classroom level.

Immediately following the release of TIMSS a ministerial taskforce for mathematics and science education identified teacher confidence and competence as major factors inhibiting effective programme delivery (Walker & Chamberlain, 1999). Similarly, a study by Lewthwaite (1999) found that "approximately half" (p.15) of primary and intermediate teachers consider that confidence was a problem in teaching science.

Along with issues of confidence, the TIMSS Revisited (TIMSS-R) asserted that effective science teaching depends on teachers having the subject matter knowledge and the professional training to maximise students' learning of the subject (Ministry of Education, 2001). No link between teacher knowledge and confidence was investigated.

earth science education has received very little systematic research either internationally, or within a New Zealand context. Vallender (1997) speculates that this reflects the status of earth sciences in school curricula or that very few geoscientists are involved in science education reform.

Much of the information regarding earth science education in New Zealand comes from research on science education in general. These sources, along with the few pieces of work on earth science itself, reveal that earth science is generally held in low regard when compared to the more traditional science disciplines (Vallender, 1997). The domain of earth science is generally misinterpreted (*ibid.*) and that the same problems of poor teacher confidence and knowledge exist in earth science as they do in other science disciplines. In some conceptual areas, such as the geological history of New Zealand or astronomy, poor teacher confidence and knowledge are even more of an issue than traditional 'hard' topics such as energy or electricity (Lewthwaite, 1999).

Rationale for the Study

The results of numerous research efforts have shown that teachers' professional knowledge and confidence are major issues in science education. However addressing these issues is not straightforward. In the wake of TIMMS, the Ministry of Education embarked on an ambitious programme to improve the implementation of *Science in the New Zealand Curriculum*. These efforts consisted largely of in-service professional development programmes and the development of teacher resource materials. These efforts were commendable, though for the most part, more effective rhetorically than professionally Lewthwaite (2001).

This study attempts to address the problems identified in studies such as TIMMS. It is by no means the intent of this study to solve such complex issues, but rather to identify the nature of the problems at hand so that they can then be more effectively addressed in the future.

The purpose of this study is to ascertain the nature of any relationship between the various types of knowledge that primary and intermediate teachers possess, and their confidence to teach programmes based in the *Making Sense of Planet Earth and Beyond*. If such a relationship does exist and is meaningful, it may be possible to build teachers' confidence in the teaching of earth science subjects through developing their professional science knowledge. Such development may include a broadening and deepening of earth science subject matter, effective teaching/explanatory strategies, useful learning activities, improving awareness of curricular requirements and resources, or any combination of similar professional knowledge requirements.

Significance of the Study

There is very little research in the areas of earth science in New Zealand schools and relationships between efficacy and knowledge structures. It is hoped that this study will provide valuable seminal data in these areas. Additionally, though it is not the intent of this study, the findings of this investigation may also have applications in other science education disciplines. It is anticipated that the findings of this study will be valuable to the teacher education community. It investigates two major factors in effective science programme delivery. Any relationships found between these two areas may be of great use to those developing programmes to address these concerns in current and future primary and intermediate teachers.

This study may be significant internationally. The concerns of primary science education in New Zealand are similar internationally (Lewthwaite, 2001). The findings of this study may be of value to educators from other countries that are also attempting to improve the effectiveness of their own earth science programme delivery.

Outline of the Thesis

This Thesis is presented in seven chapters and additional appendices.

Chapter One details the background and reasons for the study. It considers the possible significance of the findings of the study. It outlines that aims, intentions and structure of the investigation and the thesis.

Chapter Two involves a review of the literature in fields relevant to the study. It considers (1) the history, structure and implementation of the New Zealand science curriculum as well as the place and implementation of earth science in New Zealand science education; (2) self-efficacy and it's influence of teaching and science teaching and (3) the dimensions and sources of professional science knowledge for teachers.

Chapter Three reviews the methodologies involved in the collection and interpretation of data in the study. It addresses the theoretical framework of the study and explains the authors' reasoning behind the data gathering techniques chosen and considers the methods used to analyse these data.

Chapter Four considers the data gathered in the first phase of data collection, the teacher survey. These data are analysed graphically and statistically using ANOVA and regression analyses. This chapter identifies commonly occurring trends and themes and makes some consideration in light of links with other relevant data and the work of previous researchers.

Chapter Five addresses the analysis of data gathered during the second phase of data collection, the teacher interviews. It considers teachers' responses and identifies commonly occurring themes in the light of results from phase one and existing research.

Chapter Six discusses the major findings of the study in the light of the findings of both phases of data collection and with due consideration to the findings of previous workers.

Chapter Seven reviews the processes involved in the execution of the study, considers the study's major findings and their significance. It discusses the implications of the limitations in the study methodology and implementation and makes recommendations for further research.

The appendices contain additional material that is pertinent to the study. It includes the survey used in phase one and the interview framework used in phase two. A thorough bibliography of the reference material used in the study is included.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Science Education in New Zealand

2.1.1 Introduction

Earth science is an interdisciplinary field that demands a broad range of knowledge to apply and to teach and us a useful medium for teaching other science subjects (Verdon, 1988). Although earth science subjects have been a part of New Zealand primary students' science education in various forms as long as science has been part of the curriculum, it was not until the release of *Science in the New Zealand Curriculum* in 1993 that earth sciences were distinguished as a discipline in its own right.

Science in the New Zealand Curriculum is a document that is a product of its history. As a societal construct, various economic, social and theoretical factors have shaped its content and intent. The purpose of this chapter is to explore the circumstances in which New Zealand primary science education, in particular earth science education, evolved. Firstly, this chapter will present an overview of the history and issues surrounding the development New Zealand science curriculum. It will then examine the history and structure of the *Making Sense of Planet Earth and Beyond* strand and will discuss a number of issues concerning the current science curriculum and, more specifically, issues relating to the delivery of earth science programmmes.

2.1.2 A History of Science Education in New Zealand

The history of the development of *Science in the New Zealand Curriculum* has taken place within a number of separate contexts, including research and development around science education and social and economic upheavals. Print (1993) discusses curriculum foundations, describing them as "the forces that influence and shape the minds of curriculum developers" (p.32). Such forces are often deeply rooted in a social milieu, making individual influences hard to differentiate. For science education in New Zealand, these influences are clear enough to discern and address separately, that is historically, politically and through research on best practice in education.

2.1.2.1 Early Science Education in New Zealand

The first New Zealand science curriculum was established in 1878. Its intention was to initiate understanding and use of the scientific method by training students in the skills of observation and deduction of facts from those observations (Bell, Jones & Carr, 1995). This programme suffered greatly from a lack of training in science content and pedagogy for teachers, along with lack of equipment, lack of time and pressure from subjects that teachers perceived as more important (Austin, 2001). Research in more recent times (Vallender, 1997; Hoskin, 2000; Lewthwaite, 2001; Lewthwaite, Stableford and Fisher 2001) suggests that such issues have not changed in over one hundred years.

In 1904, the original science curriculum was replaced in primary schools. The replacement, *Nature Study*, contained lists of suitable topics that included both physical and life sciences. The intention of this change was to allow teachers to select topics according to their interests while still providing a means for children to receive training in observation of common phenomena in the context of their surroundings (Bell *et.* a*l*, 1995). And included topics such as cycles, plant and animal structure, density and floatation, mechanics, soils, minerals, weather, astronomy, solvents and solutions, heat and temperature. Most importantly, there was a change in emphasis to teachers selecting topics according to their own preference and an accent on using local surroundings.

This was revised in 1929 and science divided into the disciplines of chemistry, and physics, with the addition of agriculture, dairy and general science. The difficulties associated with outdoor work were acknowledged but the practice was still encouraged (Bell *et.* a*l*, 1995).

2.1.2.2 Nature Study

In 1950 the revised syllabus *The Nature Study Syllabus* was issued. Though it shared a name similar to that devised in 1904, this syllabus placed more focus on the biological sciences. Though the requirement for students to study some physical science concepts was made *Nature Study* achieved its revitalisation of science education at the expense of disciplines such as chemistry. Though it was not explicitly acknowledged, *Nature Study,* through its ecological approach, included a number of earth science topics.

Though *Nature Study* provided students with excellent learning experiences, the agricultural emphasis of the primary syllabus was perceived as incongruent to New Zealand's economic goals. This, along with the events of the 1960's, especially the 'space race' between the United States and Russia, expedited the development of new curricula that emphasised the development of conceptual knowledge and investigative methods. Ironically, possibly because of the move away from *Nature Study* and the division of science into the separate disciplines, the curriculum has alienated primary teachers (Lewthwaite pers.com). This shift in emphasis from integrated to specialised science meant that teachers began to avoid teaching science that they perceived as too difficult. Aspects of earth science (along with a great deal of other science topics) that were often addressed as part of *Nature Study*, were abandoned.

2.1.2.3 The Curriculum Review

There had been a growing dissatisfaction with the state of science education in New Zealand. The science curriculum was seen as slow to respond to the change from "...a British farm to a post-industrial, independent trading nation" (Bell *et. al.* 1995, p. 5) it was seen as irrelevant to many students and made poor provision for Maori and Pacific Island students and for girls. The general direction for the entire school curriculum had become a topic for public debate, the forum for which was the Curriculum Review that began in 1984.

The results of the many submissions made during the Curriculum Review were assimilated and the discussion document, the Draft Curriculum Statement was promulgated in 1988. It was widely criticised. While educationalists appreciated its humanistic approach, other interested parties argued that "the Draft Curriculum Statement did not recognise that education should contribute to the material well-being and needs of society" (Bell *et. al.* 1995, p.9). There were also concerns about with the lack of knowledge (content) claims in the statement.

It must be noted that the review took place in a time of immense social and economic change. The influence of the treasury was considerable; from this point on the power of market forces could be identified in every aspect of the curriculum – especially in the *New Zealand Curriculum Framework.*

The *New Zealand Curriculum Framework* was openly market driven (Codd, 1998), even though it contained rhetoric that could be interpreted as humanistic, constructivist or otherwise. The structure of the New Zealand Curriculum Framework meant that the science curriculum would always contain aspects that reflect a rationalistic, structured design. That is, the extensive use of behavioural objectives and a focus on assessment. However, a rationalist curriculum design is somewhat incompatible with the main theoretical perspective underlying the development of *Science in the New Zealand Curriculum*: constructivist learning theory (Matthews, 1995, O'Neill, 1996/97).

Researchers developed the personal constructivist view of learning in the early 1980's. Particularly influential in this movement were researchers at Waikato University who worked on the *Learning in Science Projects* (LISP) funded by the Department of Education.

The results of LISP found that students enter learning situations as active participants with strongly held conceptions about science. These conceptions are often "Messy, Contradictory and Obstinately Persistent" (Solomon, 1983), but need to be identified and addressed in order to develop a scientific view (Skamp, 1997). Also introduced was the necessity of a relevant context in which learning can occur, rather than the abstract nature of most transmission learning.

2.1.2.4 The Draft Syllabus

The new, constructivist view of learning that the work of LISP generated began to assert considerable influence on the development of New Zealand science curriculum at around the same time as the curriculum review. The science syllabus at the time was regarded as "based on behaviourist and hierarchical views of learning" (Bell *et. al.*, 1995, p. 10). There was also a widespread view that science education needed to be based on a view of learning rather than based on content.

The *Draft Science Syllabus* was written over four years (1985 – 1989). It contained a strong philosophical change and introduced constructivism as a learning theory to science education in New Zealand. It emphasised making science education accessible to all students especially Maori and girls as expressed in the phrase "Science for All." Earth science was also introduced as a separate subject.

The draft syllabus, like the curriculum review, was criticised by the political right for its lack of clear learning outcomes, lack of labour market and economic considerations and for the advocating of the use of Te Reo Maori as a medium for teaching science. The curriculum would remain unchanged at this time. Instead, wide ranging systematic and administrative changes based on public choice theory, managerialism and transaction cost analysis (Codd, 1998) dominated the educational sector. The draft syllabus, with its focus on student learning was shelved.

2.1.3 Science in the New Zealand Curriculum

The current science curriculum, *Science in the New Zealand Curriculum* (Ministy of Education, 1993), began development in 1991 with an invitation for parties to express interest in its development. Mavis Haigh of the Auckland College of Education was awarded the contract and assembled a writing team to compile a draft document in six months (Bell *et. al.* 1995). The team consisted of 13 members, 11 were experienced primary and secondary teachers and 2 were staff from colleges of education. There was no representation by university staff, from either science or education. Matthews (1995) argues that because of the structure of the writing group the curriculum document fails to properly represent the nature of science and science education and that it falls short in a number of areas, most significantly in the area of sound understandings of the structures and concepts of science.

2.1.3.1 The Structure of the Curriculum Document

Science in the New Zealand Curriculum was the third curriculum statement written during the vast reformation of the curriculum in the 1990s. It delineates the general areas of scientific knowledge and skills and attitudes that students should attain through their studies of science in school. The curriculum statement was based on the principles and structures laid out in the *New Zealand Curriculum Framework.* The NZCF "Sets out the foundation policy for learning and assessment in schools" (Ministry of Education, 1993a, p. 1). Even though the framework was never gazetted, it has been used as a policy document on which to model the structure of each of the curriculum areas.

Science in the New Zealand Curriculum maintains that science is an integrated discipline that is "both a process of inquiry and a body of knowledge" (Ministry of Education, 1993, p. 14). To reflect this, and for ease of organisation, the curriculum is ordered into six strands. Four contextual strands – *Making Sense of the Living World, Making Sense of the Physical World, Making Sense of the Material World* and *Making Sense of Planet Earth and Beyond* – identify the broad areas of scientific knowledge. And two integrating strands – *Making Sense of the Nature of Science and its Relationship to Technology* and *Developing Scientific Skill and Attitudes* – aimed at developing the skills and attitudes associated with scientific inquiry. By integrating these two strands within the other, knowledge based, strands, the concept of science as both a process of inquiry and a body of knowledge is reinforced and a model of the nature of science is presented.

Each strand contains achievement aims to establish overall goals. While at each level more numerous and specific achievement objectives describe expected learning outcomes. *Science in the New Zealand Curriculum* explains that each of these objectives embody a mixture of knowledge, skills and attitudes and that it is important for teachers to recognise that development in these areas may require several units of study and incorporate a range of learning experiences. Knowledge based learning outcomes are not suggested in the document. Instead, *Science in the New Zealand Curriculum* presents a limited range of possible learning contexts and experiences at each level (Education Review Office, 1996). These learning contexts are limited in range and present no knowledge or skills requirement (Matthews, 1995).

Each of the strands in *Science in the New Zealand Curriculum* is divided into eight levels that describe the progression of science learning through the 13 years of school from junior primary to senior secondary education. The parameters of each level and their relevant achievement objectives is based on "the judgement of experienced teachers and on findings from recent research into learning in science" (Ministry of Education, 1993. p. 15). The document does not specify what research this is. *Science in the New Zealand Curriculum* notes that it is important for teachers to recognise that individuals learn at different rates and may achieve at different levels.

2.1.3.2 Problems of Balance and Coherence

The 1996 Education Review Office report on implementation of the then new science curriculum statement recognised that one of the critical barriers to successful implementation may well be the nature of the curriculum statement itself and the inability of teachers to professionally deliver what is required.

Kelly (in Education Forum, 1995), comments on how the tensions between various forces that influenced the nature and structure of the curriculum (for example the problems of balancing the needs of students with the needs of the present and future society) have created further tensions in areas of the curriculum. The *New Zealand Curriculum Framework* set out clear requirements tfor school science programmes.

> *The school curriculum will link all learning experiences within the total school programme in a coherent and balanced way. At all levels of schooling, programmes will be built on students' previous learning experiences, and will prepare them for future learning."*
>
> (Ministry of Education, 1993a, p. 7)

Kelly (in Education Forum, 1995) notes that the use of achievement objectives and learning strands such as in *Science in the New Zealand Curriculum* provides "a framework of entitlement and aspiration within which variety can exist." (p. 6). Such scope becomes problematic however, when the sheer magnitude of choice that is available to teachers is realised.

Science in the New Zealand Curriculum is deliberately non-prescriptive, presenting a conceptual model with little information or guidance about what schools and teachers must actually do in order to implement the science curriculum. No common core of content knowledge is suggested. This poses a problem of establishing an appropriate balance between coherence and variety as well as assessment issues (especially external, comparative assessment) where students from different schools receive widely different science experiences. Matthews (1995) notes that this leaves teachers that do not have the necessary background in science with little support in planning and implementing programmes, which may perpetuate existing scientific incompetence's.

The parameters of each level of the curriculum also appear inconsistent. Kelly (1995) points out that the range of levels that separate what should be considered varying degrees of competency appear to be arbitrary judgments that have no coherent progression. For instance, is the *Making Sense of Planet Earth and Beyond* strand Level 2 objective "Understand that the earth is very old and that animals and plants in past times were very different" (p.110) really of a higher order, or even of similar content to the Level 3 "Gather and present information about the origins and history of major features of the local landscape" (p.112). *Science in the New Zealand Curriculum* qualifies such composition, claiming that achievement objectives are based on the judgement of experienced teachers and that the clear definition of learning stages is not possible. Even with this qualification considered, the required levels of knowledge, skill and attitudinal development still appear shallow and arbitrary and do not appear to contribute to a coherent, progressive curriculum.

Lewthwaite, Stableford & Fisher (2001) found that the major external factor inhibiting effective implementation of the curriculum was lack of time resulting from the crowded nature of the curriculum and the low priority placed on science in primary schools. To maintain coherence and effective coverage of the curriculum, the *New Zealand Curriculum Framework* suggests that organising programmes around subjects by using an integrated or thematic approach can ease the load associated with the crowded curriculum and supply a means of providing a coherent and balanced curriculum. Though this too has been criticised.

Kelly (in Education Forum, 1995) argues that such suggestions are based on the assumption that what students learn (and as a result how they perform) is unrelated, or only loosely related to the way the curriculum is delivered. Such an assumption would mean that (to use Kelly's example) learning about environmental issues through a thematic or integrated approach will have the same quality and character as it would through a subject based course on ecology, which is highly unlikely.

One danger with the nature of the current science curriculum is that the priority of conceptually based knowledge development may be lowered to the point where the primary science curriculum could be regarded as "content-less" (Matthews, 1995). Yet it was the work of the LISP researchers, those that provided the theoretical underpinning of the curriculum, which emphasised the development of science concepts, albeit from the perspective of the student constructing such concepts and not the teacher 'transmitting' them. Harlen (1995), one of the many researchers involved in the constructivist movement in the 1980s, makes a strong argument for the development of scientific concepts to improve children's understanding. Poole (1995) also takes a position between the development of personal understanding and developing substantive scientific concepts.

It may be that teachers with insufficient subject matter knowledge will be unable to teach for conceptual development and revert to 'content-less' teaching. Such behaviours may be found in this research. Confusion over the aims or lack of content, combined with poor knowledge of earth science subject matter may contribute to weakly held efficacy beliefs. Also, the sometimes confused and contradictory nature of *Science in the New Zealand Curriculum* may have a negative influence on teachers' perceptions of their effectiveness in implementing earth science programmes in their classrooms.

2.1.4 The Making Sense of Planet Earth and Beyond Strand

2.1.4.1 History of Earth Science Education in New Zealand

Even though *Nature* Study contained a significant quantity of earth science material, its non-prescriptive character meant that it was not until the development of *Science in the New Zealand Curriculum* that earth science has had anything other than a minor role in school science programmes in New Zealand. Until 1991/92 earth science existed only in an *ad hoc* and non-prescriptive capacity and many schools had only to make reference to earth science (Munro, 1999).

Earth science as an independent element of a national, organised framework first appeared when it was introduced into the draft of *Science in the New Zealand Curriculum*. The content and structure of this draft borrowed many ideas from earth science programmes in other countries such as Australia and the United States (Wallace pers. com). From these international programmes, the proposed earth science strand derived four broad achievement aims that addressed: The composition of, and process, that shape planet earth, geological history, astronomy and environmental studies.

Such action was applauded by many organisations, such as the Geological Society of New Zealand.

> *"This is a very welcome and major change that appears to be supported by most teachers of science in the country, as they recognise that basic earth science literacy is very important in the everyday lives of all New Zealanders"*
>
> (Hayward & Lee, 1992)

The inclusion of earth science was appreciated also for it's integrative character, which could be useful in a draft syllabus that recommended the use of "an integrated thematic approach over several subject areas" (Author unknown).

With the excitement that greeted the inclusion of earth sciences, also came a number of cautions (Hayward & Lee, 1992). Primarily, that many teachers would not have sufficient training in earth science to teach the subject adequately.

In addition, not all greeted the prospect of earth science gaining equal status with the traditional subjects such as Physics, Chemistry and Biology with the same enthusiasm. Letters to the Geological Society Newsletter expressed concern over it's inclusion, arguing that introducing earth sciences to the secondary school curriculum would

> *"...further reduce the already limited amount of basic sciences in the secondary school curriculum...most earth scientists already have an inadequate background in basic sciences."*
>
> (Black and Buckridge, 1990)

To address teachers' lack of training in earth sciences, concerned organisations such as the New Zealand Geological Society recommended the development of inservice programmes and establishing advisors to assist teachers in their professional development. As well as training, shortages of teaching resources were anticipated by a number of groups.

> *"It is obvious that the implementation of the new science curriculum is going to require a massive input of earth science resource materials."*
>
> (Earth Science Education Group, 1993, p.2)

Parties such as the Earth Science Education Group recognised the need for development of a wide variety of resources – especially in the area fieldwork. It was recommended that earth science teaching materials be developed for local area fieldwork including regional field guides and codes of practice.

When *Science in the New Zealand Curriculum* was finally gazetted in 1993, the structure of the strand was still incoherent and many of the concerns of the earth science community were still not adequately addressed (Wallace, pers.com).

2.1.4.2 The Structure of the Strand

In the *Making Sense of Planet Earth and Beyond* strand learning emphasis is placed on developing students awareness of the unique nature of planet earth within the solar system and the need to value the planet's resources and the vulnerability of living things (Ministry of Education, 1993). Earth science achievement aims were adapted from other countries' earth science education programmes (author unknown) and contain four major themes that are carried through the school system.

1. The composition of planet Earth
2. The process that shape planet Earth
3. New Zealand's geological history
4. The movement of planet Earth in relationship to other objects in the heavens.
5. The need for responsible guardianship of the Earth and its recourses.

Science in the New Zealand Curriculum, like the draft syllabus, recommended that *Making Sense of Planet Earth and Beyond* be approached in an integrated manner and that secondary school science teachers work closely with teachers of social studies and geography.

Not unlike the other strands of *Science in the New Zealand Curriculum*, there has been concern regarding the appropriateness of the sequencing of the achievement objectives of the *Making Sense of Planet Earth and Beyond* strand (Kelly 1995). Concern was also expressed over the appropriateness of level some subjects were aimed at. It was felt by some, especially with the benefit of hindsight, that the *Making Sense of Planet Earth and Beyond* strand and the document as a whole was well intended but overly ambitious (Chapman, pers.com; Wallace pers. com).

2.1.4.3 The Status of Earth science Education in New Zealand

With the introduction of *Science in the New Zealand Curriculum*, earth science has been recognised as an important part of a balanced science education. However, the practicalities of equality have not been achieved. Even before *Science in the New Zealand Curriculum* was officially gazetted, senior level teachers expressed a concern that "some aspects of the new 'Planet Earth and Beyond' curriculum [may] trespass on their subject areas" (Lee, 1992, p.2).

Vallender (1997) contends that earth science "does not yet have equal status to the traditional disciplines of physics, chemistry and biology in the senior school" (p.15). In his study of Canterbury high schools, Vallender found that the majority of high school teachers did not want to offer general science to more senior students because of a lack of confidence and competence, particularly for the earth science section. Such difficulties are apparent in course offerings at such schools, where only 12% of the high schools in Vallender's study made earth science subjects available to senior (year 12 and 13) students.

In the 1996 School Certificate science examination, earth science accounted for only 5.3% of the paper. Question headings often failed to relate to the topic being questioned and were predominantly resource-based. That is, questions in the examination provided all the information necessary to answer correctly. This tends to reduce examination questions to comprehension exercises that demeans fundamental subject content. "Questions still appear to reflect an ignorance about what earth science is all about" (Vallender, 1997, p.15).

Lewthwaite *et. al.* (2001) found that the priority placed on science as a curriculum area was a moderate factor in influencing the effective implementation of science in schools. Though such an effect is only moderate, a low priority for earth science education, combined with other areas such inadequate teacher training, could have major implications in the delivery of the *Making Sense of Planet Earth and Beyond* strand.

2.1.4.4 The Delivery of Making Sense of Planet Earth and Beyond

Vallender's findings receive further support from the findings of other workers. In his survey of 122 primary, kura kaupapa and intermediate teachers, Lewthwaite (1999) found that teachers' perceptions of their competence in teaching earth science concepts from *Science in the New Zealand Curriculum* were as poor as those related to physical world or material world concepts – those subjects traditionally considered 'hard science'.

Table 1

Perceived Competence of Primary, Kura Kaupapa and Intermediate Teachers in Teaching Concepts of Making Sense of Planet Earth and Beyond

	Not a Significant Problem	Somewhat of a Problem	Serious Problem
Planet Earth and Beyond			
Composition of Planet Earth	57%	35%	8%
Processes that shape Planet Earth	59%	32%	7%
New Zealand geological history	48%	45%	11%
Movement of Planet Earth in relationship to other objects in the heavens	56%	37%	9%
Relevant environmental issues	68%	30%	3%

Teachers rated the theme *New Zealand's Geological History* as one of the concepts that teachers felt least competent in teaching, only slightly behind Electricity and Energy, in perceived difficulty. The earth's composition and celestial relationships were rated at similar levels. The self-efficacy based notion of 'perceived competence' in specific conceptual areas, along with the comments of teachers made in the study suggests that teachers' knowledge may play an important part in the delivery of earth science material.

Hoskin (2000) in his study of the status of earth science in secondary schools found that many teachers relied heavily on resources such as videos and textbooks and often resorted to didactic, teacher centred teaching strategies, when in other strands they would not. Lee (1995) found that reliance on resources and teacher centred strategies are a sign of low perceived subject matter knowledge and/or weakly held efficacy belief.

Teachers' knowledge of the material appears to be a major factor effecting implementation of earth science programmes. Lewthwaite, *et. al.* (2001) found that while external factors were the major inhibiting factors of effective science programme implementation, teachers' limited knowledge structures were also a significant contributing factor.

Such difficulties with confidence and knowledge, may relate to the relative 'newness' of earth science as a stand-alone subject. Though many earth science topics were major components of *Nature Study*, this programme was no longer in service when most of today's teachers were students. The conceptual understanding that most primary and intermediate teachers possess is often a narrow 'high school geography' view that is biased towards topics such as volcanoes or natural disasters (Vallender 1997) – not really adequate for teaching some of the concepts involved in *Making Sense of Planet Earth and Beyond*.

In this study the relative levels of teachers' professional knowledge in earth science may correlate to weaknesses in their self-efficacy belief. Knowledge of Earth science subject matter may be especially influential. However, if participants possess the 'limited view' of Earth science that Vallender (1997) discusses, then teachers may not be aware that any knowledge deficiency exists. This will be considered during this investigation.

2.1.5 Summary

Science education has had a long history of development in New Zealand. As a construct of society, the science curriculum has been influenced by a number of forces such as research in science and education, economic and political influences. This has resulted in the New Zealand science curriculum exhibiting traits of numerous – and often contradictory – philosophies on science education. This could have a negative influence on teachers' perceptions of their effectiveness in implementing earth science programmes in schools.

Earth science was introduced as a component of *Science in the New Zealand Curriculum* in 1993 as the *Making Sense of Planet Earth and Beyond* Strand. The strand encompassed four central 'themes' that provided the basis for the strand's achievement objectives. These themes were: The composition of planet Earth; The process that shape planet Earth; New Zealand's geological history; The movement of planet Earth in relationship to other objects in the heavens and The need for responsible guardianship of the earth and its resources.

Criticism of *Science in the New Zealand Curriculum* has largely directed at the lack of any prescribed knowledge requirement included in the document, leaving teachers to deal with what is described as a 'content-less' curriculum. This research may show that teachers with insufficient subject matter knowledge could revert to 'content-less' teaching that avoids addressing conceptual development.

When earth science was introduced to the curriculum, groups such as the earth science Education Group expressed concern over teachers' levels of understanding of earth science concepts. Consequent research into primary science education in New Zealand has found that many teachers hold low perceptions of their efficacy and competence as science teachers. Earth science is no exception, with many teachers perceiving their competence to teach portions of *Making Sense of Planet Earth and Beyond* (particularly New Zealand's geological history) to be a "serious problem". Teachers' perceived lack of knowledge of earth science subject matter could have a significant influence on their strength of efficacy belief.

2.2 Self-Efficacy

2.2.1 Introduction

The effects of personal efficacy beliefs on personal behaviour are well documented. This section will explore the notion of self-efficacy in the light of available research literature. The factors that define the self-efficacy construct will be examined. As well, the various effects self-efficacy beliefs have on teachers, particularly science teachers. The construct of teacher efficacy along with the possible mechanisms for examining such constructs will be considered in the light of the practicalities of this study.

2.2.2 Self-Efficacy Defined

The way teachers perceive their own ability to teach science is a major factor in the effectiveness of science programme delivery (Baker, 1994). How a person responds, behaves or performs in a given situation depends on both their cognitive and affective attributes of that person (Bandura, 1977). The construct that integrates these socio-cognitive factors with their behaviour and agency is self-efficacy.

"Perceived self-efficacy refers to belief in ones power to produce given levels of attainment" (Bandura, 1997, p. 382). Self-efficacy is deeply engrained in a person's belief in their ability to produce and regulate the events in their life. It helps in explaining the behaviours of many people: Why some people will choose to behave in one way while others choose to behave differently; Why some people put in substantial effort in a task while others place little; Or why some people persist where others would give up. A large and growing pool of research supports Bandura's assertion that self-efficacy beliefs have wide reaching implications, ranging from whether a person thinks productively or self-debilitatingly, how well they motivate themselves and persevere in the face of adversity, or their vulnerability to stress or depression.

Often, people use the term confidence when referring to beliefs of ability. However, there is a distinct difference between this everyday term and self-efficacy. Confidence is a largely nondescript term that refers to strength of belief but does not necessarily specify what the certainty is about (Bandura, 1997). In contrast, self-efficacy is a context specific assessment of competence to perform a task in a given domain. The important difference is the specific, agency related nature of the belief. A person can be supremely confident that they will fail at an endeavour.

A self-efficacy assessment, therefore, includes both an affirmation of a capability level and the strength of that belief. Bandura (1986) noted that in some situations or on some tasks individuals have strong self-efficacy beliefs while the same individuals have weak self-efficacy beliefs in different situations or when facing different tasks. Raudenbush, Rowan and Cheong (1992), made a study of high school teachers in sixteen schools. All taught a number of classes each day. These classes differed in size, grade level or academic content. Results of the study showed that self-efficacy varied across these various contexts, supporting Bandura's notion of the domain specific nature of self-efficacy.

2.2.2.1 Rotter's Locus of Control

Rotter (1975) describes locus of control as the extent to which reinforcement depends either on a person's own behaviour (an internal locus of control) or upon factors that are beyond the persons influence such as luck, chance or influential others (an external locus of control). Bandura (1997) contends that locus of control relates not to reinforced behaviour but rather to a person's perceptions of causal relationships between behaviour and outcome. It relates to the degree which people perceive sources of reinforcement as within their control – or otherwise, out of their control.

Self- efficacy and internal-external locus of control should not be misinterpreted as the same phenomenon measured at different levels of generality. Bandura (1997) clarifies the distinction between the two. He contends that beliefs as to whether one can produce certain actions (perceived self-efficacy) are not the same as beliefs about whether actions affect outcomes (locus of control). The key distinction between the two concepts is that self-efficacy relates to a persons belief in their ability to perform actions, and is therefore a strong predictor of behaviour whereas locus of control is primarily concerned with examining causal beliefs about the relationship between actions and outcomes (Tschannen-Moran, Woolfolk-Hoy & Hoy, 1998).

2.2.2.2 Outcome Expectancy

Another distinction must be made between self-efficacy beliefs and another social-cognitive construct, outcome expectancy. Outcome expectancy is defined as "A person's estimate that a given behaviour will lead to certain outcomes" (Bandura, 1977, p.193). That is, outcome expectancy refers to a person's beliefs about the likely consequences of certain behaviours in particular situations rather than whether a person believes they are capable of an action or not. This does not mean that the two constructs are not interrelated. Temporally, efficacy beliefs precede and assist in the formation of outcome expectations.

2.2.3 Self-Efficacy Dimensions

Three dimensions prove important when assessing efficacy beliefs. Bandura (1977) labelled these three dimensions as magnitude (often referred to as level), strength and generality. Level, or magnitude, refers to task demands within a given domain (Pijares, 2002). As an individual's perception of the difficulty of a task increases, the magnitude of efficacy is likely to lessen.

The strength of an individual's efficacy is demonstrated through their willingness to expend effort in difficult situations. Strong efficacy is demonstrated when individuals persevere in there efforts despite the presence of evidence which does not support these attempts at coping. The strength of self-efficacy is the factor most commonly associated with the term *confidence* (Maddux, 1995). The terms will be used interchangeably for the purposes of this study.

Self-efficacy beliefs differ in generality. Pijares (2002) notes that self-efficacy beliefs differ in their predictive power depending on the task and context the prediction is based upon. Generality of efficacy is indicated by how much efficacy held in one situation can be transferred to similar, and to progressively dissimilar situations. For example, as a result of effectively teaching a science lesson using a new learning/teaching strategy a teacher's self-efficacy may be enhanced. This strengthened perception of self-efficacy may generalise to similar situations where the teacher previously held weaker perceptions of self-efficacy.

Gibson and Dembo (1984) found that when dealing with measures of teachers' self-efficacy (part of a separate construct referred to as *Teacher Efficacy*), these dimensions apply slightly differently. They recommend that for teachers, magnitude is apparent in task difficulty, strength is indicated by the relative susceptibility to modification of self-efficacy beliefs, and generality relates to the extent to which teachers perceive self-efficacy in a variety of different teaching situations. This may have interesting implications for this research as factors such as background in science and pedagogical content knowledge may have implications for personal factors such as strength of self-efficacy beliefs, this may be evident in teachers' effort, resilience and affective factors more than other behaviours. Factors such as content knowledge may relate more to task difficulty and hence, have effects on the magnitude of self-efficacy, effecting factors such as task selection or avoidance, or persistence.

2.2.4 Effects of Self-Efficacy

Self-efficacy beliefs have an influence on several aspects of behaviour. Pijares (2002) notes that self-efficacy beliefs influence the choices people make and the courses of action they pursue. Individuals tend to select tasks and activities in which they feel competent and confident and avoid those in which they do not (Bandura, 1997; Maddux, 1995; Pajares, 2002). Unless a person believes that their actions will have the desired consequences, there is little reason to engage in them. A person with a strong sense of personal competence is more likely to perceive a difficult task as a challenge to be mastered rather than as a threat to be avoided.

> *"Beliefs of personal efficacy constitute the key factor of human agency. If people believe they have no power to produce results they will not attempt to make things happen"*
>
> (Bandura, 1997, p. 3).

Self-efficacy beliefs also help determine how much effort people will expend on an activity, how long they will persevere when confronting obstacles, and how resilient they will be in the face of adverse situations. The higher a person's sense of efficacy, the greater the effort, persistence, and resilience they will demonstrate. Maddux (1995) notes that people with a weak sense of personal efficacy are more likely to develop doubts of their ability to accomplish a task, whereas those with strong self-efficacy beliefs have greater interest in and stronger inclination towards activities. Such people set themselves challenging goals and maintain strong commitment to them and are more likely to intensify and sustain effort in the face of failure. He also notes that initiation and persistence at a task is influenced not only by beliefs of current competency but also by the expected rate of change in competence. This means that people are more likely to initiate and persist in activities when they expect rapid improvement in ability.

Self-efficacy beliefs have an influence on and are influenced by individuals' thoughts and emotional reactions in various situations. Pijares (2002) noted that strong perceptions of self-efficacy help create feelings of calmness in approaching difficult tasks and activities whereas low feelings of self-efficacy can lead to overestimation of the difficulty of a given situation, which can generate anxiety, stress, depression and limit views on how to best solve a problem.

Bandura's (1997) key contention regarding the effect of self-efficacy beliefs in human functioning is that *"people's level of motivation, affective states, and actions are based more on what they believe than on what is objectively true"* (p. 2). As a consequence, self-efficacy beliefs can strongly influence ones' level of accomplishment. Such a self-belief system can function in creating a self-fulfilling prophecy where a person accomplishes what they believe they can accomplish. A person's sense of their ability to produce and regulate events in life can be a powerful predictor of behaviour and to a lesser extent, performance. Numerous researchers (Frayne & Latham, 1986, 1987; Bezjak & Lee, 1990; Gibbs, 1994; Lawrence & Rubinson, 1986) through work in various fields have found that self-efficacy beliefs can act as predictive indicators of functioning. Such results provide the potential for a co-relation between teacher self-efficacy and earth science teaching performance.

2.2.5 Sources of Self-Efficacy

Bandura (1977) maintains that self-efficacy beliefs are constructed from four principal sources of information: enactive mastery experiences, vicarious experiences, verbal persuasion, and physiological and affective states.

2.2.5.1 Enactive Mastery Experiences

Experiences that serve as indicators of capability are the most powerful source of efficacy information as experience provides the most valid evidence of one's ability to do what is necessary to succeed. Authentic successes build belief in one's personal efficacy, while failures undermine it, especially if failures occur before one's sense of efficacy has been securely established. Bandura (1997) notes the importance of genuine success. Some difficulties and setbacks serve a beneficial purpose in teaching that success usually requires sustained effort.

2.2.5.2 Vicarious Experiences

Vicarious experiences can alter efficacy beliefs through transmission of competencies and comparison with the attainments of others. Bandura (1986) notes that although vicarious experiences are not as dependable or as stable as those induced by direct experience, that "vicarious forms [of experience] can produce significant, enduring changes through their effects on performance" (p. 400). The act of observing a social model succeed through sustained effort can raise the observer's belief that they too possess the capabilities required to deal with comparable activities and succeed. Conversely, observation of failure despite high effort can lower an observer's judgement of their own efficacy and could undermine their efforts (Bandura, 1994).

The impact of vicarious experience on perceived self-efficacy is strongly influenced by the learners' perception of the modeller's similarity to themselves. The greater the assumed similarity, the more persuasive are the model's successes and failures. People also seek models that are possessed of the skills and competencies to which they aspire. Through a models' behaviour and communicated metacognitions, observers can acquire the effective skills and strategies for dealing with challenges.

2.2.5.3 Verbal Persuasion

Verbal persuasion and similar types of social influence are another source of self-efficacy information. People who are verbally persuaded that they possess the necessary capabilities to master a given task are likely to exhibit more effort and sustain it longer than if they hold feelings of self doubt or dwell on personal deficiencies in the face of problems (Bandura, 1994). However, verbal persuasion in itself may be insufficient to induce enduring self-efficacy beliefs. Gibbs (1994), comments that those who are persuaded that they are capable of overcoming difficulties would probably exert more effort if their performances were supported by a model that is perceived as similar and proficient. However, Bandura (1994) warns that such a model must do more than simply convey positive affirmations. They must be careful to structure situations for their protégés that enable them to experience authentic success and avoid placing them in difficult situations prematurely.

2.2.5.4 Physiological and Affective States

People also judge their capable-ness, in part, from physiological and affective states such as anxiety, stress, arousal and mood states as well as physical fatigue. People can estimate their level of efficacy by the emotional state they experience when they contemplate an action. Pijares (2002) notes that powerful emotional reactions to a situation provide cues about the expected success or failure of the outcome. People often read their somatic activation in stressful situations as a sign of weakness or vulnerability to dysfunction. When people experience negative thoughts and fears about their capabilities, those affective reactions can themselves lower self-efficacy perceptions and trigger additional stress and agitation that help ensure the inadequate performance they fear (Bandura, 1997).

The intensity of the physical or emotional reaction is not as important as how such reactions are perceived and interpreted. Those with a high sense of self-efficacy are likely to interpret affective arousal as an "energising facilitator" (Bandura, 1997, p.108) of performance while those beleaguered by feelings of self-doubt perceive their arousal as debilitating.

Mood also effects self-efficacy. Mood states can distort how events and somatic cues are interpreted. People learn faster if the learning content is congruent with their mood and will exhibit better recall when in the same mood as when it was learned (Bower, 1981 in Bandura, 1997). Positive moods are likely to enhance perceived self-efficacy, while a pessimistic mood is likely to diminish it. Bower also found that the intensity of a mood has considerable influence on perceived self-efficacy changes. Intense moods exert stronger influence than weak ones, with the notable exception of despondency, which will retard almost everything.

One way to raise self-efficacy beliefs is to address somatic and emotional states, by improving physical and emotional well-being and reducing negative emotional states. Because individuals have the capability to alter their own thinking and feeling, enhanced self-efficacy beliefs can, in turn, powerfully influence the physiological states themselves.

2.2.6 Gender Differences

There are gender differences in self-efficacy. In a range of situations, women are less likely to report themselves as efficacious (Lenney, 1977 in Gibbs, 1994). One of the most researched fields in this matter is in career decision-making, where self-efficacy has been attributed as a predictor of career and academic indecision. Gibbs (1994) found that male elementary preservice and inservice teachers scored significantly higher on self-efficacy for science teaching than their female colleagues. Eisenberg, Martin & Fabes (1996, in Pijares 2002a) argue that a source of self-efficacy differences, may be a function of gender orientation – the stereotypical beliefs about gender that people hold – rather than of gender *per se*. Other sources of gender difference include parental portrayals and expectations school counsellors recommendations and even elementary school teachers conveying messages that some activities, such as mathematics, are too difficult for them (Pijares, 2002a). Given that the majority of primary teachers are female, these findings would suggest that gender differences in perceived efficacy in teaching earth science are important considerations in the gathering and interpretation of data in this research.

2.2.7 Teacher Efficacy

Teacher self-efficacy has become an important construct in the analysis of the role of the teacher in education. The notion that the extent to which a teacher believes that he or she has the capacity to affect student performance is appealing and has benefited from a great deal of research. Teacher efficacy has been related to student outcomes such as achievement (Ashton & Webb, 1986), motivation (Tschannen *et. al,* 1998), and sense of efficacy (Appleton & Kindt, 1999). It has also been related to teacher behaviour in the classroom.

Researchers have reported that teachers' beliefs of personal efficacy affect their instructional activities and their orientation toward the educational process (Tschannen *et. al,* 1998). Teachers with a strong sense of efficacy are more likely to be open to new ideas and more willing to experiment with new methods to better meet the needs of their students (Tschannen *et. al*, 1998) and tend to have greater levels of planning and organisation. Ashton and Webb (1986) found that teachers' efficacy had influence on their planning. Teachers with high efficacy tended to plan challenging activities for students while teachers with low efficacy tended to avoid planning activities that they believed exceeded their capabilities.

Riggs & Jesunathadas (1993, in Tschannen *et. al,* 1998) found that teachers with a higher sense of personal teaching efficacy reported spending more time teaching science and were more likely to spend an ample amount of time to develop the science concept being considered. Whereas teachers with low personal science teaching efficacy spent less time teaching science, used text based approaches over hands on, activity-based approaches and used cooperative learning less (Riggs, 1995). These same teachers were also less likely to choose to teach science.

Teacher efficacy has influence on other teacher behaviours. Evidence shows that teachers' beliefs in their instructional efficacy partly determine how they structure academic activities in the classroom. A study by Gibson and Dembo (1984, in Bandura, 1997) found that teachers with a high sense of instructional self-efficacy devoted more classroom time to academic activities, provided more guidance to students with difficulties and praised academic achievements. Teachers with low perceived efficacy spend more time on non-academic pastimes, readily give up on students that have difficulty and are more critical of failure and may not reteach content in ways students might better understand (Maddux 1995).

Classroom management strategies and class environment appear to be linked to teacher efficacy. High efficacy teachers tend to use positive strategies for classroom management, that is strategies aimed at increasing or encouraging desirable behaviours, through praise, encouragement, attention and rewards. Teachers with high efficacy tend to show more enthusiasm and commitment to teaching (Tschannen *et. al,* 1998).

Preservice teachers' sense of teacher efficacy is related to their beliefs about controlling students. Teachers with a low sense of efficacy tend to hold a custodial orientation that takes a pessimistic view of students' motivation, emphasizes rigid control of classroom behaviour, and relies on extrinsic inducements and negative sanctions to get students to study (Gibbs, 1994).

2.2.7.1 The Teacher Efficacy Construct

Initially, teacher-efficacy was based on the ideas of Rotter's locus of control to determine the extent to which teachers believed they could control the reinforcement of their actions, that is whether reinforcement of behaviours came from within themselves or from the environment. However the work of Bandura in 1977 identified teacher efficacy as a sub-type of self-efficacy.

The influence of these two separate but closely related constructs has contributed to a lack of clarity about the nature of teacher-efficacy. Studies of teacher efficacy have consistently found two dimensions to teacher efficacy (Tschannen *et. al,* 1998). The first factor, commonly referred to as personal teaching efficacy, relates to the teacher's own feelings of competence as a teacher. This is similar to self-efficacy, but related specifically to teaching. The second dimension is somewhat more contentious. Often it is referred to as general teaching efficacy but other labels such as "external influences" or "outcome expectancy" (Riggs & Enochs, 1990) have been used. The parameters of each of these dimension has been subject to many challenges and interpretations by numerous researchers, leaving a situation where the tool of measurement has received more attention that the matter in question.

2.2.8 Applications in the Teaching of Earth Science

Researchers have argued that the efficacy of those who teach can be maintained as a separate construct (Tschannen *et. al,* 1998) involving: beliefs of a teacher's own personal ability to produce the necessary levels of performance, an internal factor, as well as their beliefs in their ability to exert control on external factors that affect the learning of their students.

A number of behaviours could serve as useful predictors of teachers' strength of efficacy belief when teaching topics in the *Making Sense of Planet Earth and Beyond* strand. The effort teachers make in finding and developing resources for teaching may include; persistence in explaining concepts to students, or assisting students with difficulties; their feelings regarding the teaching of earth science; and perhaps most importantly, their choice behaviours, such as topic selection, lesson activities, academic content or avoidance of earth science subjects altogether. Such behaviours could provide insights into teachers' strength of belief in the context of this study.

The experiences and interests of teachers may also have an influence on teachers' efficacy beliefs. De Laat and Watters (1995) found that teachers with a long interest in science and a relatively strong background of formal science studies had a high personal science teaching self-efficacy. It can be predicted then that teachers with numerous and successful experiences with earth science will have more strongly held efficacy beliefs (be more confident) than those that do not.

Vicarious experiences are also noted as a powerful source of self-efficacy. It is possible then that teachers who have experienced effective earth science teaching – even as students – will maintain strongly held efficacy beliefs.

2.2.9 Summary

This section reviewed the findings of research concerning self-efficacy and teacher efficacy. These findings were presented and discussed in terms of their potential to explain the behaviours of teachers in the teaching of earth science.

The notion of self-efficacy includes the beliefs in one's capabilities to organise and execute the courses of action required to manage prospective situations. Four major influences on these beliefs are performance accomplishments or mastery experiences, vicarious experiences, verbal and social persuasion and affective factors such as emotional arousal. Research indicates that self-efficacy has considerable utility in explaining why some people are motivated to behave in certain ways and persist even against seemingly insurmountable odds.

Primary and intermediate school teachers' efficacy beliefs concerning the teaching of earth science are likely to be influenced by personal experience and interest and past experiences in the area, either as a teacher or student. Those with the strongest efficacy beliefs are more likely to show more enthusiasm and commitment to teaching earth science and are likely to put in more effort in teaching earth science concepts rather than transmission or text based learning.

2.3 Professional Science Knowledge

2.3.1 Introduction

The current trend in science teaching best practice is the use of constructivist teaching approaches with an emphasis on student's conceptual development. Such approaches place demands on teachers' own mastery of science concepts, as well as their ability to design useful learning activities, develop useful analogies and assess appropriately in accordance with institutional and curricular requirements. The place of an earth science teacher's knowledge in the complex system of constructivist learning and its influence on teacher self-efficacy is best considered in the light of the available research literature.

The purpose of this section is to review current literature on the place of knowledge in teaching, especially the teaching of earth science, to inform the selection of research methodologies and development of research questions. It will characterise teacher's professional knowledge as a multidimensional entity with varying effects on teachers' practices and perceptions of ability. It will explore the various dimensions of professional knowledge including subject matter, pedagogical and curricular knowledge with special reference to their application to earth science teaching. The influence of the various dimensions of knowledge on earth science teaching and teacher's self-efficacy is also explored.

2.3.2 Knowledge and Science Teaching

Teachers require a mastery of a body of knowledge in order to function (Shulman, 1987). The relationship between teachers' knowledge and their confidence in teaching, especially in science has been explored by a number of researchers, mostly with conflicting results.

Some studies suggest that that any link between knowledge and teacher efficacy is tenuous at best (Skamp, 1989, Appleton, 1992, in Baker 1994). One of the earliest studies on the subject of teacher knowledge (Dunkin and Biddle, 1974) failed to find any clear relationship between teachers' subject matter knowledge and the achievement of their students. Gooday Payne and Wilson (1993), in a comparative study of pre-service teacher education students, found that student in their fourth year felt considerably more capable as science teachers, even though their science knowledge was little different than first year.

Contrary to this, other researchers (Shulman, 1986, 1987; Symington and Hayes, 1989; Ginns & Watters 1995; Lee, 1995; Harlen, 1997; Vallender, 1997) make reference to the effects of knowledge structures on teachers' efficacy. Symington and Hayes (1989) found that primary teachers who lacked the necessary knowledge to teach aspects of science would develop lessons within their own understanding, or avoid teaching it altogether, an allusion that there is some relationship between teachers' professional science knowledge and their personal efficacy beliefs. A lack of science background (and the knowledge such a background brings) is commonly identified as a major influence on the effectiveness of science programme delivery (Symington, 1982, Baker, 1984).

What may be happening here is that differing perceptions of what knowledge *is* or what knowledge is most important in teaching may have influenced researchers methodologies or data gathering and handling processes. What may be occurring is that these studies examined the complex construct of teachers' knowledge too specifically. Harlen (1997) alludes to this situation. She asserts that background knowledge in primary science teaching is not as straight forward as whether the teacher understands certain concepts. This study will address professional science knowledge as a multidimensional entity, taking the perspective that *how much* knowledge a teacher possesses is less important (though still a factor) than *what kind* of knowledge a teacher has.

2.3.3 Types of Professional Knowledge

A number of researchers (Shulman, 1986, 1987; Symington and Hayes, 1989; Ellis, 1995; Harlen, 1997) have examined the area of what science teachers need to know in order to teach effectively. The fruits of such research are descriptions and dimensions of the various aspects of the knowledge that effective teachers possess. In Shulman's description, an effective teacher possesses a number of distinctive types of knowledge,

1. Subject matter (content) knowledge,
2. General pedagogical knowledge,
3. Pedagogical content knowledge,
4. Curricular knowledge,
5. Knowledge of learners,
6. Knowledge of educational contexts and
7. Knowledge of educational ends.

This quite comprehensive list is often simplified into three broader categories, subject matter knowledge, pedagogical knowledge and curricular knowledge, as each of these contains the other listed forms as subsets.

Shulman's categories have been elaborated upon since their initial development. Ellis (1995), who looked specifically at the knowledge frameworks of science teachers, describes five areas, developing the notion of content further into knowledge of the aspects of science that distinguish it form other subjects, as well as management of learning.

1. Content knowledge.
2. Syntactic or process knowledge.
3. Knowledge of the aspects of the subject that distinguish it from other forms of knowing.
4. Pedagogical content knowledge.
5. Management of learning.

The New Zealand Teacher Registration Board (NZQA, 2001) has taken a similar approach in detailing what behaviours a beginning teacher should possess in order to be an effective, professional teacher. Teachers must:

1. Display knowledge of content.
2. Display knowledge of relevant curriculum documents.
3. Employ teaching practices that reflect research of best practice.
4. Display knowledge of learners and appropriate teaching approaches.
5. Demonstrates knowledge of technology and resources.
6. Demonstrates knowledge of appropriate learning activities, programmes and assessment.

What this rather exhaustive and prescriptive list demonstrates is that effective teachers must possess and utilise a working knowledge that is multidimensional. The Teacher Registration Board describes the content of this list as professional teacher knowledge. The author will use the term professional science knowledge in this study.

2.3.4 The Sources of Professional Science Knowledge

Shulman (1987) motes that there are numerous sources for a teacher's knowledge base; 1) Scholarship in content disciplines, the content knowledge that is to be passed on to students; 2) The materials and settings of the institutionalised educational process – the matrix of forces within which a teacher operates; 3) Research on education – as a source of theoretical underpinnings for practice; and 4) The wisdom of practice itself, that little codified region relating to what is learned from experience.

These sources of knowledge (especially that of experience) may have implications for the depth and breadth of professional knowledge as well as the personal efficacy beliefs of teachers. External sources such as scholarship and institutional settings may have influences on a teacher's content knowledge base, knowledge of educational ends, knowledge of learners and the ability of the teacher to develop the links between these areas and create learning activities (or, more simply put, pedagogical content knowledge). Institutional settings may provide a powerful source of knowledge – in the form of local teaching practices and general management protocols – and experiences, a powerful source of self-efficacy beliefs. More internally based sources such as the wisdom of experience appear likely to influence self-efficacy beliefs through enactive mastery experience.

2.3.5 Subject Matter and Content Knowledge

The difficulty in establishing a consistent relationship encountered by early studies may be related to the fact that teacher subject matter knowledge, teacher confidence and student achievement have been inadequately conceptualised. Grossman, Wilson and Shulman, (1989) argue that knowledge of subject matter encompasses more than what is typically measured in standardised tests. Shulman (1986, 1987) argues that to think properly about content knowledge requires consideration beyond simple knowledge of facts or concepts within a domain. What is also required, Shulman states, is an understanding of the substantive and syntactic structures of the subject as well as the methods employed in studying or developing ideas within the field. Baker (1994) asserts, "Without a deep, integrated understanding of content, the potential for teachers to help children learn 'worthwhile' content is diminished" (p. 34).

2.3.5.1 Knowledge of Facts and Concepts

> *"In order to effectively develop students' understanding of science concepts it is essential that "teachers understand the concepts they are expected to teach".*
>
> (Ginns & Watters, 1995, p. 206)

Content knowledge refers to the 'stuff' of a discipline, the factual information organising principles and central concepts. In earth science education, such facts would relate primarily to the conceptual themes of *Making Sense of Planet Earth and Beyond* – The composition and processes of planet Earth, geological history, relationship of Earth to other celestial bodies, and responsible guardianship of the planet and its resources. Because earth sciences are often applications of concepts from numerous disciplines, understanding would involve a teacher having knowledge of concepts from other disciplines such as physics or biology.

Grossman, *et al.* (1989) claim that in addition to the ability to identify, define and discuss concepts an individual with a sound content knowledge can identify relationships among concepts in a field as well as relationships to concepts external to the discipline. This implies that teachers are required to have not just a working knowledge of a subject, but a sound comprehension. It is expected that teachers understand what they teach, and ideally, understand it in several different ways, so that they can relate ideas within a subject to other ideas within the same as well as other subjects.

Hoskin (2000) found that 47% of secondary teachers found *Making Sense of Planet Earth and Beyond* difficult to implement, an alarmingly high figure. Along with external influences such as lack of resources and assessment activities, the need for skills and knowledge was clearly identified. 15% of teachers in the survey believed they would benefit from courses that would improve their earth science content knowledge, while 21% felt the need for field skills and knowledge, particularly of the rocks, geology and geomorphology of their local area. Vallender (1997) found that 86% of teachers want or need more training in the earth sciences.

The study by Vallender (1997) also found that the subject matter knowledge of the participants in his survey (practicing teachers, primary teacher trainees, secondary teacher trainees and first year geology students) was "characterized by the influence of physical geography and snippets of earth science from year 9 and 10 Science" (p.81). Results also showed that perceptions of earth science of these participants mainly related to natural hazards such as volcanoes and earthquakes, and plate tectonics, with some knowledge about rocks and minerals. Concepts such as earth structure, palaeontology and earth history scored poorly.

A common argument against accentuating the importance of subject matter knowledge in teaching is that teaching and learning would become a process of knowledge transmission, a method denounced as ineffective in developing students' understanding of science (Skamp, 1997). Symington and Hayes (1989) disagree, stating that, "...the lack of necessary content knowledge has important implications for assisting ...primary teachers to improve their teaching" (p.278). Shulman (1987) contends that sound Subject matter knowledge can *improve* the practice of teachers:

> *"Indeed, we have reason to believe that teacher comprehension is more critical for the inquiry-oriented classroom that for it's more didactic alternative".*
>
> (p.7)

There is evidence to support this argument. Grossman *et al.* (1989) note the avoidance tactics of teachers if they do not possess the necessary content knowledge. Those that do teach with limited subject matter knowledge resort to reliance on textbooks and didactic approaches with little interaction with students (Lee, 1995).

Such evidence suggests the presence of a relationship between teachers' Subject matter knowledge and their perceived self-efficacy. It appears most likely that this will be manifested in teachers' choice or avoidance behaviour or teaching/learning practices. Limited subject matter knowledge may influence self-efficacy negatively, that is limited knowledge may reduce the strength of efficacy beliefs. Those teachers whose efficacy is weak may avoid 'difficult' subjects (Lee, 1995) or avoid topics that require conceptual development and stress process related activities instead (Harlen, 1997).

Further effects may be found in teachers' inability to translate subject matter content in to explanations and activities that are useful and meaningful to students. That is that a dearth of subject matter knowledge may influence a teacher's pedagogical content knowledge.

2.3.5.2 Substantive and Syntactic Structures

Baker (1994) notes the increasing emphasis on students learning the 'process' of science and argues that teachers must develop the 'process' portions of their subject matter knowledge, that is, their substantive and syntactic structures.

Content knowledge does not exist independently of the deeper structures and paradigms of a discipline. Rather, it is generated through a process of analysis that is guided by both the substantive and syntactic constructs of a discipline. The substantive structures of a discipline are the frameworks and paradigms that practitioners use to guide enquiry and to make sense of data. Substantive knowledge relates to the organisation and interpretation of knowledge in a field. In earth science, data supported by fieldwork, direct or indirect evidence or laboratory analysis provides the basis for generation of theories, models and explanations. Syntactic structures relate to how new knowledge is brought into and accepted in a discipline. For example, fieldwork practices would be one of the syntactic structures of earth sciences in that it provides data that is considered acceptable to the scientific community. Syntactic structures guide enquiry and provide grounds for judging whether evidence for new findings is acceptable or unacceptable, sufficient or insufficient.

Grossman *et al.* (1989) note that a teacher whose substantive or syntactic structures are deficient will have difficulty learning new information within their field as they are unable to distinguish between claims that are valid or apocryphal. They are also more likely to fail to include substantive and syntactic content in their curriculum and are at risk of misinterpreting the subject matter that they teach.

The current concept of 'best practice' in science education is to place emphasis on developing students' conceptual understanding (Baker 1994) as well as developing the necessary skills and attitudes with the aim of providing students with a sound knowledge and understanding of and about science. Baker (1994) argues that a teachers' knowledge of the explanatory frameworks and processes of knowledge acquisition, along with knowledge of content provide the basis for a development of a personal engagement with science. Ginns and Watters (1995) contend that if teachers possess conceptual misunderstandings, they will have difficulty identifying and correcting students' misunderstandings. Not possessing such a background may have negative affects on the processes that are the domain of pedagogical content knowledge.

2.3.6 Pedagogical Content Knowledge

Teaching involves a wide range of practices that relate more-or-less closely to the basic purpose of helping others to understand. Pedagogical content knowledge is of special interest because of its unique nature – that is, its use in knowledge transformation for the purposes of teaching. Shulman (1987) describes pedagogical content knowledge as "that special amalgam of content and pedagogy that is uniquely the province of teachers," (p.8). It involves a teacher combining the knowledge of subject matter and pedagogical knowledge and transforming their knowledge into something useful, relevant and comprehensible to students. pedagogical content knowledge is more than simple knowledge transformation and transmission, it itself involves a command of numerous strategies,

> *"...the most useful forms of representation of ideas, the most powerful analogies, illustrations examples, explanations and demonstrations – that is , the ways of representing and formulating the subject that make it comprehensible to others"*
>
> (Shulman, 1986, p.6).

In New Zealand, the extent to which teachers have adequate pedagogical content knowledge has an impact on the quality of classroom mathematics and science programmes, and the depth of learning and enjoyment by students, has been recognised (Education Review Office, 2000). The report by the Education Review Office (2000) regarded a lack of pedagogical science knowledge as a "serious issue"(p.100) that required addressing at policy, training and practical levels. It is interesting to note that this same report used a broad view of pedagogical content knowledge that includes within its definition "...knowledge about, and understanding of, the concepts involved in a curriculum topic"(p.29).

Williamson-McDiarmid, Lowenberg-Ball and Anderson (1989) argue that teachers, whether they are aware of it or not, are constantly engaged in a process of constructing and using instructional representations of subject matter knowledge. Shulman (1987) describes transformation of subject matter and the instruction process as the aspects of teachers' behaviours that relate most to the use of pedagogical Content Knowledge.

Translation of subject matter involves the teacher examining and critically interpreting the materials of instruction in terms of their own understanding of the subject matter. Shulman notes that such scrutiny is in the light of one's own comprehension and involves the teacher considering what aspects of the material is 'fit to be taught'.

Representation involves linking the key ideas and concepts in the lesson text (whatever form that text may take) and identifying the alternative ways that it can be represented for students. This includes the analogies, metaphors, activities and demonstrations that will help develop the students' comprehension. Multiple forms of representation are desirable as they can relate to the individual differences in students. Dagher (1995) found that the most effective analogies related to students' knowledge frames, could be elaborated upon, or were narrative in nature. Such analogies 'reduce the mystique of science' and make it understandable for students.

The implications of low pedagogical content knowledge or low efficacy are that useful material could be misinterpreted as 'unfit for teaching' and omitted, or material that is unfit for teaching is judged as suitable. Both have implications for students' learning, one of unnecessary censorship the other of being exposed to material that is unsuitable for them. Shulman (1987) found that teachers whose pedagogical content knowledge was insufficient had great difficulty translating the required content into meaningful activities or representations and adapting subject matter for students. Teachers in this situation reverted to didactic teaching approaches with very little student interaction or confirmation of learning. Personal anxiety related to uncertainty about content was also a significant factor.

The Education Review Office (2002) note that the task of developing learning outcomes, lesson progressions, which ideas are learned and learning experiences are greatly aided by a teacher possessing an "adequate science content knowledge" (p.15).

It is likely that teachers that express difficulty with lower pedagogical content knowledge will have difficulty translating the content of curricula or texts into learning material for students. This may coincide with weak self-efficacy beliefs. Evidence of this may include reverting to teacher centred teaching styles or comments on the difficulty in making meaningful activities for students.

It is likely that low levels of pedagogical content knowledge will correlate to low Subject matter knowledge. As Pardhan & Wheeler (2000) note, teachers need to have conceptual understanding in order to teach conceptual understanding.

2.3.7 General Pedagogical Knowledge

General pedagogical knowledge differs from Pedagogical content knowledge in that while pedagogical content knowledge relates to translating subject matter into something understandable to students, General Pedagogical Knowledge refers to those broad principles, beliefs, maxims and strategies of classroom management that appear to transcend subject matter.

In her study of pre-service teacher education students, Harlen (1997) found that fourth year student teachers had considerably greater confidence to teach science than first years students, despite possessing very similar levels of subject matter understanding. Harlen, notes that their increased general pedagogical skill may serve to create 'misplaced confidence' in such teachers. This may be manifested in teachers using their considerable teaching skills to avoid situations where their confidence is low or their knowledge inadequate.

In the present study is it likely that most teachers will have received training or exposure to current 'best practice' in science teaching. It is also likely that teachers' General Pedagogical Knowledge will be relatively independent of other forms of Professional Science Knowledge, as the same skills are used to teach in other subject areas. Additionally, teachers may exhibit 'misplaced confidence' in that they may perceive their confidence in teaching earth science to be high when their Subject matter knowledge, or Pedagogical content knowledge – or both – are poor.

2.3.8 Curricular Knowledge

Curricular knowledge refers to a teacher's grasp of materials and programmes that serve as their 'tools of the trade'. For teachers of earth science this could include, explanation and modelling skills, knowledge of available resources, fieldtrip organisation, planning and implementation as well as a working knowledge of the curriculum and its intent. Hoskin (2000) found that even though many high school teachers were uncomfortable teaching earth science topics, they still maintained quite positive perceptions of their understanding of the curriculum and its implementation. In this study it is likely that teachers will perceive their curricular knowledge to be quite sound when compared to other knowledge dimensions.

2.3.9Summary

This section considered the current literature on the place of knowledge in teaching. It characterised the many dimensions of professional science knowledge and considered some of the various effects these knowledge dimensions may have on teachers' practices and perceptions of efficacy. It also reviewed subject matter, pedagogical and curricular knowledge with consideration to their application in earth science teaching.

It appears that teachers' professional science knowledge may well influence self-efficacy in a substantial way, though the relationships may be less direct than simple anecdotal evidence appears to indicate. It is more likely that deficiencies in subject matter knowledge, general pedagogical knowledge and curricular knowledge influence teachers' self-efficacy indirectly, through their effect on their ability to turn material into teachable points (pedagogical content knowledge).

Deficiencies in any of these forms of knowledge, particularly Subject matter knowledge, are likely to inhibit the ability of a teacher to transform content into explanations, analogies and activities that are appropriate and useful to students. It is possible that limited subject matter knowledge, low pedagogical content knowledge and low self-efficacy beliefs will correlate.

Lack of subject matter knowledge may influence teachers' self-efficacy by reducing the strength of the teachers' belief that they can design and implement learning experiences for their students. This could be manifested in avoidance behaviour, limited repertoire (approach), and reliance on others and set texts.

2.4 Research Hypotheses

2.4.1 Hypothesis 1

Differences in background experiences in earth science will have noticeable effects on teachers' perceptions of their Professional science knowledge structures.

1.1 Teachers with positive background experiences in earth science will perceive their professional science knowledge to be well developed.

1.2 Teachers with little or poor background experience in earth science will perceive their professional science knowledge to be poorly developed.

Teachers' lack of perceived competence in teaching the *Making Sense of Planet Earth and Beyond* strand has been commonly attributed to a lack of background in earth science or science in general (Hoskin 2000, Lewthwaite, 2001). Vallender's (1997) study of New Zealand primary and secondary school teachers and first year earth science students revealed that many teachers maintain narrow and insufficient understandings of earth science concepts. With these findings considered, it is possible that a link between the strength of teachers' efficacy belief and their professional science knowledge does exist.

2.4.2 Hypothesis 2

The five constituent themes of the *Making Sense of Planet Earth and Beyond* strand will have different impacts on teachers' strength of efficacy belief.

2.1 *New Zealand's Geological History* will be perceived as the most difficult to teach of the five themes. Teachers will maintain the weakest self-efficacy beliefs in this topic.

2.2 *The Processes that Shape Planet Earth* will be perceived as the least difficult to teach of the five themes. Teachers will maintain stronger self-efficacy beliefs in this topic.

A number of researchers (Verdon, 1988, Lee, 1992, Vallender 1997) have made comment on the lack of exposure that many teachers have had to earth science topics. Vallender found that teachers understanding of earth science was essentially limited to 'high school geography' topics. This may mean that many teachers operate with limited conceptual understanding of the broad integrated nature of earth science. Teachers' strength of efficacy belief may be less in areas with which they are not familiar.

2.4.3 Hypothesis 3

Differences in background experiences in earth science will have noticeable effects on teachers' strength of efficacy belief (confidence).

3.1 Teachers with positive background experiences in earth science will maintain strongly held efficacy beliefs.

3.2 Teachers with little, or poor background experience in earth science will maintain strongly held efficacy beliefs.

De Laat and Watters (1995) found that teachers with high personal science teaching self-efficacy have had a long interest in science and a relatively strong background of formal studies with opportunities for exploring out of school activities. Tosun (2000) found that teachers were often very negative in their perceptions of science. He suggests that these negative feelings have and influence on science teaching self-efficacy. This may also be evident in this study.

2.4.4 Hypothesis 4

Each of the various professional science knowledge dimensions will exhibit varying degrees of influence on each other as well as on teachers' strength of efficacy belief.

4.1 Teachers with well-developed professional science knowledge frameworks will maintain the highest strength of efficacy belief.

4.2 Subject matter knowledge will have the greatest influence on earth science teachers' efficacy belief.

4.3 General pedagogical knowledge will have the least influence on earth science teachers' efficacy belief.

Shrigley (1974, in Tosun, 2000) discovered a weak correlation between science content knowledge and teacher attitude towards science. Lee (1995) noted that normally confident teachers would 'regress' to reliance on resources and didactic teaching strategies when teachers possessed inadequate subject matter knowledge. The influence of teachers' subject matter knowledge may be more significant when the subject matter is more specific. Harlen (1995) noted that some teachers felt confident despite a deficiency in subject matter knowledge. She found that teachers would often use their "considerable teaching skills" (general pedagogical knowledge) to avoid addressing topics where they felt uncomfortable.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This investigation involves gathering data on teachers' perceptions of their (1) professional science knowledge structures: (2) strength of efficacy belief and (3) professional and personal background information related to teaching, earth science, knowledge and confidence. The purpose of this chapter is to describe the methods of data collection used during this investigation. It will describe the initiation and early development of the study. It will also describe the methods used in data collection from a teachers survey and discuss the tasks that this survey incorporated. Furthermore, this chapter will describe the implementation and procedures undertaken during informant interviews of practising teachers.

3.2 Theoretical Framework

A number of factors have necessitated the use of an *ab initio* approach to the data gathering and interpretation process. This study is peculiar in that it attempts to find common themes and links between teachers' self-efficacy beliefs, their knowledge frameworks and their contributing factors within the context of earth science education in New Zealand schools – a concept that itself has had little exploration. Each of these conceptual areas is a complex entity in its own right and along with the incipient nature of the research has necessitated the use of multiple/mixed data collection methods.

For some years, an increasing number of educational researchers have claimed the merits of using multiple research methods. The convention of choosing either quantitative *or* qualitative approaches instead of combining the two forms has received some negative comment from a number of researchers (Bell, 1993; Cohen, Manion & Morrison, 2000). The work of previous researchers in areas similar to those involved in this study revealed a number of suitable methods, all of which could have applications in this study. Gibbs

(1994) in his research on student teacher efficacy towards teaching used a series of case studies that utilised standardised efficacy tests, and interviews to gather data. The work on teachers' and student teachers' perceptions of the New Zealand Science Curriculum by Lewthwaite (1999) gathered data through the use of a large-scale survey. Lee (1995) used a mix of observer case study and interviews, to get a picture of how teachers' knowledge of subject matter effected classroom management strategies, as well as formal and informal interviews to provide additional data.

Many elements of this study are essentially naturalistic and interpretivist in nature in that the study is contextually specific, exploratory and aimed at generating rather than testing theory. In this area, the study has strong links with grounded theory.

However, the study does not strictly adhere to the methodologies associated with grounded theory research. This study was largely emergent in nature; data gathering was, by reason of necessity, guided by the construction of tentative hypotheses generated from a review of literature from various related fields. It is seldom the goal of grounded theory research to generate generalisable theory, indeed it is often the goal of such research to generate extremely rich but extremely context specific theory. It was anticipated however that the results of this study may be applicable to a number of contexts, and in that matter, may be quite generalisable.

Although the use of quantitative methods such as survey is a departure from typical grounded theory methodology, Haig (1995) notes that it is necessary for grounded theory research to begin by focusing on an area of research and gather data from a variety of sources. This study will use two stages of data collection. The use of a survey would enable the construction of a basic framework of the knowledge-efficacy relationship that could then be further explored using more traditional, qualitative methods, in this case the use of teacher interviews. An interview phase will follow to develop the ideas identified in the survey and explore them in greater depth in order to develop a more distinct model of the knowledge – efficacy phenomenon.

3.3 The Research Procedure

The data collection in this study was split into two phases. The first phase of the study would be quantitative in nature and be used with the aim of obtaining a large body of information that could be analysed so that any possible relationships between teachers' knowledge frameworks and confidence in earth science teaching could be identified and comparisons made.

3.4 Phase One: The Teacher Survey

3.4.1 Participants

A letter of intent (Appendix A-1) was sent to the principals of 200 primary, full primary, contributing and intermediate schools in the Taranaki, Ruapehu, Wanganui, Manawatu, Palmerston North and Horowhenua districts of the western and central North Island.

It invited teachers to participate in a survey intending to explore the relationships between teachers' knowledge and their confidence in teaching in the *Making Sense of Planet Earth and Beyond* strand of *Science in the New Zealand Curriculum*. Teachers of all student year groups and levels of experience were invited to participate in the Phase one survey. It was hoped that participants would be a sample population that was representative of the teaching profession at large. That is, a large number of 'typical' primary school teachers.

3.4.2 Consent

Those who accepted the invitation to participate in the survey were mailed copies of the survey (Appendix B) along with return envelopes for reply. The letter of reply that contained the survey questionnaire included a cover sheet that stated the conditions of consent. This statement informed participants that involvement in the study was voluntary, that participation in the survey was completely anonymous and that only the author or the research supervisors would have access to their responses to the survey.

Participation in the survey implied consent.

3.4.3 Coding and Confidentiality

The questionnaires used in phase one did not require the participants to reveal their identity or produce any data that could be used to do so. Returned and completed questionnaires were numbered in the order of return. Any reference to specific data was done through this numbering system. Participants who consented to participate in Phase two were required to indicate their names and school. These data were not recorded or used in Phase one in any way.

3.4.4 Administering the Questionnaires

Participants in the survey were required to complete the survey form within a two-week period. The task requirements involved in the survey were explained as focusing on their own personal perceptions of the issues addressed in the survey and not whether their answers were 'right' or 'wrong'. Each questionnaire was expected to take between 30 and 40 minutes to complete.

3.5 The Teacher Survey Tasks

Phase one of the study would make use of a survey of practising teachers. The purposes of this initial phase were to gather data from a representative population of primary and intermediate teachers on:

1. Their backgrounds in, and feelings toward science and the teaching of earth science;
2. Their perceptions of their competence in teaching the strands of *Science in the New Zealand Curriculum*;
3. Their perceptions of the strength of their professional science knowledge frameworks in the various themes of *Making Sense of Planet Earth and Beyond*;

4. Their strength of efficacy belief (confidence) in a number of earth science teaching situations with variable knowledge requirements.

The questionnaire was developed to gather broad data on teachers' background in science and in earth science and perceptions of their professional science knowledge and strength of efficacy beliefs (confidence). To explore these constructs systematically, the questionnaire (Appendix B) was divided into three sections. Section one focused primarily on participants' backgrounds in science and earth science teaching. Section two was largely quantitative in nature and gathered data concerning teachers' perceptions of their professional science knowledge. Section three was also largely quantitative and explored the participants' strength of efficacy belief, or confidence, in teaching various earth science topics.

3.5.1 Section One: Background Information

Section one of the questionnaire intended to explore the science and teaching backgrounds of the participants. Section one addressed teacher biographical details including gender, length of teaching service, current teaching level, secondary school and teacher training experiences with science and earth science, relevant personal experiences with and personal feelings towards earth science. This background information would provide an additional basis for comparison of professional science knowledge and efficacy results.

3.5.2 Section Two: Teacher Knowledge Perceptions

The intention of section two of the survey was to gauge participants' perceptions of their professional science knowledge. The section was divided into five 'question clusters'. Each cluster addressed a different theme of the *Making Sense of Planet Earth and Beyond* strand and asked questions relating to each of the various dimensions of professional science knowledge.

Questions in Section Two addressed each of the knowledge dimensions identified by Shulman (1986, 1987) and described by the Teacher Registration Board and Education Review Office (2001). These dimensions were subject matter knowledge, pedagogical content knowledge, general pedagogical knowledge and curricular knowledge.

Questions in section two used a four-point Likert scale (1 – Strongly disagree, 2 – Disagree, 3 – Agree, 4 – Strongly Agree) and were grouped into question clusters. This was used to allow teachers to express their perceived level of competency in the five themes of *Making Sense of Planet Earth and Beyond.* Each learning area was addressed separately and contained scale-based questions concerning the participants' perceptions of; their subject matter knowledge; their ability to turn subject text into teachable information (pedagogical content knowledge) Their ability to implement meaningful learning activities in the classroom (general pedagogical knowledge), and their understanding of the curriculum tools (curricular knowledge). After each question cluster, teachers were also provided with opportunity to comment as they saw fit.

3.5.3 Section Three: Teacher Efficacy Perceptions

The final section of the questionnaire was to provide an estimation of teachers' efficacy beliefs when faced with the requirement of teaching Earth science topics where the subject matter content was prescriptive and possibly unfamiliar. To do this, participants were presented with five scenarios, each directed at different learning areas within the *Making Sense of Planet Earth and Beyond* strand.

Each scenario used question clusters that were modified from the generalised self-efficacy surveys developed by Schwarzer and Jerusalem (1993) and Schwarzer (1996). Each question clusters addressed in turn the main behavioural indicators of efficacy beliefs. These included task selection or avoidance, effort and persistence and associated positive or negative feelings in given situation of each scenario.

This tool, though not as accurate or broad as other, more intensive, perceived self-efficacy scales, would provide enough trend data for initial concepts identification; interview question generation and participant selection, which was suitable the purposes of the first phase of this study.

Each of these questions was placed in clusters based on earth science scenarios and used a four-point Likert scale (1 – Strongly disagree, 2 – Disagree, 3 – Agree, 4 – Strongly Agree) to gather participants' views. Participants were invited to comment on how they would approach the teaching of each scenario and make any further comments specific to the scenario.

The survey made extensive use of a four-point Likert scale. Though the Likert scale is most commonly used in a five-point format, workers have found that participants often assume a 'false neutral' or 'fence sitting' positions when presented with a neutral option such as '3' in a five-point scale (Brown, 2000, Sclove, 2001). Garland (1991) found that removal of mid points on Likert scales slightly reduced the effect of social desirability bias. That is, the desire of the respondents to please the interviewer or not give and answer that could be perceived to be socially unacceptable. This advantage is somewhat offset by the distortion in results that arises from the participants being forced to take a position. The positive or negative effect of this distortion is context specific.

The survey was tested using both four and five-point scales and, though the results were found to be slightly positively skewed, the tendency to 'fence sit' was effectively eliminated. Other advantages, such as a reduction in the size of the survey questionnaire and slightly easier interpretation of data afforded by a reduction in variables, were also found.

The questionnaire was tested on five participants and the results analysed in a manner similar to that used in the survey proper. The participants in the initial survey were asked to note how much time was taken completing the survey and make comments on ambiguous or unnecessary questions.

The response in testing was generally positive and required the implementation of only a few syntactical and formatting changes. No discernible difference was detected between the use of four or five point scales. Some Questions in Sections One and Two of the survey scenarios used in Section Three were reworded to reduce ambiguity.

3.5.4 Processing Survey Results

Results form the surveys were placed in an excel™ spreadsheet and tabulated to show means and standard deviations for the responses to section one of the questionnaire. Means and standard deviations were also calculated for the overall knowledge scores in section two and overall efficacy scores in section three. These scores were used for determining the sample population means and distribution and for later analysis. Using statistical procedures such as ANOVA, variables within and between these sections were extracted and compared. Qualitative responses were recorded for later use.

3.6 Phase Two: Teacher Interviews

In addition to simply defining the parameters of the study, further explorations of the area were required to provide some confirmation of the data found in the survey and perhaps gain a deeper understanding of teachers' perceptions. Using an additional method of data gathering would also serve to provide a source of triangulation among the data collected from questionnaires and review of literature (Leavitt, 1991), which could serve to improve the validity of any findings. To do this, Phase two of the study involved the use of semi-structured teacher interviews.

3.6.1 Participants

Participants for the second data collection phase were drawn from those respondents to Phase one who consented to take further part in the study. It was hoped that participants would be a sample population that was representative of the teaching profession at large and would cover a wide variety of permutations of any knowledge-efficacy relationship, interests and backgrounds in earth science.

3.6.2 Consent

Those participating in the teacher survey were invited to participate in Phase two, teacher interviews. The invitation included a statement with information on their rights as participants. Participants were informed of their right to decline to participate, refuse to answer any questions, withdraw from the study, decline to have interviews taped, and were assured that all steps to protect their identity would be made. Written consent was gained from those teachers that wished to participate.

3.6.3 Coding and Confidentiality

The teacher interviews were tape recorded, and transcripts made. Copies of these transcripts were sent to the interview participants to verify their responses with the invitation to add to or change any of their comments. Although the participants' names were used during the interviews, pseudonyms were used in their transcription, in the analyses of data and in the discussion of these data.

3.6.4 Administering the Interviews

Using the themes and trends identified in the survey, questions were generated to enable further exploration of any relationships. Such an exploration would provide further depth for the generation of theory and potentially provide validation for the new identified relationships that, due to the quantitative nature of most of the survey, existed largely as statistical correlations.

The interviews were arranged with the participants and were carried out at a time that was suitable for them. The interviews consisted of a set of open ended, guiding questions that were used to encourage the participants to share their perceptions of their background experiences, what attributes and knowledge they considered important in teaching Earth science and what influence (if any) such attributes and knowledge had on their confidence as teachers. Brief notes were taken during the process of the interviews and interviews were tape-recorded when permission was granted. Transcripts were made from these interviews and used along with personal notes for analysis.

3.7 The Interview Tasks

Interviews are one of the most commonly used methods for gathering qualitative data. Interviews are useful as a data gathering technique as can provide information in great depth (Drew, Hardman & Weaver-Hart, 1996). It was anticipated that the survey used in phase one would reveal a number of repeating 'themes' and reveal a number of trends. As with many questionnaire-based data gathering techniques the survey used in phase one would yield large amounts of fairly 'shallow' information (Bell, 1993; Cohen, *et. al.* 2000). The aim of using interviews in a second phase of data collection was to gather additional, elaborative information on the themes and trends that were recurrent in phase one and, by so doing, gain a deeper understanding of the relationships that were revealed.

The interviews were semi-structured in character. In these interviews emphasis was placed more on the interviewee's responses rather than the adherence to a rigid path of set questions. This provided the participants with the "...freedom to introduce materials not anticipated by the interviewer" (Taylor, 2001, p. 65). Drew, *et. al.* (1996) also stress the importance of the interviewee being able to provide information that the researcher had not anticipated, and consider semi-structured or open interviews a very effective method of qualitative data gathering.

The interviews made use of a framework of open-ended questions (Appendix C) designed to elicit free and relaxed responses from the participants. These questions addressed personal beliefs and opinions on the influences of their background experiences, the talents, skills and knowledge of effective science teachers and their personal efficacy beliefs. The recurrent themes the interviews addressed were: (1) the influences of background experiences on teachers' efficacy; (2) teachers' perceptions of the value of different knowledge structures; (3) teacher' efficacy beliefs in teaching earth science and (4) and additional factors that affect the delivery of earth science. After the completion of the interviews, permission for additional interviews, if they were required, was sought from participants.

3.7.1 Processing Interview Results

These interviews were transcribed, then analysed with aid from NUD*IST qualitative data management software. Analysis involved exploring recurrent themes and phrases and comparing with trend revealed in Phase one. Qualitative data gathered during Phase one as well as data gathered by permission in unrecorded conversations was included in these analyses.

3.8 Summary

This study involved the identification and description of relationships between teachers' professional science knowledge structures and their strength of efficacy belief (confidence) in teaching earth science. This required the qualitative and quantitative identification and validation of teachers' perceived levels of self-efficacy and professional science knowledge and exploration of potentially related, or causal, factors such as background in formal science education and intrinsic interest in earth science.

Initial data were gathered in using questionnaires of practicing primary and intermediate teachers. The interviews contained questions on earth science and teaching background and made use of basic instruments designed to measure teachers' perceptions of their knowledge frameworks in earth science education and a modified generalised self-efficacy tool. This survey was intended to gather board data for future extraction and comparison for identification of trends and common themes.

These trends and common themes were further explored using semi-structured teacher interviews to provide deep information on the relationships between teachers' knowledge frameworks and confidence in earth science teaching.

For each phase of data gathering, procedure, consensual issues, confidentiality, development of tools and administration of the data gathering procedures were described.

CHAPTER 4

PHASE ONE RESULTS

4.1 Introduction

This study focuses on establishing the nature of and parameters for relationships between the professional science knowledge of primary and intermediate teachers and their confidence in teaching in the *Making Sense of Planet Earth and Beyond* strand of *Science in the New Zealand Curriculum.* Phase one of this study is intended to determine the existence of any such relationships and, if found, determine the influence of, and contributing factors to, such relationships. This chapter describes the implementation and results of a survey of primary and intermediate teachers and describes the trends and patterns revealed so as to provide direction for further study of the phenomenon.

4.2 Response to Phase One

A request for interest in participating in the teacher survey was sent to the principals of 200 schools in the lower North Island. Of these requests, nine responses were positive and 29 teachers consented to take part in Phase One. 87% of the schools that responded to the request were small (< 50 students) or middle sized (<150 students) and located in small or rural communities. Of those schools that declined to participate, the most common reason for declining to take part was that the teachers in the schools were already too busy to take part. Commonly cited reasons were high teacher workload, Education Review Office evaluation and, most commonly, participation in other research projects, either scholarly or governmental.

Eighteen teachers, representing eight schools completed the survey. Even though the response to the survey was small, a reasonably broad range of class levels was represented. The majority (47%) of the teachers that responded to the survey taught senior primary and intermediate school classes, that is, year 6 to 8. 32% of respondents taught middle primary classes, years 3 to 5, while 21% of respondents taught at junior primary level, years 0 to 2. 16% taught classes at more than one of these levels. Most of the respondents taught mixed year group classes of usually two, but up to four year groups in a single class. Only 10.5% of teachers in this survey taught a single year group.

The average class size of the teachers that responded was 22 children, but was highly variable. The smallest class size was four students, while the largest had 34 students.

The average experience level of the respondents was 10.4 years, though this was also highly variable. The least experienced teacher was in their very first term as a full-time teacher while the most experienced respondent had been teaching for over 35 years. The largest group of respondents (47%) had taught for five years or less, half of this group were in their first two years of teaching. 17% had taught for between 5 and 10 years, 11% for between 10 and 15 years and remaining 24% had more than 15 years of teaching experience. These results are different to those found by the Education Review Office (2001) in that the sample population of experienced teachers is slightly underrepresented. Education Review Office (2001) noted that the experience distribution was slightly bimodal. The current distribution of experience in primary schools has a similar large numbers of 'new' teachers and similarly few teachers with 'moderate' experience while teachers with more than 15 years of teaching experience were more common than moderately experienced teachers. This small variation in population distribution may have implications on the validity of the findings of this study.

The most commonly held qualification was a teaching diploma (Dip Tchg) and Bachelor of Education (B Ed). One participant had a tertiary science qualification (BSc), though the major was not stated. One participant held an overseas teacher education qualification.

84% of the respondents to the survey were women.

4.3 Process

To protect the identity of those who responded to the survey, completed questionnaires were numbered in the order of return. Any reference to specific data or comments made by respondents was done through this numbering system.

Data gathered in the survey were analysed using methods appropriate to the data. That is, sections of the survey that were qualitative in nature were examined for common phases, trends and intimations, that a common picture might develop. These data would also allow for the categorising of the participants to a limited extent. Such categories may be useful when compared with quantitative data. Sections of the survey involving the collection of quantitative data were analysed using statistical methods. ANOVA and multiple regression analyses were used where appropriate.

4.4 Teachers' Backgrounds

Section one of the questionnaire was designed to establish the earth science background of the participants. Most questions in section one required the participants to comment on their perceptions of their background in earth science. Questions related to experiences at high school, in preservice teacher education, in university study or informal study. Accordingly, the information provided in this section was largely qualitative in nature. The data were recorded and grouped by common themes and phrases pertaining to science background, experiences or interests, or grouped into areas of common interest, such as student class levels or experience as a teacher.

For most of the teachers in the study, school science background was quite limited. Though 61% of the participants had taken *some* science in high school, few had taken anything other than a compulsory science curriculum delivery course during their pre-service teacher education. 45% of the participants had taken geography in high school. For most this was their only exposure to earth science as a subject.

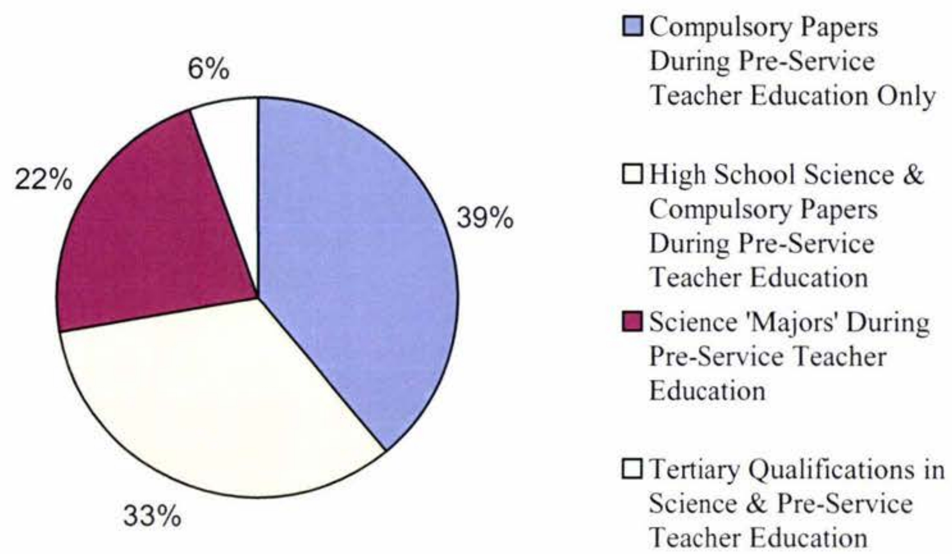

Figure 1. Participants' formal background in science.

Most respondents could remember very little about the earth science that they experienced as school students. Those few that did mentioned 'doing' the solar system, making models of planets, field trips or high school geography.

> *"Very little that I recall, many basics that I have been teaching the children have been new information for me also".*
>
> (Respondent 6)

> *"I can't remember, that must reflect how interesting it was and how much I really learned about it".*
>
> (Respondent 17)

4.4.1 Background and Efficacy Belief

Teachers with low perceptions of their knowledge and efficacy expressed generally negative opinions of the usefulness of their informal, high school, or pre-service teacher education experiences in helping them to teach earth science. This was also the largest 'category' of respondents. 37% of the participants in the survey perceived their professional science knowledge to be at a level below the calculated mean (2.93, SD 0.60) and held efficacy beliefs weaker than the calculated mean (3.14, SD 0.59).

> *"I felt the whole science curriculum paper wasted my time. Our lecturer had little idea of what he was doing. I feel very unprepared".*
>
> (Respondent 17)

Conversely, 23% of respondents had high perceptions of their knowledge and efficacy. These teachers expressed generally positive opinions of the usefulness of their pre-service teacher education in preparing them to teach earth science.

> *"I chose to do extra papers in science therefore I feel reasonably prepared".*
>
> (Respondent 3)

> *"[Teachers' College] gave me more confidence"*
>
> (Respondent 3)

Though it is suggested by these data, a clear relationship between positive feelings about previous formal study in science and perceived efficacy cannot be so simply established. A large proportion of the responses (39%) revealed relationships between background experience, teacher professional knowledge and self-efficacy that are in some way more complex. 22% of participants perceived their knowledge to be low but still remained highly efficacious. Their comments on the effects pre-service teacher education had on their confidence in teaching science were generally positive.

> "[Teachers college was]...*Of some help - I wouldn't say I'm an expert at all but it has given me some confidence".*
>
> (Respondent 16)

> *"I was given a positive attitude to approaching teaching all science areas".*
>
> (Respondent 6)

One group (17%) could be 'categorised' as having weaker than average efficacy beliefs despite stronger than average perceptions of their professional knowledge. These teachers often made negative comments about their pre service education.

"Planning, Resources, Teaching. Could have been more practical".

(Respondent 2)

"At college it was very brief over all the strands".

(Respondent 10)

4.4.2 Efficacy, Knowledge and Background in Science

Data provided by Section One of the survey was then compared to aspects of Section Two, which addressed teachers' perceptions of their Professional Science Knowledge, and section three which addressed teachers' efficacy beliefs in teaching earth science.

Participants' backgrounds in earth science and science teaching were examined and compared with overall professional science knowledge scores (K) and overall efficacy scores (E). Four categories, classified by K and E score combinations, were found. The first two categories related to opposite ends of the K-E relationship spectrum. Teachers with higher than mean K scores (> 2.93) as well as higher than mean E scores (> 3.14) were classified as 'Hihi' teachers. Teachers with lower than mean K scores (< 2.93) and lower than mean E scores (< 3.14) were classified 'Lolo'.

Two intermediate categories were also generated, Hilo, referring to teachers with higher than mean K scores and lower than mean E scores and Lohi, referring to those teachers with lower than mean K scores and higher than mean E scores. Teachers' comments on their background in science were then compared with their 'category' placing. Rather fortunately, teachers' backgrounds in science could be fitted into four categories; 1) those whose only science background was the compulsory papers provided by pre-service teacher education; 2) pre-service teacher education plus high school science; 3) science 'majors' – those who took optional science papers during pre-service teacher education and 4) those with tertiary science qualifications.

Table 2

Comparison of teachers' background in science with knowledge-efficacy categories.

	Lolo	Lohi	Hilo	Hihi
Compulsory Papers During Preservice Training Only	////	/	//	
High School Science & Compulsory Papers During Preservice Training	//	//	/	/
Science 'Majors' in Preservice Training		/		///
Tertiary Qualifications in Science & Preservice Training	/			

n = 18

The two largest clusters of participants were placed at opposite ends of the K-E relationship spectrum. They also had rather different backgrounds in science. Teachers that had little background in science, in this study, that is only the compulsory science education papers during pre-service teacher education were most likely to exhibit low perceptions of their professional science knowledge as well as maintain weakly held efficacy beliefs. That is, they felt they had weak knowledge structures and felt less confident.

Conversely, participants who had taken optional science papers during pre-service teacher education displayed perceptions of their professional science knowledge that were higher than mean as well as having strong efficacy beliefs. That is, they thought themselves more knowledgeable and felt more confident.

It is also interesting to note the distribution of the intermediate categories. These data (table 2) suggest that background in science may effect the strength teachers' efficacy beliefs more than perceived knowledge.

A second, smaller, group of participants whose science background consisted solely of compulsory papers during pre-service teacher education was also positioned in the Hilo category. This could indicate that even when teachers with a limited earth science background perceived their knowledge to be strong, they held weaker than average efficacy beliefs. Similarly, the only outlying result of science 'major' participants is classified as a Lohi. That is, they felt that their knowledge was poorer than average, but still maintained strong efficacy beliefs.

An interesting irregularity in this comparison is the result of the only person in the study to hold a tertiary science qualification (See Table 2). This person had an efficacy (E) score below the sample mean (K = 2.702, mean K = 2.927) as well as a perceived knowledge (K) score that was below the sample mean (E = 3.060, mean E = 3.143).

These data show that there is a trend between science background and strength of efficacy belief. De Laat and Watters (1995) found that highly efficacious teachers had, in general, a long history of science that has been successful or at least generated interest. Consistent with these findings, participants in the 'science major' category have been exposed to more science that they generally perceived as positive.

> *"It helped me gain 'authority' in the area; built confidence in preparation of lessons and curriculum delivery".*
>
> (Respondent 8)

An area for further exploration is the influence additional, optional studies in science subjects, has on teachers' knowledge structures. Data from table 2, qualitative responses of participants and the results of previous workers in similar areas (de Laat & Watters, 1995) suggest that a positive background in science has considerable positive effects on personal and teaching efficacy. It is possible then, that such a background also has some effect on the various knowledge structures that they possess.

It is also possible that 'majors' have had more exposure to the modelling provided by competent practitioners, have participated in activities that can be transferred to classroom level, as well as receiving a stronger subject matter base. This too will require further exploration.

4.4.3 Gender Differences

Figure 2 indicates that men perceived themselves as more efficacious and more knowledgeable than women.

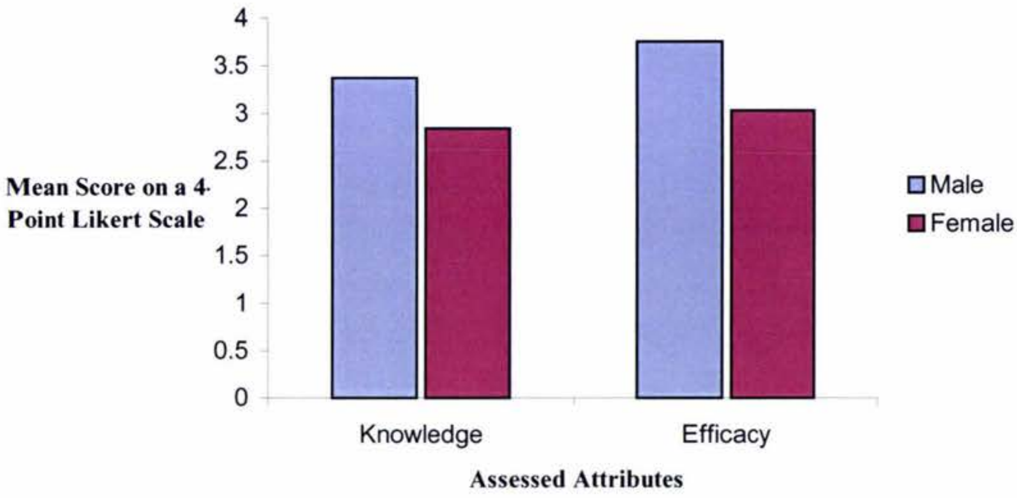

Figure 2. Comparison by gender of perceptions of knowledge and efficacy in the teaching of the *Making Sense of Planet Earth and Beyond* strand.

Men perceived themselves as more knowledgeable and more confident than their women colleagues. These results were significant (SD = 0.32). Male teachers in this survey also appear to have had a stronger background in science. 66% of male respondents to the survey were classified as 'majors', while only 13% of the female respondents could be classified as 'majors'.

This is congruent with the work of previous researchers (Gibbs, 1994, De Laat & Watters 1995). These results may concur with the findings of Pijares (2002), that such efficacy beliefs are a function of gender stereotyping rather than gender *per se*. This result may reflect the continued existence of the belief that science (in this case, Earth Science) is a subject that is better suited for boys. This will also provide an interesting avenue for further exploration.

4.4.4 Class Size and Student Age Group

Data relating to teachers' strength of efficacy belief were compared with class size and student age group data to determine the existence of any relationship between these variables.

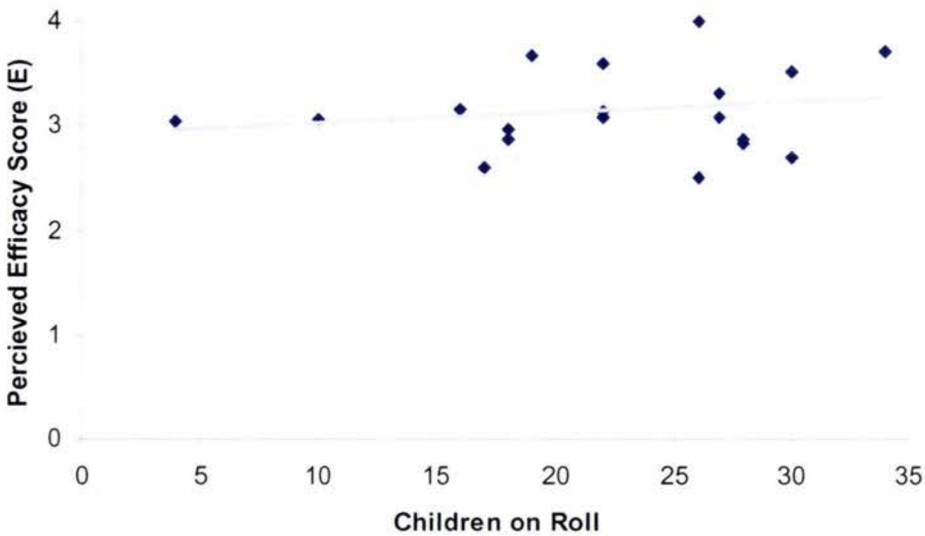

Figure 3. Comparison of class size with teachers' efficacy scores.

Figure 4. Comparison of class year group with teachers' efficacy scores.

The data generated revealed that class size and student age group appear to have little impact on the strength of teachers' efficacy beliefs when teaching Earth Science. Generation of graphs and a regression analysis revealed that there is no discernable relationship between teachers' strength of self-efficacy beliefs and the size of the class they teach (R = 0.19, $P = 0.45$) and no relationship between teachers' strength of self-efficacy beliefs and the age group of their students could be found (R = 0.034, $P = 0.89$).

4.4.5 Teaching Experience

Data relating to teaching experience were compared with data relating to professional science knowledge and strength of efficacy belief to determine the existence or strength of any relationship between these variables.

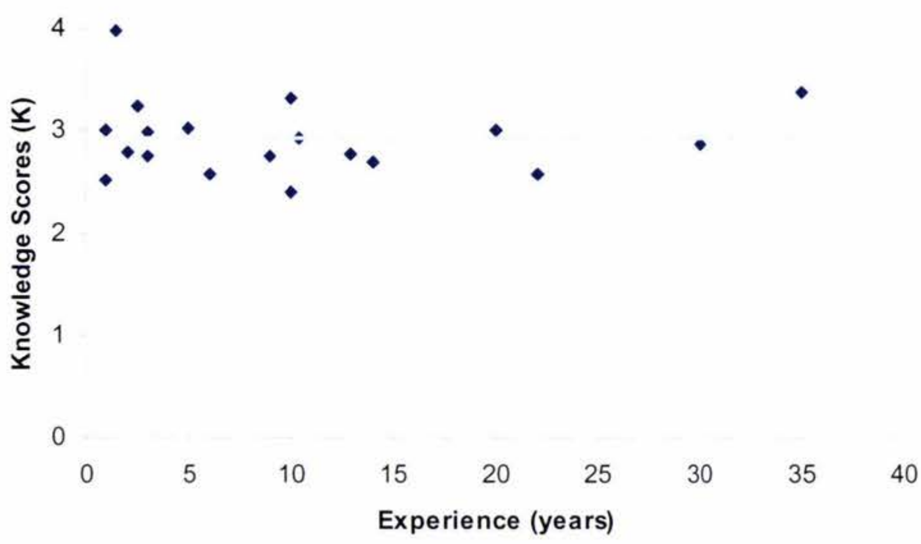

Figure 5. Comparison of teachers' experience and perceived knowledge scores.

Data relating to teacher experience were compared with K scores. Though the trend line in Figure 5 shows no increase or decrease in K scores as teachers become more experienced. The strength of any correlation (R) was very weak indeed, effectively no correlation could be found (R = <0.0001). The small sample size and large cluster of teachers with less than 15 years of teaching experience tends to make any trend line added to this scattergram quite arbitrary. A regression analysis of the data confirmed that with the current data the variance between the two data groups could not be explained (R^2 = >0.0001, $P = 0.99$).

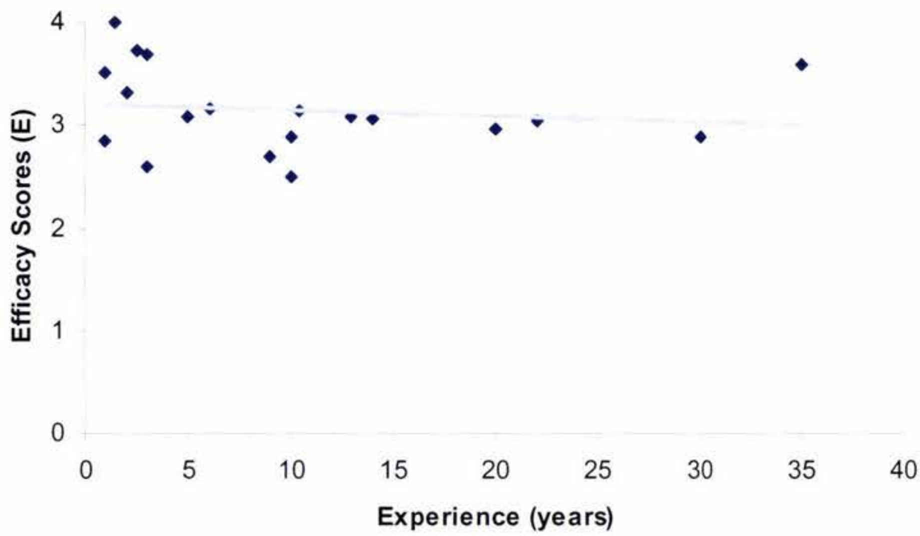

Figure 6. Comparison of teachers' experience and efficacy scores.

When comparing E scores with experience, a similar situation occurred. Though a trend line, added for visual interpretation, revealed a downward trend in efficacy over time, any relationship between these two factors could not be considered valid (R = 0.14). A regression analysis (R^2) found that the variance between the data could not be meaningfully explained and were not quite significant. ($R^2 = 0.02$, $P = 0.55$).

4.5 Teachers' Perceptions of their Professional Science Knowledge

Section two of the survey was intended to gain a perspective on the professional science knowledge frameworks of the participants. It did not attempt to quantify or make judgement of teachers' abilities or level of understanding. Instead it was designed to get information on teachers' *perceptions* of various, earth science related, aspects of their professional knowledge. The tools used to investigate these perceptions asked questions in contexts related to the five "themes" of the *Making Sense of Planet Earth and Beyond* strand. That is, the composition of planet Earth, the processes that shape planet Earth, New Zealand's geological history, the movement of planet Earth in relationship to the heavens and guardianship of the Earth and its resources.

Each question cluster required the participants to use a 4-point Likert scale to answer questions related to various dimensions of their professional science knowledge. Specifically, subject matter knowledge (SMK), pedagogical content knowledge (PCK), general pedagogical knowledge (GPK), all of which relate to turning subject matter into meaningful, concept based activities for students, and curricular knowledge (CK), which relates to teachers understanding of the place of earth science in the curriculum and the activities and resources that are useful in teaching it.

Data from this section were largely quantitative, though participants were invited to comment about each "theme" in each question cluster. The participants' answers were recorded and combined in order to generate overall scores. Data on each theme used individual question clusters.

4.5.1 Perceptions of Strand Difficulty

Teachers were further asked to rank the strands of *Science in the New Zealand Curriculum* in order of difficulty.

Table 3.

Difficulty of the strands of *Science in the New Zealand Curriculum*, as perceived by primary, and intermediate teachers.

	Extremely Difficult	Difficult	Easy	Extremely Easy	Mean Score	SD
Living World	-	6%	61%	33%	3.33	0.60
Physical World	11%	22%	50%	17%	2.72	0.89
Material World	-	39%	50%	11%	2.72	0.67
Planet Earth and Beyond	-	28%	56%	17%	2.89	0.68
Scientific Skills and Attitudes	6%	11%	56%	28%	3.06	0.80
The Nature of Science and Its Relationship to Technology	-	33%	61%	6%	2.72	0.57

n = 18

These data indicate that teachers in this survey were most comfortable teaching the *Making Sense of the Living World* strand of the curriculum, with 94% of participants classing the strand as either *easy* or *extremely easy* to teach. Participants were not comfortable teaching what are consistently considered the 'hard' strands of the curriculum – *Making Sense of the Physical World* and *Making Sense of the Material World*. 33% of teachers in the survey perceived *Making Sense of the Physical World* strand as either 'extremely difficult' or 'difficult'. None of the participants in the survey perceived *Making Sense of the Material World* as 'extremely difficult' but 39% still considered the strand to be 'difficult' to teach.

The strand that teachers indicated they were most uncomfortable with teaching is the integrating strand – *The Nature of Science and its Relationship to Technology*. 33% of participants rated this strand as 'difficult' and only 6% of participants considered teaching the strand to be 'extremely easy'.

Making Sense of Planet Earth and Beyond received slightly higher scores than *Making Sense of the Physical World* and *Making Sense of the Material World*, with 28% of teachers perceiving the strand as 'difficult' to teach. These data indicate that although teachers are more slightly comfortable in teaching this strand than the physical sciences of *Material World* and *Physical World*, it is still perceived as much more difficult to teach than strands dealing with the *Living World* or integrating strands such as *Scientific Skills and Attitudes*.

The trends revealed in these data are congruent with those of previous workers. Lewthwaite *et. al.* (1999) found that teachers felt most competent in teaching the *Living World* strand, while in all other strands; competence was a problem to many teachers.

4.5.2 Perceptions of Making Sense of Planet Earth and Beyond Theme Difficulty

Participants were asked to give their perceptions of the difficulty of the various themes with in the *Making Sense of Planet Earth and Beyond* strand. Responses were recorded on a 4-point Likert scale with a "strongly disagree' response indicating that the respondent was very uncomfortable teaching in a theme, while a "strongly agree" response indicated that a respondent felts very comfortable teaching a theme.

Table 4

Teachers' perceptions of efficacy in teaching the themes within the *Making Sense of Planet Earth and Beyond* stand.

	Strongly Disagree	Disagree	Agree	Strongly Agree	Mean Score	SD
Composition of planet Earth (Seismology)	2%	18%	44%	36%	3.16	0.58
Processes that shape planet Earth (Weather)	-	9%	63%	28%	3.17	0.55
New Zealand's geological history (Fossils)	-	14%	67%	19%	3.06	0.49
Movement of planet Earth in relation ship to other objects in the heavens (Lunar cycles)	-	7%	62%	31%	3.15	0.42
Guardianship of planet Earth (Local issue)	-	18%	54%	28%	3.17	0.55

n = 18

These data show that although teachers generally consider themselves as effective in teaching earth science subjects, their strength of efficacy belief varied amongst the different themes of the strand. Participants in Lewthwaite *et al.* (1999) found that topics with achievement objectives relating to New Zealand's geological history were perceived as the most difficult to teach. Table 4 shows a similar trend exists, participants in phase one also perceived New Zealand's geological history to be the most difficult theme in *Making Sense of Planet Earth and Beyond* to teach (mean E = 3.06, SD = 0.49).

Participants felt most comfortable teaching the themes the processes that shape planet Earth and [The] *need for responsible guardianship of the planet and its resources* (mean E = 3.17, SD = 0.55). What is unusual is that although the data presented in Table 4 show that teachers feel relatively comfortable teaching topics based on environmental guardianship, data from section one of the survey showed that only 56% of teachers in this survey include this theme as a regular part of their science programme.

4.6 Knowledge in Teaching Earth Science

Table 5

Teachers' perceptions of their own knowledge in the teaching of *Making Sense of Planet Earth and Beyond.*

	Strongly Disagree	Disagree	Agree	Strongly Agree	Mean Score	SD
I have a sound scientific understanding of the topics involved in planet Earth and beyond	5%	15%	66%	14%	2.76	0.70
I can effectively explain the concepts of planet Earth and beyond to students in a way that will develop their understanding.	-	12%	70%	17%	2.95	0.65
I can design class activities that develop students' understanding of planet Earth and beyond	5%	27%	53%	15%	3.02	0.54
I know where the ideas of planet Earth and beyond fit into the curriculum.	-	22%	62%	16%	2.99	0.53

n = 18

Participants in the survey were generally positive in their perceptions of their knowledge of the *Making Sense of Planet Earth and Beyond* overall (Mean K = 2.93, SD = 0.60). Participants felt that subject matter knowledge was their weakest area of professional science knowledge. While they perceived their knowledge that related to matters pedagogical were somewhat stronger. Teachers in this survey indicated that their ability to design useful earth science activities (general pedagogical knowledge) was greater than their ability to explain conceptual ideas to children (pedagogical content knowledge).

4.6.1 The Composition of Planet Earth

Table 6

Teachers' perceptions of their knowledge in the teaching of the composition of planet Earth.

	Strongly Disagree	Disagree	Agree	Strongly Agree	Mean Score	SD
I have a sound scientific understanding of the composition of planet Earth.	6%	28%	61%	6%	2.67	0.69
I can effectively explain the concepts of Tthe composition of planet Earth to students in a way that will develop their understanding.	6%	6%	72%	17%	3.00	0.69
I can design class activities that develop students' understanding of the composition of planet Earth.	-	6%	83%	11%	3.06	0.42
I know where the ideas of the Earth's composition fit into the curriculum.	6%	17%	72%	6%	2.78	0.65

n = 18

Teachers were generally positive in their perceptions of their professional science knowledge in the composition of planet Earth theme (Mean K = 2.88), though this was below the mean score for the strand as a whole (See Table 4). Participants were most positive in their perceptions when asked about their general pedagogical knowledge. 94% of teachers in this survey responded with 'agree' or 'strongly agree'.

A lack of subject matter knowledge appears to be the greatest concern of teachers in this theme. Table 6 shows that 34% of teachers 'disagree' or 'strongly disagree' with the statement "I have a sound scientific understanding of the composition of planet Earth". the composition of planet Earth has the second lowest subject matter knowledge score of the *Making Sense of Planet Earth and Beyond* strand.

When asked whether the composition of planet Earth was a theme that was regularly addressed as part of their school science programme, 67% of teachers on the survey responded positively (SD = 0.48). However, the fact that 33% of teachers in this study did not regularly include the composition of planet Earth as part of their school science programme is a major concern. This may reflect the high difficulty rating that respondents gave this strand.

4.6.2 Processes That Shape Planet Earth

Table 7

Teachers' perceptions of their knowledge in the teaching of the processes that shape planet Earth.

	Strongly Disagree	Disagree	Agree	Strongly Agree	Mean Score	SD
I have a sound scientific understanding of the processes that shape planet Earth.	-	22%	67%	11%	2.89	0.58
I can effectively explain the concepts of the processes that shape planet Earth to students in a way that will develop their understanding.	-	17%	61%	22%	3.11	0.58
I can design class activities that develop students' understanding of the processes that shape planet Earth.	-	6%	78%	17%	3.11	0.47
I know where the ideas of the processes that shape planet Earth fit into the curriculum.	-	-	94%	6%	3.06	0.24

n = 18

Table 7 indicates that teachers in this survey generally perceived themselves as quite knowledgeable in teaching topics based on of the processes that shape planet Earth (Mean K = 3.04). Pedagogical content knowledge based areas show the highest mean scores, while subject matter knowledge is the area that scored lowest. In this theme, factors related to general pedagogical skills and to pedagogical content knowledge received similarly high scores (K_{GPK} & K_{PCK} = 3.11), though the pedagogical content knowledge score was more variable. These scores may relate to how frequently teachers in this survey teach topics related to earth processes.

When asked whether the theme, the processes that shape planet Earth was regularly addressed as part of their school science programme, 78% of participants responded positively. This is the most frequently taught theme of the *Making Sense of Planet Earth and Beyond* strand and may be linked to what teachers perceive the *Making Sense of Planet Earth and Beyond* strand (and Earth Sciences) entail. Vallender (1997) found that tertiary science students, geology majors and primary and secondary teachers' key perceptions of earth sciences related largely to disasters such as earthquakes and volcanoes, and to a lesser extent, physical geology relating to the shape (but not the origins) of landforms – a perception that can provide a rather limited view of what earth science as a discipline involves.

4.8.3 New Zealand's Geological History

Table 8

Teachers' perceptions of their knowledge in the teaching of New Zealand's geological history.

	Strongly Disagree	Disagree	Agree	Strongly Agree	Mean Score	SD
I have a sound scientific understanding of New Zealand's geological history.	11%	33%	39%	17%	2.61	0.92
I can effectively explain the concepts of New Zealand's geological history to students in a way that will develop their understanding.	6%	28%	56%	11%	2.72	0.75
I can design class activities that develop students' understanding of New Zealand's geological history	-	28%	61%	11%	2.83	0.62
I know where the ideas of New Zealand's geological history fit into the curriculum.	6%	22%	67%	6%	2.72	0.67

n = 18

Although the perceptions of the respondents were still positive (mean K = 2.72), New Zealand's geological history received the lowest overall scores of all the themes in *Making Sense of Planet Earth and Beyond.* Subject matter knowledge (K_{SMK} = 2.61) was rated as the dimension of knowledge that was weakest. Table 8 shows that 44% of the teachers in the survey did not believe their understanding of the concepts involved in New Zealand's geological history were sound.

The respondents' usually positive perception of their pedagogical content knowledge was also notably lower. Content Knowledge score for New Zealand's geological history was much lower (K_{PCK} =2.72) than the mean score for the other themes (Mean K_{PCK} = 2.93).

This theme also presented the lowest curricular knowledge score. This may relate to both the low subject matter knowledge score and the difficulties expressed in constructing learning activities. Shulman (1987) comments that curricular knowledge includes an understanding of the 'tools of the trade', which for New Zealand's geological history requires more practical work outside the classroom. Teachers in Hoskin's (2000) survey of secondary teachers expressed concern over the difficulties they had getting "hands-on activities that are at a suitable level." (p.8), with many teachers desiring extra support in the form of teachers guides with suggested classroom activities.

New Zealand's geological history is also very infrequently taught in classrooms. Section one of the survey found that only 67% of respondents regularly include this theme as part of their school science programme. This lack of coverage may relate to teachers' lack of knowledge and confidence in the subject, again a relationship that will require further exploration.

4.6.4 The Movement of Planet Earth in Relationship to Other Objects in the Heavens

Table 9

Teachers' perceptions of their knowledge in the teaching of the movement of planet Earth in relationship to other objects in the heavens.

	Strongly Disagree	Disagree	Agree	Strongly Agree	Mean Score	SD
I have a sound scientific understanding of astronomy concepts.	-	39%	56%	6%	2.72	0.57
I can effectively explain concepts of astronomy to students in a way that will develop their understanding.	-	28%	61%	11%	2.86	0.59
I can design class activities that develop students' understanding of astronomy.	-	11%	72%	17%	3.06	0.54
I know where the ideas of astronomy fit into the curriculum.	-	11%	72%	17%	3.06	0.54

n = 18

Table 9 shows that in astronomy related themes, subject matter knowledge received the lowest scores. As in New Zealand's geological history and composition of planet Earth, teachers also feel less able to explain the concepts involved in the theme than they do designing learning activities for their students. This may reflect the view of Harlen (1997), who found that many teachers "use their considerable pedagogic skills and various strategies for avoiding situations where their understanding might be challenged" (p. 329). This can be seen again in the difference between the general pedagogical knowledge score and the pedagogical content knowledge score. Teachers perceive their pedagogical skill as better developed than their ability to explain the concepts involved in a subject.

Only 61% of respondents indicated that the theme movement of planet Earth in relationship to other objects in the heavens was regularly addressed as part of their school science programme. This is less than New Zealand's geological history, the theme traditionally perceived as the 'hard' topic in the making sense of planet earth and seyond strand (Lewthwaite 1999).

4.6.5 The Need for Responsible Guardianship of the Planet and its Resources

Table 10

Teachers' perceptions of their knowledge in the teaching of the need for responsible guardianship of the planet and its resources.

	Strongly Disagree	Disagree	Agree	Strongly Agree	Mean Score	SD
I have a sound scientific understanding of current environmental issues.	0%	33%	44%	22%	2.92	0.73
I can effectively explain environmental issues to students in a way that will develop their understanding.	0%	17%	61%	22%	3.06	0.64
I can design relevant class activities that develop students' understanding of environmental issues and prompt them to take action.	0%	17%	61%	22%	3.06	0.64
I know where the ideas of environmental issues fit into the curriculum.	0%	11%	72%	17%	3.06	0.54

n = 18

Table 10 shows that the theme, responsible guardianship of the planet and its resources received the highest subject matter knowledge score of all the themes of the *Making Sense of Planet Earth and Beyond* strand (though it should be noted that subject matter knowledge is still perceived by teachers in the survey to be their weakest dimension in this theme).

The knowledge data for responsible guardianship of the planet and its resources also exhibit the smallest margin between subject understanding and pedagogical knowledge and skill. Table 10 indicates that general pedagogical, pedagogical content and curricular knowledge scores are identical and positive. This may relate to the more immediate relevance that topics involving environmental issues provide. Vallender (1997) and Hoskin (2000) both noted how teachers often found many areas of *Making Sense of Planet Earth and Beyond* "abstract" and uninteresting. Topics on environmental issues, through virtue of their immediacy may override or at least reduce, this problem.

Despite the generally positive perceptions teachers hold of their knowledge in this area, responsible guardianship of the planet and its resources is the least frequently addressed theme of the *Making Sense of Planet Earth and Beyond* strand. Responses to section one revealed that only 56% of the respondents include topics based on this theme as part of their regular science programme. These data show that the problems with student achievement in the topic responsible guardianship of the planet and its resources may have a similar source to those found by the TIMMS project and Hoskin, (2000) when they studied the *Making Sense of Planet Earth and Beyond* as an entire strand. That is, students are not receiving regular and meaningful exposure to *Making Sense of Planet Earth and Beyond.*

4.7 Relationships Between Knowledge Dimensions

Data generated form sections one and two of the survey suggest that teachers' perceptions of their professional science knowledge vary in different contexts. The data presented in Tables 5 to 10 also suggest that certain dimensions of knowledge influence, or are related to other dimensions.

Participants' specific K scores within each question cluster in section two appear at first glance to exhibit some influence on other scores within the cluster. Most notable of these appears to be the influence of subject matter knowledge scores (K_{SMK}) on pedagogical content knowledge scores (K_{PCK}). In each question cluster, results for K_{PCK} are invariably higher than K_{SMK} results (See Table 4), low perceptions of subject matter knowledge appear to negatively influence teachers' perceptions of their pedagogical content knowledge.

To further assess the existence and possible strength of these relationships, respondents' scores for each dimension of professional science knowledge were compared.

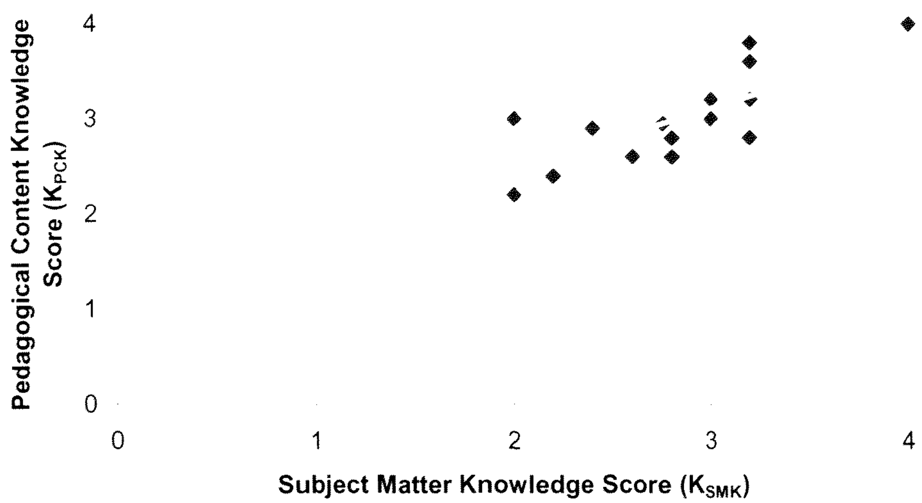

Figure 7. Comparison of participants' subject matter knowledge with pedagogical content knowledge.

An analysis of variables related to this trend revealed in Figure 7 shows that there is a strong relationship between teachers subject matter knowledge scores and pedagogical content knowledge scores ($R = 0.73$). The trend revealed by these data is moderately meaningful ($R^2 = 0.53$) and is very significant ($P = 4.2 \times 10^{-4}$). This result implies that teachers understanding of subject content and their ability to turn such content into conceptual based learning for students are closely related.

The data generated in section one of the survey on teachers' professional science knowledge showed similarities in scores between questions relating to pedagogical content knowledge and general pedagogical knowledge.

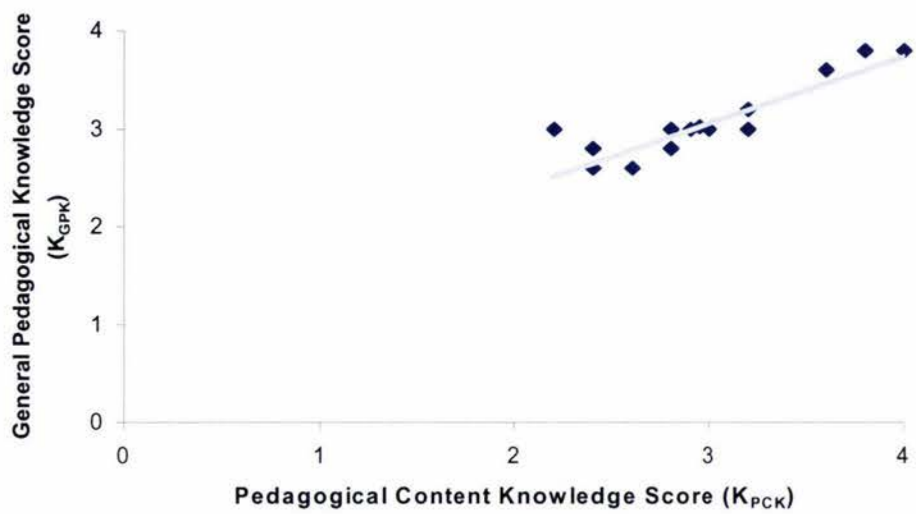

Figure 8. Comparison of participants' pedagogical content knowledge with general pedagogical knowledge.

An analysis of variables revealed a strong relationship between teachers' perceptions of their pedagogical content knowledge and their perceptions of their general pedagogical Skill in this context ($R = 0.89$). The trend line used in Figure 9 does meaningfully explain the relationship ($R^2 = 0.79$). These data are highly significant ($P = 3.4 \times 10^{-7}$).

When the conclusions of previous workers (Shulman 1986, 1987) along with the results from sections one and two of the survey are considered, such a result is predictable. It would follow that if a teacher feels well able to explain ideas, then they should also feel able to design activities to reinforce such concepts. Conversely, a teacher unable to explain the concepts of a subject would have greater difficulty in designing meaningful activities aimed at developing those concepts.

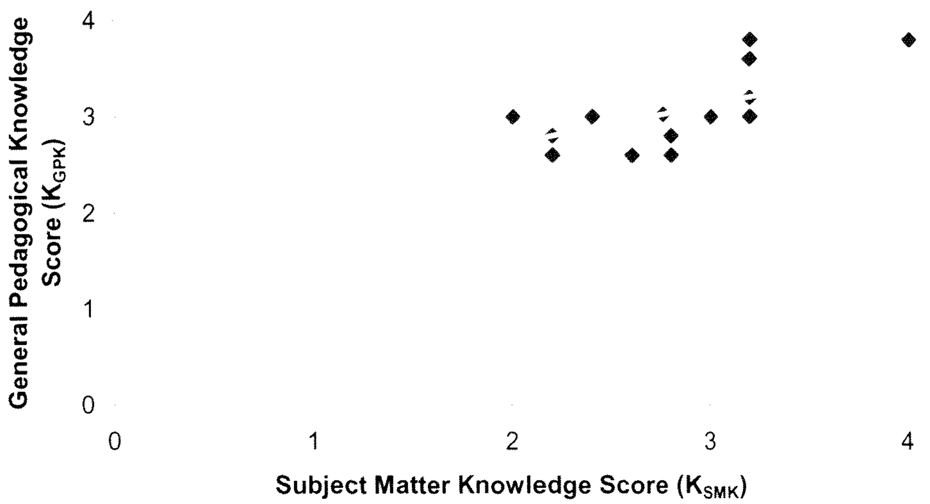

Figure 9. Comparison of participants' subject matter knowledge with general pedagogical knowledge.

Appraisal of Figure 9 and an analysis of the data reveal a more moderate correlation (R = 0.59) between respondents' perceptions of their subject matter knowledge and their pedagogical content knowledge. Neither is the relationship particularly meaningful (R^2 = 0.35) as the data involved were quite variable. The tenuous nature of this relationship along with the highly significant nature of the analysis ($P = 0.007$) demonstrates that teachers' general pedagogical knowledge may be reasonably independent of their grasp of the subject matter.

It seems unusual that a teacher's general pedagogical knowledge would be so independent of their grasp of the subject matter, especially when the relationship between subject matter knowledge and pedagogical content knowledge and the strong relationship between general pedagogical knowledge and pedagogical content knowledge are considered. What may exist is an indirect relationship between these two dimensions. That is, subject matter knowledge *does* influence general pedagogical knowledge, but only through it's relationship with pedagogical content knowledge. This will require further exploration.

There may be other, contextual factors involved. The relative independence of general pedagogical knowledge evidenced in Figure 9 may possibly result from the high degree of portability of general pedagogical knowledge. That is, teachers' ability to create learning activities would be used in every other learning/teaching context

Teachers' perception of their curricular knowledge was also explored. Respondents were generally positive in their perceptions of their knowledge of the curriculum (Mean K_{CK} = 2.94, SD = 0.53). Curricular knowledge appeared to be weakest in the composition of planet Earth and New Zealand's geological history themes. All the other themes of the strand were equally positive (K_{CK} = 3.06 SD = 0.44).

Data generated by the questionnaire revealed only very weak relationships between teachers' curricular knowledge and each of the other dimensions of professional Science knowledge.

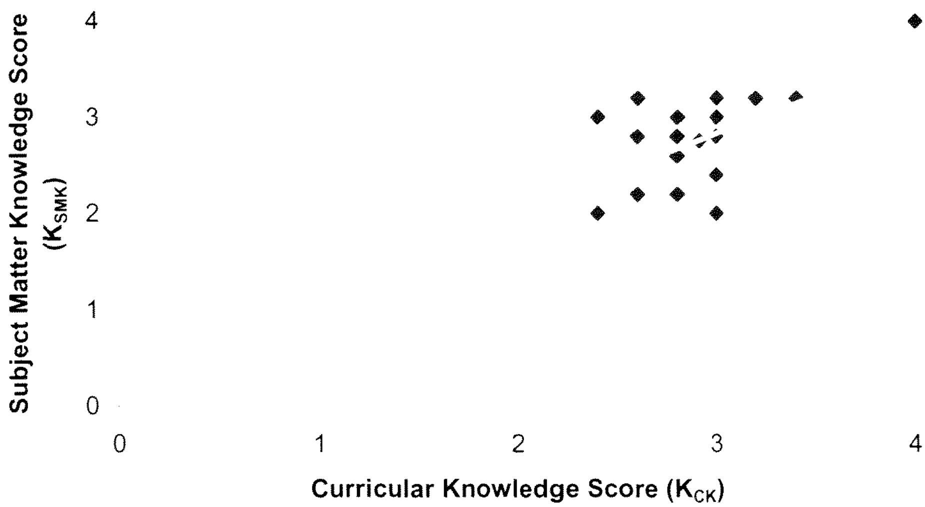

Figure 10. Comparison of participants' curricular knowledge with subject matter knowledge.

It appears from the data presented in Figure 10 that a teacher's knowledge of the 'tools of the trade' has only a moderate influence on their overall subject matter knowledge. A comparison of participants' curricular content knowledge with subject matter knowledge revealed only a moderate correlation (R = 0.55). The very large cluster in Figure 10 means that the addition of a trend line is rather arbitrary and only explains a small portion of the data in the sample (R^2 = 0.31). The high significance of this result (P = 0.014) confirms the lack of any noteworthy relationship.

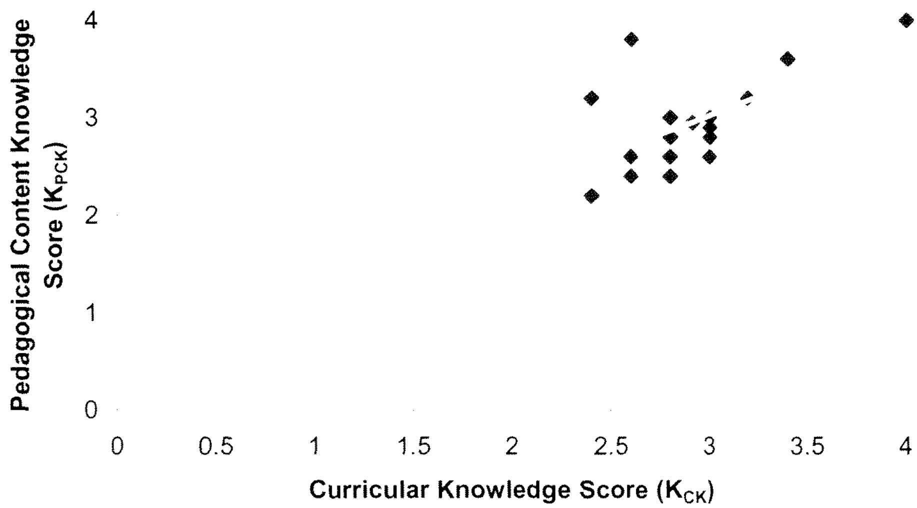

Figure 11. Comparison of participants' curricular knowledge with pedagogical content knowledge

Figure 11 demonstrates the presence of a relationship between teachers' grasp of the curriculum (curricular knowledge) and their ability to link subject matter with concept based learning (pedagogical content knowledge). An analysis of variates revealed that though a relationship does exist, the correlation is not that strong (R = 0.61). The large cluster of results does reduce the meaningfulness of the trend considerably ($R^2 = 0.37$), meaning that the trend line in Figure 11 is somewhat subjective. This analysis was significant ($P = 0.006$). It appears that pedagogical content knowledge and curricular knowledge are reasonably related. That is, knowledge of the 'tools of the trade' appears to have some influence on how well teachers feel they are able to explain concepts meaningfully to their students.

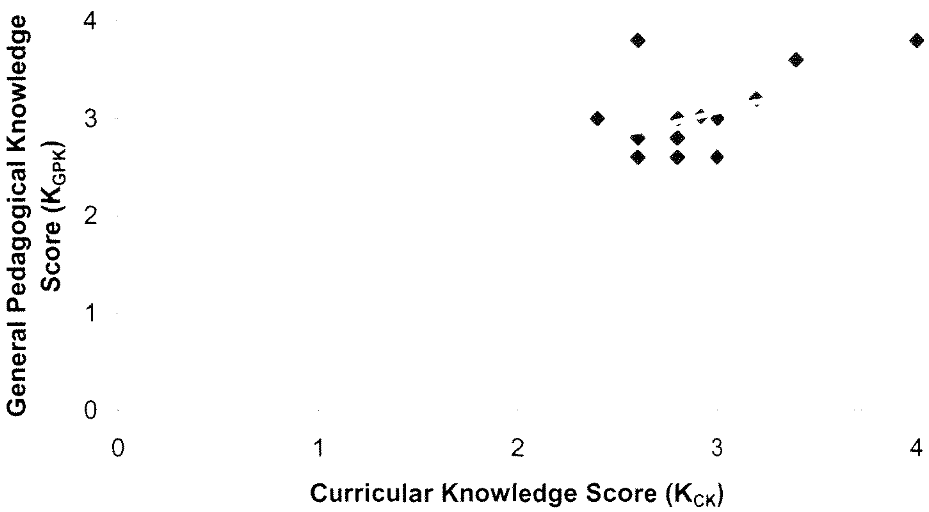

Figure 12. Comparison of participants' curricular knowledge with general pedagogical knowledge.

Only a moderate relationship could be found between participants' general pedagogical knowledge and their curricular knowledge (R = 0.51). The trend line added to Figure 12 serves only to explain a very small portion of the data ($R^2 = 0.26$). The data were significant ($P = 0.006$). The tenuous nature of the relationship between curricular knowledge and general pedagogical knowledge supports the earlier notion that general pedagogical knowledge exists as an entity relatively independent of other dimensions of professional science knowledge.

4.7.1 Relationships Between Knowledge Dimensions and Teachers' Backgrounds

Table 11

Comparison of Teachers' Background in Science with Knowledge Scores

	SMK	PCK	GPK	CK	Mean
Compulsory Papers During Preservice Training Only	2.51	2.72	3.19	2.94	2.84
High School Science & Compulsory Papers During Preservice Training	2.69	2.78	3.13	3.02	2.83
Science 'Majors' in Preservice Training	3.11	3.26	3.29	3.29	3.24
Tertiary Qualifications in Science & Preservice Training	2.72	3.02	2.58	2.90	2.81

When participants' various K scores were compared to teachers' background in science, and interesting trend was noted. Teachers with strong backgrounds in science and earth science displayed notably higher K scores than those with less science background. The largest differences appear in the "conceptual" knowledge areas of subject matter knowledge and pedagogical content knowledge. This trend is evident even in the one participant with a tertiary science qualification. Though this participant was categorised as a 'Lolo', their experiences in science in general have influenced their conceptual knowledge frameworks in a moderately positive way – exceeded only by those participants from the science 'major' category.

4.8 Efficacy in Teaching Earth Science

Pijares (2002) notes that self-efficacy beliefs are context specific. To determine the strength of teachers' self-efficacy, scenarios based on similar classroom situations, but with variations in knowledge base, were used. Each scenario used similar question clusters that referred to behavioural indicators of efficacy, such as task selection or avoidance, effort expenditure and, perseverance (Maddux, 1995, Pijares, 2002). Teachers were asked to respond to each statement on a four-point Likert scale (1 – Strongly disagree, 2 – Disagree, 3 – Agree, 4 – Strongly Agree). A question relating to the teachers' general perception of their knowledge in each context was included for comparison with Section Two of the questionnaire.

To generate general efficacy scores, the results from each of the question sets from section three of the questionnaire were combined. Though each question set had variations in contextual setting, the aspects of self-efficacy belief investigated remained constant throughout the section facilitating the generation of a 'general earth science teaching efficacy' score.

Table 12

Teacher's perceptions of their efficacy in teaching in the making sense of planet earth and beyond strand.

	Strongly Disagree	Disagree	Agree	Strongly Agree	Mean Score	SD
I would choose to teach this unit to a class.	5%	18%	41%	36%	3.16	0.58
I would Enjoy teaching this unit.	0%	9%	63%	28%	3.17	0.55
I believe my knowledge is adequate to teach the concepts involved in this unit.	0%	14%	67%	19%	3.06	0.49
I believe my students can gain a sound understanding of the concepts in this topic if I put in the necessary effort in teaching it.	0%	7%	62%	31%	3.15	0.42
If a student asks a difficult question about this topic I could find a way to answer it.	0%	18%	54%	28%	3.17	0.55

n = 18

When a comparison of teachers' efficacy beliefs across the whole strand was performed, the results were reasonably significant. Teachers' overall perceptions of their self-efficacy were quite positive. Predictably, teachers were least confident in the strength of their conceptual understanding – a question included more as a cross-reference to Sections One and Two than as a specific efficacy question. The subject matter knowledge scores in section one add further weight to these data. Possibly related to this weakness of efficacy is the participants' slightly lowered score related to teachers' ability to help students learn conceptually ($E_{effort} = 3.15$).

The questions aimed at assessing choice/avoidance behaviours (*I would choose to teach this unit to a class, I would enjoy teaching this unit*) were quite positive (E_{Choice}, $= 3.16$, $E_{affect} = 3.17$). These results are similar in trend to those seen in Section One. That is, teachers generally feel more positive about teaching in earth science than their professional science knowledge would initially indicate.

4.8.1 Scenario One: The Composition of Planet Earth

For the theme the composition of planet Earth, the participants were presented with a scenario based on using Earthquakes to explore the Earth's structure.

Table 13

Teacher's perceptions of their efficacy in teaching a topic based on the composition of planet Earth.

	Strongly Disagree	Disagree	Agree	Strongly Agree	Mean Score	SD
I would choose to teach this unit to a class.	0%	17%	56%	28%	3.14	0.60
I would enjoy teaching this unit.	6%	11%	50%	33%	3.14	0.63
I believe my knowledge is adequate to teach the concepts involved in this unit.	0%	33%	39%	28%	2.97	0.74
I believe my students can gain a sound understanding of the concepts in this topic if I put in the necessary effort in teaching it.	0%	17%	39%	44%	3.31	0.66
If a student asks a difficult question about this topic I could find a way to answer it.	6%	11%	39%	44%	3.25	0.66

n = 18

Consistent with the trend revealed in this survey, Table 13 indicates that participants' belief in their understanding of the topic was rated lowest. Questions associated with effort and perseverance rated the highest, while questions relating to choice/avoidance and enjoyment rated similarly to each other and quite positively. Participants generally believed themselves to be quite effective in teaching this.

What is unusual is that although the participants' rating of their conceptual understanding of the topic was relatively low, it is far higher than the perceived knowledge of the composition of planet Earth as found in section one. This may relate to the use of specific content rather than a decontextualised theme. However, this increase in perceived subject matter knowledge may be misplaced.

Vallender (1997) notes that teachers' perceptions of earth science are biased towards a 'high school geography' perspective. That is, they are likely to perceive earth science as relating to topics such as volcanoes, geomorphology and earthquakes as disasters. It may be that teachers in this survey reflected this traditional 'cause and effect' perception of earthquakes and did not see earthquakes as a tool for exploring the shape and structure of the earth.

4.8.2 Scenario Two: The Processes that Shape Planet Earth

For the theme the Processes that Shape Planet Earth, the participants were presented with a scenario that they were required to plan a syndicate-wide unit on the weather. This unit would require a focus on individual student investigations as a learning activity.

Table 14

Teacher's Perceptions of Their Efficacy in Teaching a Topic Based on the Processes that Shape Planet Earth.

	Strongly Disagree	Disagree	Agree	Strongly Agree	Mean Score	SD
I would choose to teach this unit to a class.	0%	11%	67%	22%	3.06	0.57
I would Enjoy teaching this unit.	0%	11%	67%	22%	3.06	0.57
I believe my knowledge is adequate to teach the concepts involved in this unit.	0%	11%	61%	28%	3.17	0.66
I believe my students can gain a sound understanding of the concepts in this topic if I put in the necessary effort in teaching it.	0%	6%	61%	33%	3.28	0.60
If a student asks a difficult question about this topic I could find a way to answer it.	0%	6%	61%	33%	3.28	0.60

n = 18

Table 14 shows that for the first time, teachers' beliefs of their knowledge levels were greater than their choice and enjoyment related behaviours. Questions relating to choice/avoidance behaviour and affective responses received identical scores (E_{choice}, $E_{affect} = 3.06$). These were also the lowest scores in the cluster, implying that although teachers feel relatively familiar and able, they would rather not teach this unit if they could avoid it. The highest scores related to perseverance and effort related behaviours; which were also identical ($E_{persist}$, $E_{effort} = 3.28$).

4.8.3 Scenario Three: New Zealand's Geological History

This scenario presented the situation where participants had to teach a unit on fossils, covering the processes of fossilisation and the use of fossils as indicators of geological time.

Table 15

Teacher's perceptions of their efficacy in teaching a topic based on New Zealand's geological history.

	Strongly Disagree	Disagree	Agree	Strongly Agree	Mean Score	SD
I would choose to teach this unit to a class.	0%	17%	67%	17%	3.00	0.63
I would Enjoy teaching this unit.	0%	17%	67%	17%	3.00	0.63
I believe my knowledge is adequate to teach the concepts involved in this unit.	0%	28%	61%	11%	2.78	0.66
I believe my students can gain a sound understanding of the concepts in this topic if I put in the necessary effort in teaching it.	0%	6%	67%	28%	3.22	0.58
If a student asks a difficult question about this topic I could find a way to answer it.	0%	6%	72%	22%	3.17	0.54

n = 18

As could be predicted from the results of section two, the lowest score in this cluster related to teacher knowledge of the subject ($E_{knowledge} = 2.78$). Other efficacy related scores on this subject are also lower than normal. Table 15 shows that questions relating to choice/avoidance behaviour and enjoyment responses received scores that were low and identical (E_{choice}, $E_{affect} = 3.00$), implying that while teachers would generally choose teach this unit, they would avoid it if they could.

Scores relating to effort expenditure and perseverance were the highest in this cluster ($E_{persist} = 3.22$, $E_{effort} = 3.17$). These scores, while still positive, are lower than scores for other themes. It appears that teachers not only perceive a problem relating to their knowledge, but also their self-efficacy when it comes to teaching New Zealand's geological history.

4.8.4 Scenario Four: The Movement of Earth in Relationship to the Heavens

In the scenario given in this question cluster, teachers were required to prepare and teach a unit on the spatial relationships between the Earth, the moon and the sun, and investigate their effects on planet Earth.

Table 16

Teacher's perceptions of their efficacy in teaching a topic based on movement of planet Earth in relationship to other objects in the heavens.

	Strongly Disagree	Disagree	Agree	Strongly Agree	Mean Score	SD
I would choose to teach this unit to a class.	0%	6%	72%	22%	3.17	0.54
I would Enjoy teaching this unit.	0%	11%	61%	28%	3.17	0.58
I believe my knowledge is adequate to teach the concepts involved in this unit.	0%	17%	56%	28%	3.11	0.66
I believe my students can gain a sound understanding of the concepts in this topic if I put in the necessary effort in teaching it.	0%	0%	56%	44%	3.44	0.52
If a student asks a difficult question about this topic I could find a way to answer it.	0%	5%	63%	32%	3.33	0.50

n = 18

Respondent teachers' efficacy beliefs were very positive. The highest scores related to perseverance behaviour ($E_{persist} = 3.44$). Replies concerning perseverance behaviours also received high scores ($E_{effort} = 3.33$). Again, choice/avoidance and enjoyment scores were positive and similar (E_{choice}, $E_{affect} = 3.17$).

4.8.6 Scenario Five: The Need for Responsible Guardianship of the Planet and its Resources

The final scenario presented in the survey was quite open in nature. It presented teachers with the need to prepare a unit on a local environmental issue that provided students with a scientific perspective that would allow students to justify a personal position.

Table 17

Teacher's perceptions of their efficacy in teaching a topic based on the need for responsible guardianship of the planet and its resources.

	Strongly Disagree	Disagree	Agree	Strongly Agree	Mean Score	SD
I would choose to teach this unit to a class.	0%	22%	50%	28%	3.06	0.72
I would Enjoy teaching this unit.	0%	22%	56%	22%	3.03	0.64
I believe my knowledge is adequate to teach the concepts involved in this unit.	0%	17%	61%	22%	3.11	0.51
I believe my students can gain a sound understanding of the concepts in this topic if I put in the necessary effort in teaching it.	0%	11%	56%	33%	3.25	0.54
If a student asks a difficult question about this topic I could find a way to answer it.	0%	17%	50%	33%	3.19	0.63

n = 18

Table 17 indicates that Teachers' choice/avoidance and enjoyment scores were almost as low as New Zealand's geological history, (E_{choice}, = 3.06, E_{affect} = 3.03). That the knowledge based question scored more highly ($E_{knowledge}$ = 3.11) than choice/avoidance and enjoyment scores, a reversal of the normal trend, could be an additional indicator that teachers would prefer not to teach this unit if they could avoid it.

However this result did not reduce teachers' beliefs that they could, if they put in enough effort, enable students to learn the concepts involved in such a scenario. This pattern of higher perseverance and effort expenditure scores and lower knowledge, choice/avoidance and enjoyment scores occur in every scenario presented. This may be a key trend in the investigation of teachers' efficacy beliefs. It may be that the efficacy indicators of effort and persistence are high because they relate to teachers' perceptions of their roles in facilitating learning: That teachers feel they are able to teach a subject regardless of their feelings and shortcomings. This will require further investigation.

4.9 Teachers' Efficacy Beliefs

A number of patterns in participants' efficacy scores are evident in the data provided in section three. Responses to each indicator question were compared with others to investigate the possibility of correlations in the hope that this may provide some insight into what behaviours or characteristics teachers identify as defining an effective teacher or simply as important to their role as a teacher.

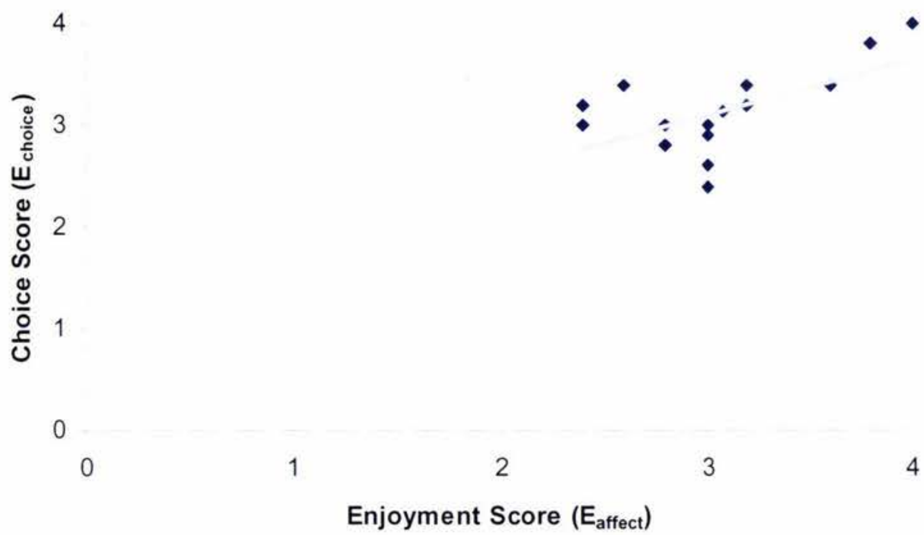

Figure 13. Comparison of teachers' choice and enjoyment scores.

A comparison of teachers' opinion of whether they would choose to teach earth science topics with their perceptions of whether they would enjoy doing so (Figure 13), yielded a strong correlation (R = 0.62) with quite high accuracy (*P*= 0.005). This implies that teachers are more likely to teach earth science topics they enjoy. Evidence from this survey suggests that teachers would most enjoy (and therefore would teach) topics based on the solar system and on earthquakes and would avoid if they could teaching units on fossils and environmental issues.

To discern whether there was any relationship between teachers' professional science knowledge and their choice/avoidance behaviour, an analysis of different question clusters was performed. When these factors were compared a moderate correlation was found (R= 0.54). This relationship is slightly weaker than that between enjoyment and choice/avoidance. From this data it could be inferred that teachers would be more likely to choose an earth science topic they enjoyed rather than a topic they knew more about.

Though there is a strong correlation between enjoyment and choice/avoidance, it appears that there are other influences at play. The cluster in Figure 13 suggests that other factors, such as mandatory requirements, resource limitations or school climate may have a noteworthy influence choice/avoidance behaviour in teachers.

Data for either regression were not particularly meaningful. This implies that other, probably external, influences are involved. To make conclusions based solely on data aimed at such specific factors would be naive. The use of combined efficacy scores and further collection of data by other means may serve to increase the accuracy and generality of such comparisons.

Further examination of participants' responses to all three sections of the survey indicates that those participants with strong backgrounds in earth science (classified as Hihi's) were more likely to choose to teach topics in the *Making Sense of Planet Earth and Beyond* strand than any other 'category'.

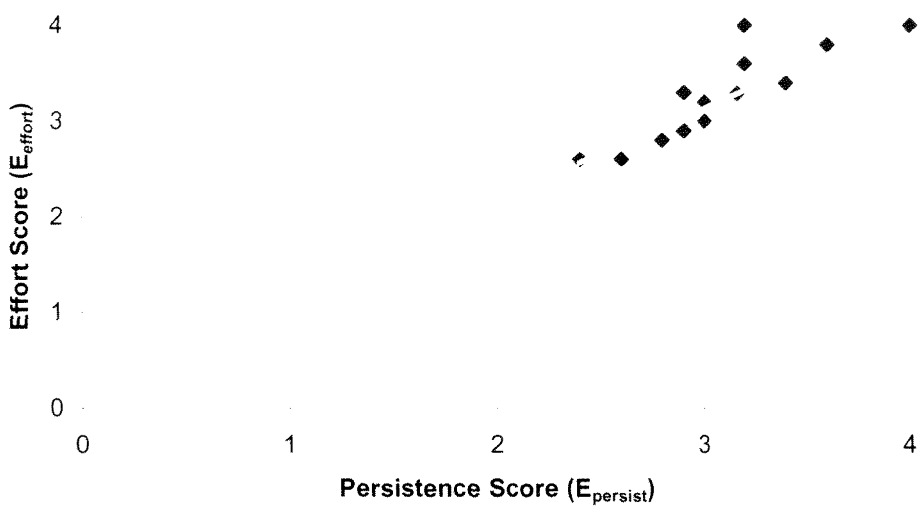

Figure 14. Comparison of teachers' persistence and effort scores.

Comparing data relating to participants' perceptions of their effort expenditure and Persistence beliefs yielded a very strong correlation($R = 0.90$) that was very accurate

(P= 1.8 x 10^{-7}). The trend line added to Figure 14 serves to explain the trend in the data very accurately (R^2 = 0.81). This result is not surprising. Numerous workers have identified these two traits as key indicators of efficacy belief (Bandura, 1977, 1986, 1994, Schwarzer & Jerusalem, 1993, Maddux, 1995, Pijares, 2002). The predictability of such a result aside, these data may provide an insight into teachers' perceptions of their role as effective earth science teachers: That persistence and effort may make up for a deficiency in subject matter knowledge.

The possibility of teachers' professional science knowledge frameworks having some influence on Effort Expenditure and Persistence was investigated. A moderate, though not very meaningful correlation was found (R = 0.46, R^2 = 0.21).

The relative meaninglessness of the correlation with professional science knowledge, as well as the strength of the relationship between perseverance and effort, may show that teachers rate their own effort and perseverance as of greater importance than their knowledge of subject or ability to teach concepts.

Further examination of participants' responses to all three sections of the survey indicates that those participants with strong backgrounds in earth science(those who could be classified as Hihi's) were more likely to more likely to expend more effort and persist longer when teaching earth science topics.

Comparison between Choice/Enjoyment and Effort-related behaviours confirmed previous workers' (Schwarzer & Jarusalem, 1993; Maddux, 1995) conclusions that the indicators used in this survey are related and useful in measuring the strength of personal efficacy belief.

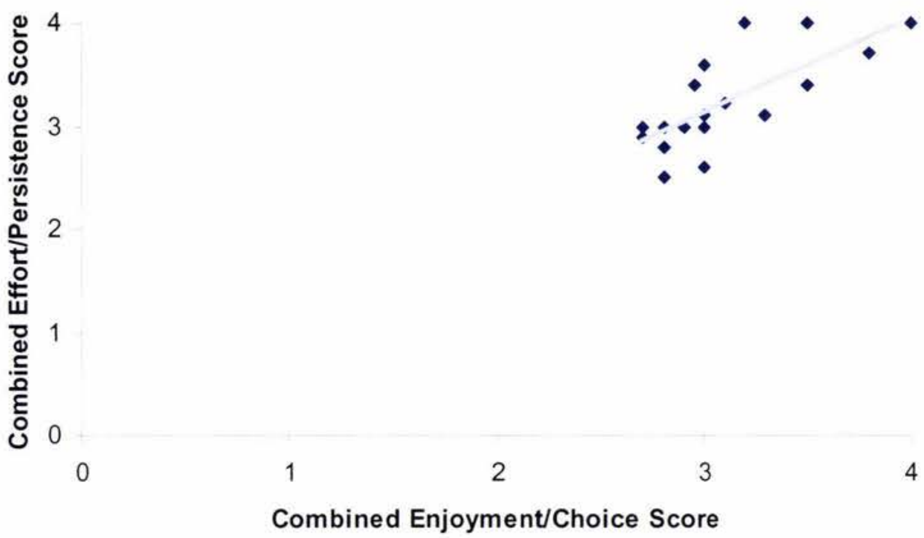

Figure 15. Comparison of teachers' enjoyment/choice and effort/persistence scores.

Figure 15 shows how teachers are likely to put in more effort and persist longer with earth science topics that they enjoy and/or choose. A strong correlation (R = 0.74) was revealed and, though a multiple regression failed to explain a portion of the data (R^2 = 0.55), the trend line added to Figure 15 is still moderately meaningful. Despite the small sample size, the findings yielded by this comparison are significant ($P = 0.0003$).

4.10 Knowledge and Efficacy

Sections one and two of the survey showed that teachers appear to have perceptions of their professional science knowledge that vary according to the subject matter. So too did the respondents' strengths of efficacy belief. A comparison of participants' knowledge and efficacy scores may provide evidence of a relationship between the two constructs. From each section of the survey, an overall knowledge score (K) and overall efficacy score (E) were generated from the total mean scores of each participant. These scores were used for graphical and statistical comparisons.

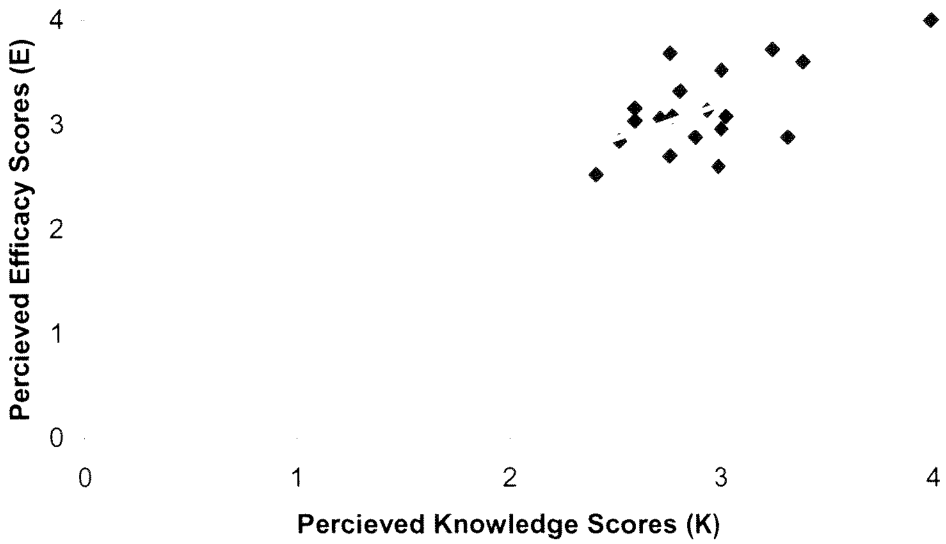

Figure 16. Comparison of teachers' overall knowledge and efficacy levels.

Figure 16 shows that any relationship between overall knowledge scores (K) and efficacy scores (E) would appear to be rather weak. However, further investigation of the possibility of a relationship between K and E showed that teachers' perceived knowledge does have some influence on the strength of their efficacy beliefs.

A multiple regression analysis revealed the presence of a strong correlation (R = 0.72) between teachers overall Knowledge scores and Efficacy scores. However, it should be noted that, these results were not significant ($P = 0.12$). This is possibly a factor of the small sample size and the use of a questionnaire designed primarily for gathering qualitative, rather than purely statistical data.

There is also some degree doubt regarding the predictability of the K-E relationship. The meaningfulness of the data ($R^2 = 0.52$), though quite strong, demonstrates that though a correlation between teachers' efficacy beliefs and knowledge structures does exist, the trend line used in Figure 16 still fails to explain 48% of the variation in the sample. This accompanied by a lack of significant data, means that a knowledge–efficacy relationship, while one appears to exist, is not as straightforward as a single source of data would reveal.

When individual dimensions of professional science knowledge were investigated for possible influences on the strength of teachers' efficacy beliefs, results were variable.

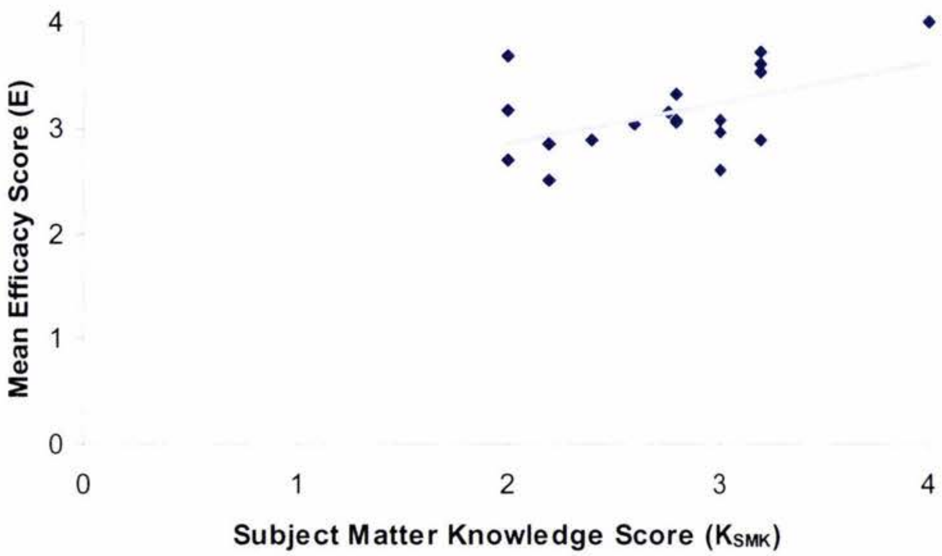

Figure 17. Comparison of teachers' subject matter knowledge and efficacy levels.

As can be seen in Figure 17, when overall efficacy scores were compared to the knowledge dimension of subject matter knowledge, the correlation between the two factors becomes more moderate. ($R = 0.51$). The trend line serves to explain much less of the data ($R^2 = 0.26$), implying that subject matter knowledge alone does not have a great influence on any knowledge-efficacy relationship.

However, even though the comparison of subject matter knowledge with overall Efficacy revealed only a moderate correlation, this relationship was found to be the strongest of each of the individual professional science knowledge dimensions. This implies that teachers feel that of all the domains of their functional teaching knowledge, knowledge of earth science subject matter has the greatest individual effect on their confidence as earth science teachers.

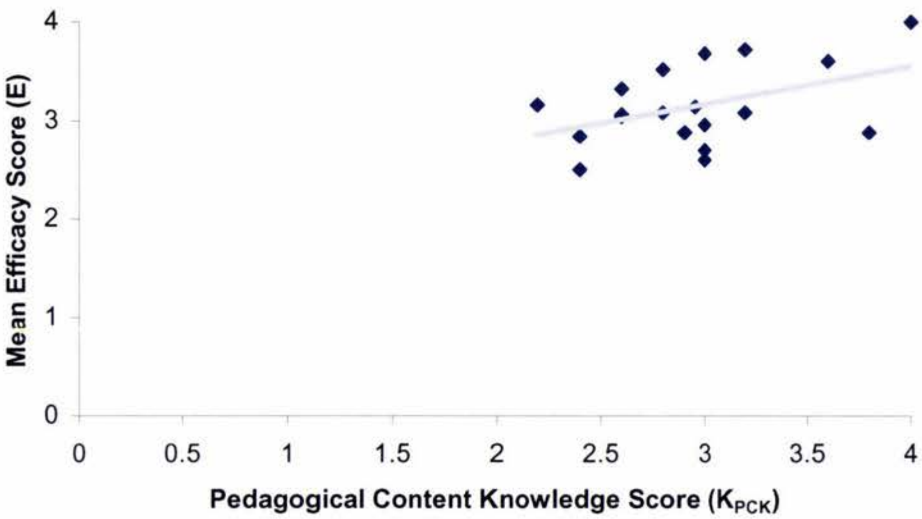

Figure 18. Comparison of teachers' pedagogical content knowledge and efficacy levels.

When teachers' pedagogical content knowledge was compared with their strength of efficacy belief the correlation was again more moderate (R = 0.45), and less meaningful ($R^2 = 0.21$) than an overall knowledge score.

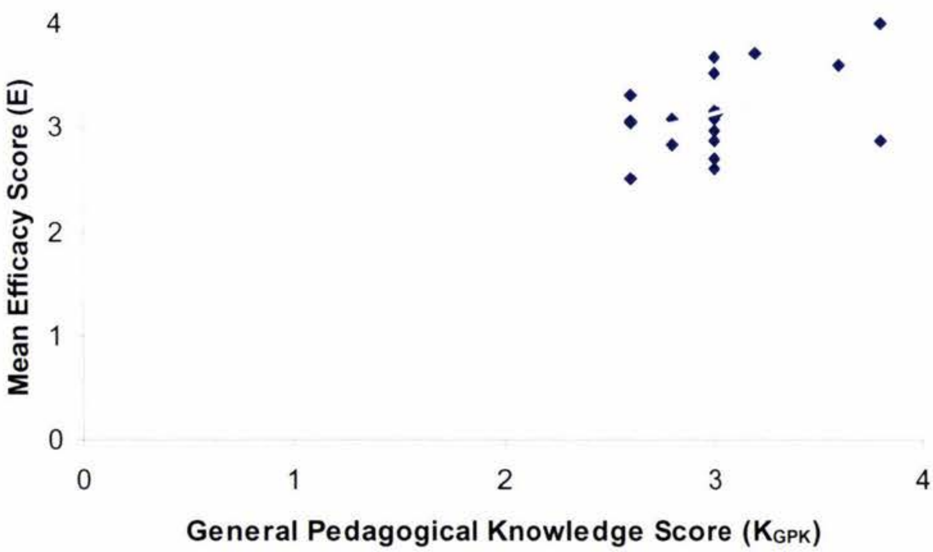

Figure 19. Comparison of teachers' general pedagogical knowledge and efficacy levels.

As general pedagogical knowledge is quite closely related to pedagogical content knowledge (See Figure 19), it is not surprising that a similarly moderate trend is evident. (R = 0.45, $R^2 = 0.20$).

Figure 19 shows a large number of participants showed very similar K scores that maintain efficacy belief that have wide variations in strength of efficacy belief. This suggests that teachers' strength of efficacy belief may be more independent of their General Pedagogical than this moderate correlation would imply. Harlen (1995) notes that teachers' confidence in teaching science 'may be misplaced' as, though teachers may feel they teach science topics well, their lessons may actually contain very little content, and simply mask their lack of conceptual understanding. This notion may serve to explain some of the variation in these data.

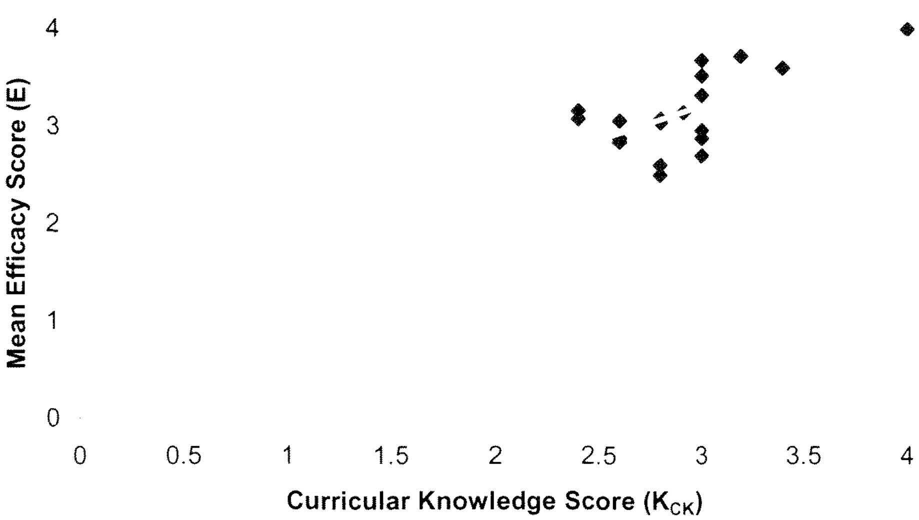

Figure 20. Comparison of teachers' curricular knowledge and efficacy levels.

It is unusual that, of all the individual knowledge dimensions compared with teachers' efficacy beliefs, curricular knowledge yielded the strongest relationship ($R = 0.64$, $R^2 = 0.42$). This result was also remarkably significant ($P = 0.003$). From this result, it could be inferred that knowledge of the learning requirements for students, appropriate learning experiences and the resources available to teachers of earth science have more impact on a teachers' strength of efficacy than do all other forms of knowledge. However, without further investigation such a conclusion would be premature.

Unfortunately, the utility of the questions used to investigate curricular knowledge may be somewhat questionable. Shulman (1985, 1987) describes curricular knowledge as a teacher's knowledge of the "tools of the trade". This includes, but is not exclusive to, a working knowledge of the curriculum requirements – which was the main intent of the questions addressing curricular knowledge in the survey. However, Shulman notes that curricular knowledge also includes knowledge of available resources, programmes and instruction materials. These, less obvious components were not explicitly addressed in the survey, which may have led to inaccuracies in the data collected on curricular knowledge. Further investigation in this area may clarify the trends these data provide.

Data presented in figures 16 to 20 reveal that some form of efficacy-knowledge relationship does exist, though the nature of this relationship is not very clear and appears to be more complex than the data in Figure 16 would imply.

Comparisons of individual knowledge scores show that while each dimension of K has a moderate influence, it is only when a teacher's overall professional science knowledge is considered that knowledge has a substantial influence on their confidence in teaching earth science. Of the individual dimensions of professional science knowledge, knowledge of the subject matter appears to have the greatest effect on the strength of efficacy belief.

However, the clusters of participants with similar K scores while maintaining different levels of confidence must be considered. It is likely that while the influence of professional science knowledge on teachers' strength of efficacy belief is higher than first anticipated, other factors – such as teacher background– may also have a great influence.

This notion was supported when a further analysis of the effect of the various knowledge dimensions on specific, efficacy-related, behaviours was performed. Though the relationships identified in this analysis were moderate at best, the data generated provide an intriguing hint of the structure of a knowledge-efficacy relationship.

A regression analysis was used to find possible correlations between respondents' individual knowledge dimension scores and their efficacy-related behaviour scores. Most noteworthy of the trends found is that teachers' choice/avoidance behaviour is most influenced by their grasp of the subject matter (R = 0.53). This trend is also seen in Figure 17 and is least influenced by their general pedagogical knowledge (R = 0.32). Similarly, respondents indicated that their enjoyment of teaching earth science topics is most influenced by their understanding of the subject matter (R = 0.38) and least influenced by their general pedagogical knowledge (R = 0.12).

The possible influences of professional science knowledge on teachers' effort expenditure and persistence behaviours were examined. Subject matter knowledge appeared to have the highest influence (R = 0.43). However, other influences on teachers' Effort and Persistence behaviours were considerably weaker, pedagogical content knowledge (R = 0.33) and general pedagogical content knowledge (R = 0.32) appear to influence teachers effort expenditure and perseverance almost equally. It appears that the effect of subject matter knowledge, while not particularly strong in any one aspect of teachers' efficacy beliefs, is wider reaching than first anticipated. It influences teachers' confidence related behaviours, especially choice/avoidance behaviours more than any other professional science knowledge dimension. Further exploration of the effects, sources and perceived importance of subject matter knowledge is required.

Summary

The purpose of this chapter was to examine data gathered in a survey of primary and intermediate teachers to determine the existence of any relationships between teachers' knowledge frameworks and their confidence to teach earth science topics and, if any such relationships are found, to determine the influence of, and factors that contribute to, such relationships.

Although it would be imprudent to draw any conclusions from the statistical analyses of this phase of the study alone, the data that the survey present do provide a tantalising glimpse of the nature of the effect of professional science knowledge on teachers' efficacy beliefs. These data can provide a basis for the generation of research questions and hypotheses for use in further investigation of the phenomenon to be further investigated in this study.

Teachers' perceptions of the difficulty of *Making Sense of Planet Earth and Beyond* were consistent with those determined by earlier workers (Vallender, 1997, Lewthaite, 1999, Hoskin, 2000). *Making Sense of Planet Earth and Beyond* was considered by teachers as slightly easier to teach than the strands involving the physical sciences and considerably harder to teach than the biological sciences.

Earth science is not a regular part of science programmes in primary schools. 33% of teachers do not regularly include any earth science as part of their programme. This is a major concern and may be a powerful factor in the lack of student achievement in earth science as evidenced in the TIMMS and TIMMS-R studies.

The large majority of teachers who responded to this survey had very limited backgrounds in science. Those who did have more background in science were generally more confident and felt more knowledgeable than those who had not, and they held more positive perceptions of science and science teaching. Those who perceived themselves as the most knowledgeable and confident were teachers who had taken science as an optional subject during their pre-service teacher education. A positive background in science teaching appeared to have some influence on teachers' knowledge structures, though it appears to have greater influence in their strength of efficacy belief.

Teaching experience appeared to have no influence on their perceived level of professional science knowledge or strength of efficacy belief, though a gender difference was detected. Men perceived themselves as more knowledgeable and held stronger efficacy beliefs than women.

Data relating to teachers' perceptions of their professional science knowledge show that teachers hold views of their levels of expertise that vary according to changes in application (conceptual understanding, teaching, activity design and curricular understanding) and the subject matter itself.

Overall, teachers felt that their subject matter knowledge was weakest (Mean K_{SMK} = 2.76, SD = 0.42) and this varied across each of the themes of the strand. Teachers felt their subject matter knowledge of New Zealand's geological history was poorest (K_{SMK}

= 2.61) while teachers perceived their subject matter knowledge as highest in addressing the theme the processes that shape planet Earth (K_{SMK} = 3.04) – also the most frequently taught theme.

Teachers felt that their pedagogical content knowledge was reasonable (Mean K_{PCK} = 2.950, SD = 0.392). Teachers perceptions of their pedagogical content knowledge were closely related their perceived understanding of subject matter knowledge.

The dimension of professional science knowledge which teachers felt most positive about was general pedagogical knowledge (Mean K_{GPK} = 3.022, SD = 0.34). Participants' level of general pedagogical knowledge was closely related to pedagogical content knowledge but was relatively independent of their understanding of topical subject matter.

Teachers' perceptions of their curricular knowledge were generally positive, though less so than pedagogically related knowledge (Mean K_{CK} = 2.911, SD = 0.35). curricular knowledge appeared to be moderately influenced by all the other dimensions of professional science knowledge.

Teachers were generally positive in their efficacy beliefs concerning earth science topics. Teachers in this survey were least confident about teaching topics on New Zealand's geological history (Mean E = 3.06). The themes in which teachers held the strongest efficacy beliefs were the processes that shape planet Earth and the need for responsible guardianship of the planet and its resources (Mean E = 3.17).

When specific efficacy-related factors were investigated, the data became less generalisable but revealed a number of trends. Participants' strongest efficacy beliefs related to their effort expenditure and perseverance. Persistence and effort expenditure scores were very closely related. It is likely that this is related to the participants' perceptions of their role as teachers. Though this will need further investigation.

Enjoyment and choice/avoidance behaviours were very closely related and were moderately influenced by professional science knowledge frameworks. Teachers were likely to choose topics that they enjoyed. They were also more likely to choose topics because they enjoyed them rather than because they knew a lot about them.

Teachers appeared more likely to persist and put in more effort if they enjoyed the topic they were teaching. Perceived levels of professional science knowledge had only a moderate influence on teachers' effort expenditure.

CHAPTER 5

PHASE TWO RESULTS

5.1 Introduction

Phase one of this study provided insight into the nature of relationships between teachers' professional science knowledge structures and their strength of efficacy belief (confidence) to teach in the *Making Sense of Planet Earth and Beyond* strand of *Science in the New Zealand Curriculum*. The purpose of this chapter is to reveal and describe primary and intermediate teachers' perceptions of professional science knowledge – confidence relationships with the intention of using these descriptions to verify or refute the trends revealed in Phase one.

This chapter will identify and describe commonly recurring themes that arose during the interview process. It will discuss the influence of teachers' backgrounds in science on their professional science knowledge structures and confidence to teach earth science. It will consider the various behaviours associated with high or low self-efficacy that were identified during Phase One and in the review of literature and explore them in the context of teaching earth science. Finally this chapter will consider several other factors associated with primary teachers' self-efficacy and professional science knowledge. The results are summarised in relation to the hypotheses outlined for the study.

5.2 Response to Phase Two

Phase one of the study entailed the use of a survey designed to ascertain primary and intermediate school teachers' perceptions of science teaching, strand difficulty, their professional science knowledge in earth science Subjects and their strength of efficacy belief (confidence) in teaching in these areas. This survey contained a request for consent to participate in phase two. Participation in phase two was optional. Of the 18 participants in the first phase of the study, eight consented to participate in phase two. Requests for interviews were sent to these respondents after completion of phase one of the study. Four teachers responded to these requests and agreed to take part in the interview process.

The four participants in the interviews have a range of formal science education backgrounds and vary in teaching experience from beginning teacher to more than 30 years of various teaching experience. The mix of class levels taught by interview participants is similar to spread seen in phase one, with teachers of Years 7-8, Year 6, Years 3-4, and Years 2-3, taking part.

Each participant represented one of the knowledge-efficacy (K-E) score classifications identified during phase one. That is, K-E combinations ranging from lower than mean K scores and lower than mean E scores (Lolo), to higher than mean K scores and higher than mean E scores (Hihi) and the intermediate categories (Lohi and Hilo). In addition to the comments made by these participants in the interviews, other sources were used with permission from qualitative responses during phase one and from informal and unrecorded conversations with interested professional parties.

The gender distribution is similar to that in phase one, with women making up 75% of the interview participants.

5.3 Process

The survey used in phase one of the study provided valuable insights into teachers' perceptions of their backgrounds, knowledge and self-efficacy in earth science teaching. Unfortunately, like many survey based data gathering techniques, large amounts of data do not necessarily provide *depth* of data that aid in the study of social phenomena. To compensate for this lack of depth a second, qualitative phase of data collection was used to provide depth to the broad data generated from the survey.

After consent to participate was gained, interviews were arranged with the participants. Interviews took place in either the participants' home or classroom after school had finished and were tape-recorded.

Semi-structured interviews were used. These interviews utilised a loose framework of guiding questions (Appendix C) intended to allow participants to discuss their ideas openly and as comfortably as possible and reduce the possibility of participants being 'led' through the conversation. Participants were posted these interview frameworks before the interviews took place so that they may make some consideration of their responses.

Each interview contained questions regarding the respondents' perceptions of earth science in the curriculum, their background in science and the impact (or otherwise) this has had, and their perceptions of the nature and importance of knowledge and efficacy on earth science teaching.

These interviews were transcribed and analysed with aid from NUD*IST qualitative data management software. Qualitative data gathered during phase one as well as data gathered by permission in unrecorded conversations were included in these analyses.

5.4 The Influence of Teachers' Background on Knowledge and Self-Efficacy

The results from phase one of the study indicated that the majority of teachers have very limited backgrounds in science and that a teachers' background in earth science had considerable impact on their knowledge frameworks and efficacy as earth science teachers. 37% of respondents had poor perceptions of their professional science knowledge and had weakly held efficacy beliefs. Teachers with positive backgrounds in earth science were more likely to have sound professional science knowledge and strongly held efficacy beliefs.

Participants' responses during interviews are very similar to those from phase one. Personal experience with earth science appears to have a major influence on interview participants' confidence as earth science teachers. Three areas identified as particularly relevant were 1) interest and enthusiasm, 2) experience and 3) subject matter knowledge.

The results from phase one revealed that teachers who had taken optional science-based papers during their pre-service teacher education (science 'majors') held the strongest perceptions of their own professional science knowledge and maintained stronger efficacy beliefs (were more confident). These trends were supported by data gathered in phase two. A number of responses demonstrate that a strong background in science that includes some focus on teaching, like that seen in participants that undertook additional science studies during their pre-service teacher education, had higher than mean professional science knowledge.

> *I mean I've always been kind of interested in science and technology and things but I really became aware of earth science when I turned up to Massey and did those studies and subjects. That really opened my eyes and I became really excited by it.*
>
> Stephen

> *"The extra study helped me gain 'authority' in the area - build my confidence in preparation of lessons and curriculum delivery."*
>
> Respondent 9

The response form one participant however illustrated that more than just 'extra science' is necessary to improve knowledge and efficacy. It appears that how such experiences are perceived also has some influence.

> *"Yes, I have had quite a lot of earth science when I think about it. Well, a lot more than most people anyway. 5th Form geography was a lot of earth science about coral and all that sort of stuff. I did biology as well. My first year I did science subjects at Teachers College and I only did that for a year, which I hated. It just didn't suit me then. Lecturers - one in particular I won't name names."*
>
> Katie

This interview participant (Katie) that studied some additional science subjects during her pre-service teacher education responded slightly differently in phase one and phase two. Though her responses indicate a higher than mean perceived professional science knowledge, her strength of efficacy belief is lower than the sample mean (*hilo*). Her generally dispassionate feelings regarding her earth science experiences may be a contributing factor.

Similar trends are evident in other interviews, though the consequences are slightly different. Instead of affecting the confidence of the participant, a poor opinion of science as a subject was the result. That is, while her general confidence (including her confidence to teach earth science) was higher than the tested mean during Phase One, her knowledge of earth science content was poor.

> *Oh it was just a waste of time. I felt like the ...no, we just didn't do a lot. Everything comes back to, I think that the tutor himself didn't know, wasn't planned or wasn't prepared and he came in to try and teach us something when he wasn't sure himself. And instead of stopping and saying "Ok I'll find this out". He just tried to bluff his way through so we all got confused. So I sort of went away feeling – what do I know? And that probably has affected the way I think about Science.*
>
> Julia

5.5 Teachers' Knowledge Structures

Phase one results provided information on teachers' perceptions of their professional science knowledge. In general, participants perceive their professional science knowledge for the *Making Sense of Planet Earth and Beyond* strand to be better than their knowledge in other strands such as *Making Sense of the Physical World* and *Making Sense of the Material World* but still not strong enough to competently teach some earth science topics. The survey also provided information on the nature of the relationships between the various dimensions of teachers' professional science knowledge. A strong, though not significant correlation was found between professional science knowledge and self-efficacy. Further investigation revealed the nature of the relationships between the various dimensions of professional science knowledge and teachers' efficacy beliefs. Subject matter knowledge and pedagogical content knowledge displayed a moderate influence on teachers' self-efficacy belief. General pedagogical knowledge appeared to be relatively independent of teachers' strength of efficacy belief, at least in the teaching of earth science.

Participants in phase two placed considerable emphasis on subject matter knowledge and comment on how an earth science background contributed positively to their subject matter knowledge.

5.5.1 Subject Matter Knowledge

Interview participants were questioned on their perceptions of the role of various knowledge frameworks in teaching earth science. Their responses are similar to those found in phase one. Participants consider subject matter knowledge to be of substantial importance. Every participant made some mention of how subject matter knowledge can helps teachers to be more effective when teaching science.

> *"...You should have a good overall grasp of the basics of the topic before you start. Probably you don't need to know the finer details. You need to know what constitutes various sections of it and with that try and extend that knowledge. But you can't just teach something if you don't know anything about it."*
>
> Bronwyn

> *"I think it's important to be confident. But I think it's more important that you know what you are talking about - to have some background knowledge."*
>
> Stephen

Participants' perceptions of earth science as a subject also appear to be influenced by their understanding of the subject matter, and consequently by earth science background. This was most obvious when discussing the potential difficulties encountered when teaching earth science. Those participants with higher than mean professional science knowledge scores feel that the abstract nature of many earth science concepts presented the greatest challenge in effectively teaching the *Making Sense of Planet Earth and Beyond* strand.

> *"Earth science is something that you have to – you can perhaps look at various features of the earth and then there's a lot of perhaps abstract thought because you can't see what's happening in the earth.*

> *You can record what you see on the surface but you kind of got to think the big picture of what's happening"*
>
> Stephen

> *"...Probably it would be one of the harder ones to teach, like it's really hard to explain those sorts of things to kids - it's all abstract concepts and the kids just don't get it."*
>
> Katie

In contrast, those teachers that demonstrated lower than mean professional science knowledge scores consider teaching the *Making Sense of Planet Earth and Beyond*, to be reasonably straightforward, commenting that the concrete 'hands on' nature of the strand makes it easier to teach.

> *"Its something that's concrete that you can actually define. You can actually research and present it rather than looking at experiments and physics and that side of things which is weakness. I'm not into that."*
>
> Bronwyn

Vallender (1997) noted that first year student and trainee teachers' understanding is limited to that provided by physical geography, such as landforms, volcanoes, earthquakes and plate tectonics. Other concepts such as earth history, earth composition and structure and palaeontology were found to be either immaturely developed or non-existent. The findings on teachers' preference for the processes that shape planet Earth theme during phase one along with teachers' responses to interview questions allude to the same 'high school geography' trend existing among practicing primary and intermediate teachers. Only the teachers with higher than mean professional science knowledge scores made mention of earth science topics from outside a "high school geography' perspective.

> *"What do I think earth science is? [laughs] This is where I look bad. Rocks and Geology. Land formations and things like that. I guess. I don't really know. I'll get a curriculum document and have a look. Or is sort of the spacey thing as well? Is when you look at planet earth and beyond and that takes in space and that, doesn't it? The solar system and where we fit in relation to that. At a guess."*
>
> Julia

5.5.2 Pedagogical Content Knowledge

A number of participants discuss the use of personal experiences as a source of analogy or a means of adding a context that would make the subject material meaningful. Those teachers in the study that can relate the subject matter to some 'story' for their class are generally more confident in teaching the subject.

These 'stories' provide teachers with a means for explaining earth science subject matter to their students. These stories are a source of analogy and metaphor that are powerful representations of subject matter that can assist student learning (Dagher, 1995).

Teachers in both the survey and interview phases comment on the importance of being able to turn subject matter into something understandable to their students. As was indicated in the data from phase one, pedagogical content knowledge appears to have strong links to personal background. Participants' comments on converting subject matter into teachable material also emphasise the importance of personal background through formal and informal experience with earth science subject matter as well as personal experiences that provide the means to make concepts meaningful to others.

> *"If you've got that personal background full of experiences and stuff that you can relate it to the kids then it will come across, or you will come across better because you've got the stories."*
>
> Julia

"But to make it more teachable you've got to have those more personal experiences to draw on and you know they just makes the context so more relevant and so more meaningful. And if the kids can relate to it as well then that's something that they understand then they're going to learn better. So I think its that personal knowledge and those personal experiences that you can bring to it that make a Science unit either a great science unit or a good one. I mean, you can learn anything out of a book."

Julia

I think a good science teacher relates it to real life. And you know, it's not just something that happens in the lab. And I think that's particularly important when it comes to earth science, to actually draw those connections.

Stephen

Participants comment on the important role of subject matter knowledge when explaining concepts to their students. During the course of the interviews teachers were often unable to discuss pedagogical content knowledge without mentioning subject matter knowledge in some way. These responses support the phase one finding that pedagogical content knowledge is strongly influenced by subject matter knowledge.

"If there was an option of something to do with earth science and something that I know a lot about, then of course I'd choose one I know lots about. Because I felt personally more comfortable with it because I knew more about it and could explain it better to the kids."

Julia

" ...This teacher was using big words and technical jargon to hide his own lack of understanding. The students would go home and say 'Oh he knows so much that we can't understand him', when really he was doing what he was doing because he didn't understand the concepts himself".

John (pers.com)

Most respondents remark that they are always ready to admit to their students that they do not have sufficient understanding to explain some concepts to them. Respondents with higher than mean professional science knowledge scores appear more inclined to adapt their pedagogical strategies to suit their students. They demonstrate a confidence to answer 'difficult' questions and are readily disposed to locate information on topics or ask for assistance from more knowledgeable peers when they consider their knowledge to be insufficient. Responses from phase two indicate that teachers with higher than mean professional science knowledge scores place the most importance on the place of subject matter knowledge in teaching earth science.

> *"...we're in the midst of a Planet Earth Beyond type unit and just listening to comments and things – some teachers were very comfortable with you know 'lets learn about the planets – what its like on the planet – lets write a postcard home'. But they didn't want to teach about the movement of the earth and the moon, the seasons, day and night, phases of the moon because to them its like 'this is boring'. But I took that to mean that 'I don't understand it'."*
>
> Stephen

Teachers in intermediate 'categories' are more inclined to freely admit their knowledge deficiencies to their children and alter their pedagogies to compensate for this lack of personal understanding. Such strategies include a mixture of use of resources, outside assistance and personal research to build their subject matter knowledge.

> *"If I knew what earth science is about I might be able to put it into something that is relevant for the kids...If you only like, 80% understand the concept and you're trying to explain it to the kids when you're not sure yourself. Then they're not going to understand it either. There's been a couple of things that I've come across and I've thought "Hang on, I don't really understand that" and I'll just stop half way through something and say, "Ok guys just forget what I've just said. I need to go and do some more reading about it"... And that's just showing them that it's ok to be wrong or not to be sure*

about something and stop and go and find out. Rather than bluff your way through it. What's the point?"

Julia

Alternatively, respondents with lower than mean professional science knowledge Scores and weakly held efficacy beliefs indicate that they are more likely to alter their pedagogies to avoid dealing with subjects where they perceive their knowledge to be inadequate. Lee (1995) noted that teachers with limited knowledge of science content had a heavy dependence on resources such as textbooks and pedagogies such as individual activities with little teacher interaction. Hoskin (2000) found that secondary school science teachers found *Making Sense of Planet Earth and Beyond* to be "less hands-on"(p. 95) and would often employ different teaching strategies for the *Making Sense of Planet Earth and Beyond* strand, often using teacher centred or resource-dependent strategies. Responses in both phases of data collection revealed a number of similarities to these previous studies.

"...We could do some physical modelling with our bodies, use the library, research books, the internet, videos, that sort of thing - find out about the planets."

Respondent 13

Interview results with other teachers indicate that it is also common for teachers to 'do' earth science topics while avoiding the more conceptual aspects of a subject. Such a strategy could be used to mask deficiencies in understanding similar to that seen in the expository approaches used by teachers in Lee's (1995) case studies.

"One of the things that frustrates me is sometimes you see or you hear of some teachers that are perhaps teaching a topic. And it's all drawing pictures of volcanoes or making a volcano out of clay or something and there's no or very little learning. You know they're not really learning how it works or what drives it. It's, colouring in volcanoes, you know, something like that. And they're just fill in activities without real learning underneath it."

Stephen

Pardhan and Wheeler (2000) claim that the students of teachers that utilise conceptual-change pedagogy make considerably larger gains in their content knowledge than those that received more transmissive instruction. However, they note that to use such pedagogies, the teachers themselves require a conceptual understanding of the material and a sound pedagogical proficiency.

5.5.3 General Pedagogical Knowledge and Curricular Knowledge

Interview data supports the findings of phase one – that, when teaching earth science, General Pedagogical Knowledge appears to be relatively independent of a teacher's strength of efficacy belief.

> *"As part of a major topic I think just your general teaching skills and abilities would help to make the topic interesting. And the ability to use and find resources. Things like encyclopaedias, internet, people and bring them in. And having a knowledge of where to go to find those resources."*
>
> Bronwyn

Teachers' general pedagogical skills, it appears, are transferable enough that a skillful teacher should not find issues such as classroom management or finding the appropriate resources a significant factor in affecting their belief that they can teach their students (efficacy). Conversely, Harlen (1997) noted that teachers were often able to use their considerable classroom skills to avoid addressing difficult concepts. Participants' comments on sometimes shallow learning in earth science are consistent with this finding.

Phase one results regarding curricular knowledge and it's possible influence on other knowledge structures and self-efficacy behaviours are inconclusive. Though the data gathered indicate strong correlations between curricular knowledge and teachers' strength of efficacy belief, the tool used to determine teachers' perceptions of their curricular knowledge is of questionable utility. Participants in phase two made little mention of the effect of personal background on teachers' curricular knowledge.

Responses to the surveys and interviews indicate that participants possess a reasonable understanding of the required curriculum, the necessary teaching strategies and resources available regardless of their perceptions of their earth science related knowledge or their personal efficacy beliefs. This result is similar to the findings of Hoskin (2000) who noted that even though teachers felt less comfortable teaching earth science than they were with other subjects, they still possessed a sound understanding of the intentions and structure of the *Making Sense of Planet Earth and Beyond* strand of the curriculum.

5.6 Teachers' Efficacy Beliefs

Appleton (1992) found that once pre-service teacher education students had received instruction in pedagogical strategies for teaching science felt much more confident in teaching science. The reasons for this improvement in confidence was attributed to the realisation that teachers 'did not have to know everything about a topic in order to teach it. Though they did realise that some knowledge of the topic was necessary. In this study, similar sentiments were made.

> *"You should have a reasonable depth of knowledge. They don't have to be experts. And they shouldn't be afraid of admitting that they don't know. You can look things up or ask for help. But you can't just teach something if you don't know anything about it."*
>
> Katie

However, participants' responses in this study are slightly different to those found by Appleton (1929). Although teachers often note that it was not necessary to know everything, even those teachers with low knowledge scores emphasise the need for strongly developed knowledge structures as well as sound pedagogical skill in creating confidence. Data from phase one suggests that professional science knowledge structures, in particular subject matter knowledge, have a significant impact on teachers' strength of efficacy belief. Participants' responses in phase two further contribute to these findings.

> *"Well, knowledge is very important. If you don't know what you're talking about you don't have the confidence in it that you should have. That would be a major one that affects confidence."*
>
> Bronwyn

5.6.1 Choice or Avoidance of Earth Science Topics

The key influence any perceived lack of professional science knowledge seems to have is on teachers' choice or avoidance of teaching earth science related topics. Participants' comments reveal that teachers would most likely to avoid teaching topics they perceived as abstract or containing material that could be regarded as overly challenging. In *Making Sense of Planet Earth and Beyond*, teachers are most likely to avoid topics based on New Zealand's geological history or The movement of planet Earth in relationship to other objects in the heavens. This result is consistent with teachers' responses in Lewthwaite (1999).

> *"It's not something that they [teachers] find personally interesting so they avoid it."*
>
> Julia

> *It's not something I approach with great delight... Because its not a subject that interests me. I haven't probably got as much depth of knowledge and background – I could probably wing some of it. Whereas the Language lesson I could do it with my eyes closed.*
>
> Bronwyn

> *I've got a reasonable general knowledge and I do tend to pick subjects that I know something about.*
>
> Bronwyn

The decision to face or avoid challenging situations is a powerful indicator of self-efficacy (Bandura, 1977). When participants were asked what the source of the efficacy that leads to the selection of earth science topics, the most common responses included the necessity for a positive personal background, a sound knowledge of the subject matter and a personal interest in the subject.

5.6.2 The Influence of Interest and Enthusiasm

The importance of a teacher's personal interest and enthusiasm is a particularly recurrent theme, especially in participants' interview responses. Every interview participant perceives personal interest in earth science and in science in general to be a powerful factor in affecting teachers' strength of efficacy beliefs in teaching subjects from the *Making Sense of Planet Earth and Beyond* strand.

Interview participants regard enthusiasm for earth science as equal to or above subject matter knowledge in order of importance. Those teachers with higher than mean professional science knowledge scores and strongly held efficacy beliefs comment on their own interest in the subject, while those with lower scores describe interest and enthusiasm as aspects of 'good science teachers'.

> *Well if you're interested in something it's a breeze to teach. I mean sure there's preparation, but you can get up there and you know what you're talking about.*
>
> Stephen

> *"...a good Science teacher would be one that's personally involved and they do that sort of thing outside of teaching. They're the ones that took Science right through Teachers College. You know, every paper they could. They've just got that Science 'bent'. Which I don't have and I don't know many teachers that do."*
>
> Julia

> *"Yes. Because I'm more into it myself. Because I'm enthusiastic about it – it rubs off on the kids."*
>
> Stephen

> *"Well I think a good science teachers' enthusiasm for the topic transmits itself to the kids. That's got to be number one."*
>
> Bronwyn

A key source of this interest and enthusiasm appears to come from a positive background in earth science. A positively perceived background in earth science seems to act as a source of previous successes, or enactive mastery experience and vicarious experience, for those involved.

> *"...They've got that interest. I could go in and I could teach a unit on 'how plants grow'. And I could seem really enthusiastic about it and that could come across to the kids. But that's sort of a put on. You know, just for that. But I guess a really good Science teacher would be one that's personally involved - they do that sort of thing outside of teaching. Or they're the ones that took Science right through Teachers College. You know, every paper they could. You know, they've just got that Science 'bent'. Or bend. Which I don't have and which I don't know too many teachers that do."*
>
> Julia

5.6.2 Effort Expenditure and Persistence

In Phase one, data indicated that teachers generally had strong effort scores regardless of knowledge or efficacy scores. Responses in the interviews continue this trend. They suggest that effort expenditure and persistence in difficult situations are fairly independent of teachers' perceptions of their knowledge of and perceptions towards their ability to teach earth science.

> *"...Still reasonably confident, because I know it's a weakness and therefore I have to work harder get more prepared for. It's not something I approach with great delight. But yeah, because I know I can get resources and where I can get them from – it gives me confidence. But I couldn't just bowl into a room and do science as I could with say Social Studies or Language.*
>
> Bronwyn

5.7 Other Factors Affecting Participants' Delivery of Earth Science

Results from both phases of this study have shown that professional science knowledge has considerable effect on teachers' strength of efficacy belief when teaching earth science. In addition to the body of data gathered on participants' views on the effects of knowledge structures on their confidence, a number of other factors that do not directly contribute to teachers' self-efficacy but certainly affect the quality of earth science programme delivery were identified.

Participants in phase two of the study make mention of the influence of the school they work in on their delivery of earth science programmes in their classes. Factors such as the value schools place on science, school or syndicate planning systems, lack of time and resource related issues were all mentioned.

Lewthwaite (2001) comments that effective science programme delivery (or otherwise) can be strongly influenced by the culture of current attitudes and practice in a school. Factors such as the school staff and leaderships' opinions of the status of science can have impacts on other factors such as collegial support, time allocation or resource adequacy. Participants' comments mirror these findings.

> *"Like I've been here nearly three years and there are a few things that I think – lets just say I don't think I teach science well because I don't think our school focuses on it."*
>
> Katie

> *"...In a large school where what you teach is prescribed, I don't think personal interest comes into it at all. You just have to do it. Term 3 is Planet Earth. So Term 3 you do it whether you want to or not. Whereas in a school like this we can – so long as we cover the curriculum we can pick and choose the topics to do when and where we want."*
>
> Bronwyn

"...Because I was new the long-term plan had already been done for my class. So the last teacher had put down in the long-term plan that she was going to teach a unit on skin. Which related to our health unit on the body and things like that. So it did tie in with what else we were doing but it wasn't my choice. So it was sort of dictated. And because I was new I had to just go with the flow."

Julia

Tilgner (1990) nots that inadequate time allocation is a major impediment to science programme delivery. A number of participants mention the crowded nature of the curriculum. Respondents in both phases of the study comment that earth science is often addressed either briefly or in a shallow manner as other 'more important' curriculum areas or topics receive more of the limited time available.

There are so many curriculum areas to fit in that to be able to do justice to each one I think teachers tend to select the strands that they have knowledge of.

Bronwyn

Summary

This chapter identified and described primary and intermediate teachers' perceptions of professional science knowledge – Confidence relationships and used these descriptions to verify or refute the trends revealed in Phase One. It discussed the influence of teachers' backgrounds in science on their professional science knowledge Structures and confidence to teach earth science. Additionally, it considered the various behaviours associated with high or low self-efficacy that were identified during phase one and in the review of literature.

The five constituent themes of the *Making Sense of Planet Earth and Beyond* strand were found to have different impacts on teachers' strength of efficacy belief. Respondents were found to feel most comfortable teaching topics based on The Processes that Shape Planet Earth and less confident about teaching topics based on New Zealand's geological history and The movement of planet Earth in relation to other objects in the heavens. Teachers' reasons for avoiding or selecting these topics were based largely on knowledge of the content involved in these topics, interest in the subject and, to a lesser extent the ability to explain the concepts involved to their students.

Differences in background experiences in earth science had some effect on teachers' perceptions of their professional science knowledge structures. Primarily, participants felt that background experiences made it possible to make concepts meaningful to students. That is, experiences in a topic act as a source of pedagogical content knowledge.

Differences in background experiences in earth science were found to have a considerable effect on teachers' strength of efficacy belief (confidence). Responses from survey and interview participants indicate that a positive background in science is a powerful source of both professional science knowledge and of self-efficacy.

Teachers with a positive background in science appear to have greater interest and enthusiasm toward teaching earth science, have broader and deeper understandings of what constitutes earth science, and place more value on teaching science concepts to their students. All the interview participants considered interest and enthusiasm to be the most important aspect of an effective earth science teacher.

Teachers with less background or negatively perceived experiences in earth science are more likely to avoid teaching earth science topics, have a narrower perception of what earth science involves and are more likely to rely on resource based or 'concept light' teaching strategies.

CHAPTER 6

DISCUSSION

6.1 Introduction

It was found in the review of the literature that any link between teachers' knowledge self-efficacy is tenuous at best (Skamp,1989; Appleton 1992). Numerous other researchers (Schulman, 1986,1987; Symington & Hayes, 1989; Ginns & Watters, 1995; Lee, 1995; Harlen, 1997; Vallender, 1997) make reference to the effect of knowledge on teachers' efficacy beliefs. None of these authors however made a purposeful attempt to investigate the impact of knowledge itself. Instead most of these deductions were secondary findings or related points of interest. Conventional wisdom and anecdotal evidence suggest that teachers' knowledge frameworks would indeed have some influence on their strength of efficacy belief (confidence). As well, different types of knowledge may effect confidence in different ways. This study approaches such issues by attempting to address the questions:

(a) Do teacher's professional science knowledge have any influence on their confidence in teaching earth science?

(b) Do the various dimensions of professional science knowledge affect teachers' confidence in different ways?

(c) Do the various themes of the *Making Sense of Planet Earth and Beyond* strand have different impacts on teachers' strength of efficacy belief?

(d) In what ways do teachers' background in earth science affect their knowledge frameworks and confidence?

In interpreting the results it is important to consider that this study differs in intent, context and execution from many related studies that have investigated the many effects of self-efficacy in science teaching and the place of knowledge in science teaching or earth science teaching in New Zealand schools. These differences contribute to make any analysis both distinctive and in some ways difficult. One important feature of this study is that it attempts to integrate the concepts of teachers' self-efficacy belief (confidence), teachers' knowledge structures and their contributing factors with the context of earth science in New Zealand primary and intermediate schools – a context that itself has had little exploration.

Response rates to both the survey and interview phases of data collection were very low, meaning that this study is very small in scale. Consequently, any conclusions drawn using the data gathered during the course of this study must be done tentatively, or with careful consideration to previous research in similar areas, or both. With such considerations in mind, the results of this study are discussed in terms of the hypotheses generated from the guiding question outlined earlier.

6.2 The Influence of Professional Science Knowledge on Strength of Efficacy Belief

A number of researchers (Verdon, 1988; Lee, 1992; Vallender 1997) have made comment on the lack of exposure that many teachers have had to earth science topics. TIMMS and other subsequent reports (ERO, 2000; Lewthwaite, 2001) have shown that New Zealand teachers (primary teachers in particular) perceive their competence to teach science to be less than adequate. Commonly cited reasons for this perception are a lack of knowledge about the concepts involved and a lack of confidence in teaching science. The reason for this lack of confidence has often been attributed to a lack of conceptual knowledge (Appleton, 1992). The investigation of the possibility of a relationship between these two 'problem' areas is the main reason for this study. Both phases of the study revealed a number of relationships between teachers' professional science knowledge structures and their strength of efficacy belief.

It was hypothesised that each of the various professional science knowledge dimensions would exhibit varying degrees of influence on each other as well as on teachers' strength of efficacy belief. More specifically it was anticipated that of the various dimensions of professional science knowledge, subject matter knowledge would have the greatest influence on earth science teachers' efficacy belief while general pedagogical knowledge would have the least.

To investigate the validity of such a proposition, data from the survey used in phase one were interpreted to ascertain the strength, or existence, of any such relationships. Even though the sample size was quite small, a number of interesting relationships were discovered. Phase two of the study explored these relationships further and developed common themes in greater depth. A number of relationships were found.

Investigation of the specific professional science knowledge dimensions during phase one revealed that teachers could hold different perceptions of their understanding in different knowledge dimensions. In every theme of *Making Sense of Planet Earth and Beyond*, teachers' perceptions of their subject matter knowledge were weakest, while general pedagogical knowledge and curricular knowledge scored consistently well. During the course of the study, the importance of subject matter knowledge became apparent. Similar to the findings of Shrigley (1974, in Tosun 2000), analysis of the survey results from phase one revealed a strong (though not significant) correlation between participants' professional science knowledge and strength of efficacy belief.

6.2.1 Subject Matter Knowledge and Efficacy Belief

The professional science knowledge dimension shown to have the strongest influence on participant's confidence was subject matter knowledge. Teachers felt that their subject matter knowledge was weakest in earth science themes that addressed New Zealand's geological history and was strongest in themes based on the processes that shape planet Earth. Participants' self-efficacy scores corresponded to this trend. Analyses of all the themes in the strand showed a moderate correlation between subject matter knowledge and strength of efficacy belief.

This result is noteworthy as it reveals a trend, although not significant, and additional qualitative responses of interview participants and the findings of previous workers can support it. Shrigley (1974, in Tosun, 2000) discovered a weak correlation between science content knowledge and teacher attitude towards science. Additionally, Lee (1995) and Hoskin (2000) noted that when subject matter knowledge was perceived as deficient, normally confident teachers would 'regress' to reliance on resources and didactic teaching strategies – behaviours noted by researchers in personal efficacy (Gibbs, 1994; Bandura, 1997) as an indicator of low personal teaching self-efficacy.

A number of other findings add strength to this line of reasoning. It was found that respondents were more likely to choose to teach topics they enjoyed. Those respondents who had positive background experiences with earth sciences had generally higher professional science knowledge Scores and were more likely to choose to teach earth science topics. A number of teachers with more weakly held efficacy beliefs alluded to a number of strategies they used when teaching subjects where they perceived their subject matter knowledge to be inadequate. Most common of these was avoiding the topic altogether, or alternatively, using strategies that avoid the raising of 'difficult' topics such as process-oriented, or research-based lessons.

Results indicated that 33% of teachers do not include any earth science as part of their school science programme. The decision to pursue or avoid a particular course of action is a powerful indicator of self-efficacy (Pijares, 2002). Teachers in this study indicated that they were most likely choose to teach topics based on *The Processes that Shape Planet Earth* and would most avoid topics based on *New Zealand's Geological History*. This is consistent with Vallender's (1997) findings that many teachers' perceptions of earth science are limited to 'high school geography' topics such as earthquakes or volcanoes.

Currently, 'best practice' in science teaching emphasises the teaching of conceptual understanding of science topics (Baker, 1994; Skamp, 1997). It is not unusual then that many participants in both phases of this study placed a great deal of importance on the necessity of teachers a sound understanding of the subject matter. Shulman's (1987) comment that; "teacher comprehension is more critical for the inquiry-oriented classroom than for it's more didactic alternative"(p.6) appears to be more than just a statement of opinion in the light of such findings.

Participants' responses during phase two showed that those teachers with a strong understanding of the subject matter had great confidence to deliver 'meaningful' conceptually based earth science programmes. Those with weaker understandings of earth science concepts displayed preferences for familiar topics and an aversion to concept-based learning. Those participants that perceived their subject matter knowledge to be deficient appeared to prefer lessons where their own teaching role was minimised in such activities as resource-based 'research' units, writing projects or museum visits were common 'content free' approaches. This parallels Harlen's (1995) assertion that some teachers felt confident despite a deficiency in subject matter knowledge. The study found that many such teachers would use their "considerable teaching skills" (general pedagogical knowledge) to avoid addressing topics where they felt uncomfortable. Similar avoidance tactics were found in other studies (Grossman, *et. al.* 1989; De Laat & Watters, 1995; Ginns & Watters, 1995; Lee, 1995; Harlen, 1997).

What is clear from these findings is that teachers' strength of understanding of earth science subject matter has a powerful effect on teachers' strength of efficacy belief. This confirms the conclusions reached by Vallender (1997) and the Education Review Office, (2002). It is also clear that a large number of teachers have poor and limited understandings of earth science concepts. The subsequent lack of personal efficacy may have serious consequences. Primary teachers may either avoid teaching earth science altogether, or that they do so in a manner that does little to develop children's conceptual understanding.

6.2.2 General Pedagogical Knowledge and Efficacy Belief

Phase one of this study revealed a moderate correlation between teachers' general pedagogical knowledge and strength of efficacy belief, although there is a degree of doubt regarding the validity of these findings. In phase one, a large number of respondents with very similar general pedagogical knowledge scores with widely varying efficacy scores suggests that, teachers' strength of efficacy belief may be more independent of their general pedagogical knowledge than a moderate correlation would imply.

The qualitative responses of participants in phase two contribute to this inference. The participating teachers in this study made comments that suggest that general pedagogical knowledge has less influence on confidence than other knowledge dimensions.

Gooday *et. al.* (1993) also studied the subject matter knowledge and confidence of pre-service teacher education students. In their comparison of the confidence of first year and fourth year students, it was found that fourth year students were considerably more confident about teaching science than first year students – despite there being very little difference in their subject matter knowledge.

It is notable however, that Gooday *et. al.* (1993) add caveats to their conclusions, commenting that it is necessary to question whether the confidence of some teachers is relatively misplaced in the light of a generally poor understanding of scientific concepts. Harlen (1997) also comments on the possibility of 'misplaced' confidence, especially among less experienced teachers.

These warnings seem to be borne out in the comments made by participants in this study. Many participants made comments on the use of strategies such as integrating earth science with other subjects, redirecting lessons so that no 'real science' was involved or even 'fake it' if necessary. Such comments imply that the degree of influence of general pedagogical knowledge on teachers' confidence can be blurred by teachers' use of the same knowledge to avoid teaching areas of earth science that they do not wish to approach.

This finding is supported by the earlier findings of Lee (1995) and Harlen (1997). They made similar observations, noting that teachers could utilise a number of strategies that would help them cope with any lack of conceptual understanding. These included avoidance of the topic altogether; keeping to topics where understanding was greater; and relying on resources and underplaying questioning and discussion in favour of expository teaching. Although teachers in this study made no comments whatsoever on the use of expository teaching, avoidance of difficult topics could be seen in responses to both phases of the study.

From these findings, it can be surmised that general pedagogical knowledge does indeed have an influence on teachers' strength of efficacy belief. Its influence is somewhat less than that of subject matter knowledge. Data also suggest that the increase in confidence that may result from strong general pedagogical knowledge may be misplaced. Teachers with strong general pedagogical knowledge may also possess strong beliefs in their effectiveness to teach earth science, but whether they teach in a manner that promotes conceptual understanding in their students or merely keeps them busy cannot be determined within the realms of this study.

6.2.3 Pedagogical Content Knowledge and Efficacy Belief

The analysis of results from this study revealed that the ability to turn topical subject matter into teachable material (pedagogical content knowledge) is of great importance to the study participants.

Pedagogical content knowledge is the knowledge that a teacher needs in order to teach the topic and respond appropriately to students' questions. A sound pedagogical content knowledge allows a teacher to ensure that learning activities give their students accurate information, and can help them create links in their understandings about related ideas. Such knowledge is essential if a teacher is to teach appropriately, accurately and creatively (Education Review Office, 2000). Pardhan and Wheeler (2000) contend that teachers with a strong understanding of conceptual science teaching pedagogies are more effective in enhancing students' understanding of subject matter.

Pedagogical content knowledge has been recognised as a weakness in New Zealand teachers. "It is widely believed that many teachers entering the profession in New Zealand do not have adequate pedagogical content knowledge" (Education Review Office, 2000, p.30).

In this study, participating teachers' perceptions of their pedagogical content knowledge were more positive than those for subject matter knowledge, but still poor compared to more 'generalisable' forms of knowledge such as general pedagogical knowledge. A strong correlation was found between pedagogical content knowledge and subject matter knowledge and a moderate correlation was found between pedagogical content knowledge and participants efficacy scores. Teachers' comments on the status of pedagogical content knowledge repeatedly referred to the necessity of having a sound understanding of the subject matter and a personal investment or interest in the topic being taught.

The interrelated nature of teachers' mastery of these two knowledge dimensions is somewhat predictable. Subject matter knowledge and pedagogical content knowledge are closely related enough that the Education Review Office (2000, 2002) describe knowledge of the subject matter and related substantive and syntactic structures as being part of pedagogical content knowledge. Teachers' responses during the study reflect this close correlation in that every interview participant could not discuss one without mentioning the other.

Such an occurrence can be expected as Shulman (1986) discusses pedagogical content knowledge as going "beyond knowledge of subject matter *per se* to the dimension of subject matter knowledge *for teaching*" (p. 9). Ginns and Watters (1995) contend that for a teacher to effectively develop students' understanding of science concepts it is essential that they understand those concepts themselves and note that if a teacher possesses conceptual misunderstandings, they will have difficulty identifying and correcting students' misunderstandings.

A moderate correlation was found between pedagogical content knowledge and participants' strength of efficacy belief. Again this is rather predictable given the very close relationship between the two dimensions. Most of teachers' comments on the effect of pedagogical content knowledge on confidence refer not so much to their ability to transform the subject matter into teachable concepts rather, about how well they understood subject matter itself, and their personal experiences with it.

These notions are consistent with the thesis put forward by Shulman (1987) that before a teacher is able to transform ideas into meaningful representations, they must first understand them and, "when possible understand it in several ways. They should understand how a given idea relates to other ideas within the same subject and to areas in other subjects as well" (p. 14).

Most of the participants' responses regarding knowledge during this study are comparable to the previous work of researchers such as Shulman, (1986, 1987) or Ginns and Watter (1995), although further investigation of the sources of pedagogical content knowledge took this study in a somewhat unexpected direction. Participants, in their difficulty to separate knowledge of the subject from the ability to teach it, made numerous comments about the influence of their personal background in earth science on both their subject matter knowledge and pedagogical content knowledge. Participants' responses in both phases of data collection suggest that in the teaching of earth science, pedagogical content knowledge and subject matter knowledge are important, but these are themselves only the product of a much more wide reaching entity – teacher's background.

From these results it can be reasoned that a well-developed pedagogical content knowledge has quite considerable impact on teachers' confidence or lack thereof. Pedagogical content knowledge has a strong correlation with subject matter knowledge and influences teachers' confidence in similar ways. Teachers require a broad and deep understanding of earth science subject matter if they are to effectively teach to develop their students' understanding of the subject. Given the evidence provided in the course of this study and through the results of previous workers, understanding of earth science subject matter appears to be deficient in many primary and intermediate teachers. A strong background in earth science appears to be a powerful factor in teachers' perception of their pedagogical content knowledge.

6.3 The Influence of Background on Professional Science Knowledge

It is clear that personal background has some influence on self-efficacy; numerous researchers have researched this subject (Bandura, 1977; De Laat & Watters, 1995; Lee, 1995; Riggs, 1995; Maddux, 1995; Pijares, 2002). The most powerful sources of self-efficacy belief – enactive master experiences and vicarious experiences – exist only as the product of a persons' understanding developed from their own encounters with the object of the efficacy belief (Bandura, 1997). De Laat and Watters' (1995) case study of primary teachers' personal science teaching self-efficacy indicated that teachers with high personal science teaching self-efficacy (PSTE) had a long interest in science and a relatively strong formal background in science with opportunities for exploring out of school activities. Conversely, teachers with low PSTE had backgrounds that were "substantially more limited than the high PTSE teachers" (p.458).

Little has been done on the effects of personal background on professional science knowledge structures *per se*, but inferences can be made from the findings of research in similar fields. Numerous studies have found that New Zealand teachers' professional science knowledge (more specifically, subject matter and pedagogical content knowledge) is frequently inadequate and that many teachers possess misconceptions that are similar to their students (Harlen, 1997; Hoskin, 2000). Other surveys have found that many teachers lack the confidence to teach science effectively.

Teacher confidence is regarded, as one of the greatest inhibitors to effective science programmes (Lewthwaite, 1999) while Appleton (1992) contends that a key cause of this lack of confidence can be attributed to a lack of content knowledge. Lee (1995) noted that a lack of formal background in science was attributed to the lack of subject matter knowledge and a lack of knowledge was a major cause of low self-efficacy when teaching science. The Earth Science Education Group (1993) aired its concerns over the rapid introduction of an earth science strand into the New Zealand science curriculum. The majority of their concerns related to teachers' dearth of experience in the earth sciences.

From such research it was hypothesised that teachers with positive background in science and earth science will exhibit stronger professional science knowledge structures, while teachers without such background experiences would lack the subject matter knowledge and pedagogical content knowledge required for effective teaching to occur.

To investigate this prediction, data from phase one were used to determine the existence of any relationship between formal earth science education, perceived professional science knowledge and strength of efficacy belief. Participants' responses to questions during phase two of the study also provided elaborating information on the trends revealed in the survey.

Results from phase one of the study indicated that participants' background in earth science do have an effect on their professional science knowledge. Analysis of teachers' responses to the survey in phase two revealed that those with strong formal and informal backgrounds in science had considerably higher professional science knowledge scores than those who did not.

The greatest differences between participants with strong backgrounds in earth science and those with weak backgrounds, were participants' perceptions of their subject matter knowledge and pedagogical content knowledge. Though there were differences in the other professional science knowledge dimensions, these were not so substantial.

Results in this study indicate that the differences in teachers' subject matter knowledge and pedagogical content knowledge scores can be linked to background. Results from this study indicate that teachers that have a strong background in earth science possessed a stronger understanding of earth science as a discipline and a broader and deeper understanding of subject matter.

Those participants with stronger backgrounds in science and earth science also placed more importance on the need for developing students' conceptual understanding of the topic than those with weaker backgrounds and expressed very different views of what factors made earth science easier-or more difficult to teach than other science disciplines. Those that had stronger backgrounds in earth science commented that one of the difficulties of teaching earth science was the 'abstract', 'hidden' or 'big picture' nature of many earth science concepts. Those with less background were more inclined to consider *Making Sense of Planet Earth and Beyond* 'easier' to teach than other strands because of it's 'hands on' character.

The work on teachers' perceptions of what defined earth science as a discipline by Vallender (1997) does help to clarify this counter-intuitive finding. Those in the study with low knowledge scores were likely to maintain what Vallender called a 'high school geography' perspective of earth science. This perspective is quite valid, but provides only a limited view of the scope and depth of earth science.

Such a finding is important, as it establishes the existence of a link between teachers' background experiences with earth science and their level of understanding of earth science concepts (subject matter knowledge).

Given the strong correlation between pedagogical content knowledge and subject matter knowledge found earlier in the study, it could be predicted that participants' background experiences in earth science would also have considerable impact on their ability to make science concepts meaningful to children.

Results from both phases of data collection confirm this prediction. Even though participants with stronger backgrounds perceived earth science as containing many abstract or 'big picture' concepts, they still maintained stronger than mean efficacy beliefs. When asked what factors contributed to their ability to make earth science concepts interesting and meaningful to students, all participants made similar responses. Comments on developing personal knowledge of the subject, interest and enthusiasm were most frequent – all of which relate to background experiences. De Laat and Watters (1995) made similar findings noting that such entities were often the product of long and positive backgrounds with science with opportunities to explore science outside formal settings.

Participants would often refer to the use of 'stories' to aid in explaining concepts to students. Dagher (1995) found that teachers use a wide variety of analogies and similes to transform scientific concepts into material that is meaningful to students. Teachers involved in this study made a number of comments on the source of these 'stories', which usually came from personal experiences derived from their own interest in the subject area. Those teachers in the study that discussed relating the subject matter to a 'story' for their classes were generally those who were more confident in teaching earth ecience.

Participants noted that the source of these stories was a personal involvement with the subject matter. That is, those teachers that possessed a prior interest in the subject had better developed links between the subject matter and real life contexts that helped them to make earth science more meaningful to students.

6.3.1 Background Experiences that Contribute to Professional Science Knowledge

Shulman (1987) discusses a number of sources of teachers' knowledge structures. These sources, including formal education and scholarship, institutional maxims and practices, research on education and the wisdom of practice itself, could all fit the classification of 'background' that was used in this study. De Laat and Watters' (1995) study of the influence of teachers' backgrounds on their personal science teaching self-efficacy included other notions such as personal experiences, informal exploration and personal interest in their definition of background. Participants in this study used these, and other similar terms in their descriptions of background.

Formal education is noted by Shulman (1987) as being of primary importance in establishing a teacher's professional knowledge frameworks. In earth science education, formal studies act as a source for all the dimensions of professional science knowledge, particularly subject matter knowledge.

The influence of formal study on participants' knowledge frameworks was evident in the study. All participants often made mention of their educational background when discussing their knowledge of subject matter and their knowledge of the curriculum and its delivery. Less mention of formal education was made when discussing matters relating to pedagogical content knowledge and classroom management.

Participants with high subject matter knowledge scores repeatedly discussed matters such as general interest in science, a long (but not always successful) history of formal science education and an enthusiasm for earth science topics. Those with lower scores made few, and often negative comments, regarding their science education. Most of these teachers commented that they considered their understanding of earth science topics to be inadequate.

For most participants, their only exposure to any earth science was in the form of geography during high school or as part of curriculum delivery course taken during pre-service teacher education. This is the sort of background discussed by Vallender (1997) that provides only a limited understanding of earth science – something reflected in the findings of this study. Vallender did note however, that with earth science becoming a compulsory portion of *Science in the New Zealand Curriculum* in 1993, students will be exposed to an increasing quantity of earth science, which may alter this trend.

Unfortunately, Vallender's tentative optimism may be misplaced, as this study showed that earth science subjects are taught very little in primary and intermediate schools. It seems that, unless steps are taken to build their understanding of earth science, a lack of subject matter knowledge among teachers will continue to be a significant problem in earth science education.

From these findings it can be inferred that formal education in earth science can be a powerful source of background experiences that contribute to teachers' subject matter knowledge. Other knowledge dimensions do appear to be effected by formal background, though less so. Unusually, pedagogical content knowledge, despite its close relationship with subject matter knowledge appeared to be influenced more by personal, informal experiences than by formal education.

Previous workers (Shulman. 1986, 1987; Grossman *et. al.* 1989; Baker, 1994) have noted that formal education can give the links between concepts that allow teachers to use different concepts to aid in their teaching. However, participants' responses in the study indicate that though formal education does provide essential conceptual links, personal experiences are more useful in allowing teachers to explain concepts in a way that is meaningful to students. Although given most of the participants' lack of formal experiences in earth science, personal experiences are probably the only thing most teachers can draw their explanations from.

Dagher (1995) found that teachers would often use analogies and metaphor that were seemingly completely irrelevant to the topic at hand to explain science concepts to their students. These analogies often required the teacher involved to be creative in making the concepts meaningful to their students. Similar trends were evident in participant's talk of using 'stories' to engage their student and explain difficult concepts in their classrooms. Teachers with strong backgrounds in earth science demonstrated a greater willingness to use conceptually based (theoretical) examples as well as stories, demonstrating that subject matter knowledge, and accordingly, formal education does play a part. For most participants however, the source of these 'stories' originated from informal experiences arising from a personal interest in the subject.

6.3.2 The Role of Interest and Enthusiasm

The importance of teachers' interest and enthusiasm in effective science teaching was a particularly recurrent theme in phase two of data collection. Participants ranked it as equal to or above subject matter knowledge as an attribute of an effective earth science teacher. In phase one, a strong correlation was found between participants' enjoyment scores and behaviour scores, indicating that participants were most likely to choose to teach topics that interested them in some way. Teachers that did not perceive the topics presented in the survey scenarios as enjoyable would indicate that they would avoid teaching the topic altogether if possible.

Bandura (1997) notes that people with strong senses of self-efficacy are more likely to perceive difficult situations as potentially rewarding challenges to be overcome while those with weak self-efficacy would perceive the same situation as threatening and one to be avoided, or put simply, they perceive situations as either potentially enjoyable or burdensome. Bandura identifies such behaviours as powerful indicators of self-efficacy. De Laat and Watters (1995) found that feelings of personal interest or enthusiasm were strongly associated with their participants' personal science teaching self-efficacy. Those with high self-efficacy scores usually had a long history of interest in the subject, this interest was often informal in nature and was not always associated with success in formal study.

This finding is relevant to this study as it provides further evidence of the nature of the relationship between primary teachers' backgrounds in earth science, their professional science knowledge and their strength of efficacy belief (confidence). It appears that effective earth science teachers appear to possess a genuine interest and enthusiasm about earth science, this interest it seems, is also closely linked with teachers formal and informal experiences with earth science and with the knowledge frameworks that these experiences create.

From the findings of this study, it is evident that the rather nebulous term 'background' is in fact a source for many of the phenomena that are examined during the course of this study. Teachers' knowledge frameworks and subject matter knowledge in particular are strongly affected by formal science education backgrounds, while informal experiences seem to act as valuable sources of examples and analogies that help to develop pedagogical content knowledge beyond the more limited realms of formal education. More importantly it appears that informal experiences with earth science, that include failure as well as success, are powerful sources of personal efficacy belief and are strongly associated with teachers' perceptions of whether they would enjoy teaching earth science topics.

Personal background in science is a complex phenomenon with many contributing factors, including formal education, personal experiences with a subject, links to hobbies, even television viewing. Although background was not the key focus of this study it's influence is still significant. This study has shown background experiences as a source of teachers' professional science knowledge as well as a source of enactive and vicarious experiences that contribute to self-efficacy.

It must be noted however, that it is essential that background experiences develop teachers' professional science knowledge frameworks as well as their strength of efficacy belief. As Harlen (1997) cautioned, teachers can use their considerable classroom skills to avoid topics where their content knowledge was inadequate. Results form this study pertaining to the relative independence of general pedagogical knowledge from subject matter knowledge, and participants' comments on shallow teaching practices, are congruent with this warning. Background experiences that build strength of efficacy belief (confidence) without also developing knowledge frameworks may actually do a disservice to teachers and their students. This has important implications for pre-service teacher education.

CHAPTER 7

CONCLUSIONS

7.1 Introduction

This study has explored the nature and parameters of the relationships between the professional science knowledge of primary and intermediate teachers and their confidence in teaching the *Making Sense of Planet Earth and Beyond* strand of *Science in the New Zealand Curriculum*. It has used a number of methods to explore these relationships, from broad quantitative techniques to more focused qualitative approaches. The purpose of this final chapter is to summarise the intentions and findings of this examination into the relationships between teachers' knowledge frameworks and confidence in teaching earth science.

This chapter will present a review of the investigation process and present the major findings of the study. It will also identify the limitations of the study, provide recommendations for further research and consider the significance in implications of the research. Finally this chapter will summarise the study.

7.2 Review of the Study

This study was conducted to satisfy a curiosity regarding the importance of teachers' conceptual understanding when teaching the rather complex strand that is *Making Sense of Planet Earth and Beyond*. It is hoped that the insights made from such an investigation will contribute to the growing body of knowledge that is the 'science of science teaching'.

Additionally it is hoped that the findings of this study can contribute to pre-service teacher educators to more purposefully develop current and prospective teachers' personal understanding and confidence in teaching earth sciences and in so doing provide higher quality earth science experiences for students.

The data collection for this study began after a thorough literature review into New Zealand science and earth science education, self-efficacy and professional science knowledge. The identifying factors and methods of analysis of these entities was of concern as this literature review aided in the construction of a teacher survey.

Primary and intermediate school principals were sent requests for participation in the survey of practising teachers. This survey was intended to identify any relationships that may exist between the multifaceted construct of professional science knowledge and the strength of teachers' efficacy belief (confidence) in the context of earth science teaching. The survey identified several relationships of varying strength between knowledge frameworks and confidence that often related to teacher's background experiences with earth science and science in general.

The second phase of data collection was intended to investigate in greater depth the relationships identified in phase one. Four practicing teachers, representing a range of knowledge framework–confidence relationships were interviewed. Participants' responses were considered in the light of the findings of the previous data collection phase. Results from phase two revealed further insights into the sources and relationships between professional teachers' understandings of earth science and their confidence to teach earth science topics. It also provided much data on the relationship between these two constructs and teachers' background experiences.

Results from both phases of data collection were discussed with consideration to the work of previous workers in related areas. The findings of this study was concordant with much of this earlier work, though a number of findings that did not conform to the claims of some researchers.

7.3 Major Findings of the Study

The intended direction of this research led to the production of a number of research hypotheses. The major findings of this research relate to and elaborate upon these earlier predictions.

(1) Does a teacher's professional science knowledge have any influence on their confidence in teaching earth science?

The findings of this thesis support the passing references of previous researchers (Shulman, 198, 1987; Symington & Hayes 1989; Ginns & Watters, 1995; Lee, 1995; Vallender, 1997) that teachers' professional science knowledge does have an influence on their confidence. The findings of these previous workers were often simple or minor mentions of some sort of cause and effect connection between knowledge and confidence. This study is different in its intent in that is a purposeful attempt to find such a relationship. Responses gathered during both data collection phases frequently stressed the importance of various types of knowledge when teaching earth science. Additionally, results indicate that certain aspects of teachers' professional science knowledge effect confidence more than others do.

(2) Do the various dimensions of professional science knowledge affect teachers' confidence in different ways?

From the responses of participants in both phases of the study it is clear that certain aspects of professional science knowledge have very different degrees of influence on teachers' strength of efficacy belief. This further develops the relationship identified by Shrigley (1974) who found a weak correlation between the two entities. Subject matter knowledge was found to have the strongest influence on participants' confidence. The responses gathered in both phases of data collection repeatedly emphasised the importance of maintaining a strong subject matter knowledge when teaching earth science topics

The assertions of Baker (1994) that "Without a deep, integrated understanding of content, the potential for teachers to help children learn 'worthwhile' content is diminished" (p. 34) were supported by the findings of this study. Results described a variety of behaviours involving regression to didactic teaching approaches or avoidance of unfamiliar areas.

Teachers in this study display fairly limited understandings of the topics covered in the *Making Sense of Planet Earth and Beyond* strand. Teachers in this study appear to conform to Vallender's (1997) findings that many teachers' knowledge of earth science is limited to a "high school geography" perspective.

Shulman's (1987) discussion on the interrelated nature of many professional science knowledge dimensions is borne out by the results of this study. Subject matter knowledge and pedagogical content knowledge are very closely related.

General pedagogical knowledge as less influence on strength of efficacy belief in teaching earth sciences than do subject matter knowledge or pedagogical content knowledge. The findings of this study relate to general pedagogical knowledge support the work of Harlen (1997) who warned that teachers can use their considerable classroom skills to avoid teaching any 'real' science.

(3) Do the various themes of the *Making Sense of Planet Earth and Beyond* strand have different impacts on teachers' strength of efficacy belief?

Consistent with the findings of Vallender (1997), teachers in the survey indicated that they were most comfortable with themes involving 'high school geography' content. Less familiar themes such as The movement of planet Earth in relation to other objects in the Heavens and New Zealand's geological history received very low knowledge scores. Correspondingly, teachers are more inclined to use avoidance strategies when required to teach those subjects that are less familiar.

(4) In what ways do teachers' backgrounds in earth science affect their knowledge frameworks and confidence?

Findings of the study confirm the findings of many previous workers (Bandura, 1977; De Laat & Watters, 1995; Lee, 1995; Riggs, 1995; Maddux, 1995; Pijares, 2002). Teachers with strong backgrounds in science maintain notably stronger efficacy beliefs than those will little or negative experiences in science. In this study those participants that could be regarded as having strong backgrounds in science had a personal interest in science, a fairly strong formal background in science, and had opportunities for exploring their interests in informal contexts. This finding is consistent with the findings of De Laat and Watters (1995).

Teachers' background in science also appears to have an influence on their professional science knowledge. Participating teachers with stronger backgrounds in earth science maintain more sophisticated and more integrated understandings of earth science subject matter.

A combination of formal and informal experiences contributes to teachers' pedagogical content knowledge. Formal earth science education provides the necessary subject matter understanding while informal experiences act as a valuable source of analogies and examples that are useful in building pedagogical content knowledge. More importantly, these informal experiences influence and are influenced by personal interest and enthusiasm.

Although this study looked specifically at this relationship in the context of earth science education, there is little evidence to suggest that these findings are not applicable to other areas of science education.

7.4 Limitations of the Study

There are a few potential limitations to the findings of this study. The process of generalising conclusions from such a small sample population is a potentially major factor in the validity of the findings in this study The size of the survey population in both phases of data collection was disappointingly small. Comparison against existing or related literature is possible with many of the findings of this study. Most of the trends and themes identified during the course of the investigation are tentatively generalised with consideration to the results of these previous workers. As such there is relatively little to suggest that the teachers involved in this study are unique and not reasonably representative of the wider primary and intermediate teaching community.

The relative inexperience of the sample population may have an influence on the validity of this study. Almost half of the sample population of this study had been teaching for less than five years. This is not representative of the general primary and intermediate teaching community. However, this possible bias may be moderated by other elements of the study. Comparison of scores during phase one data analysis revealed no correlation between teachers' experience with Efficacy and Knowledge, implying that experience as a teacher has little or no effect on the entities that are explored in this study. Also, comparison of results with other New Zealand science teaching research has shown that where they are appropriate, the trends revealed in this study are consistent with the findings of other researchers.

Many of the teachers that participated in the two phases of data collection were known to be the science 'specialists' of their respective schools. This probably yielded more positive results concerning the state of earth science education, teachers' knowledge frameworks and their strength of efficacy belief than results that would be found in a survey of a much larger and diverse survey population. Nevertheless, the results these data provided revealed trends that do not appear to be overly biased, as many of the findings are similar to those of previous workers in similar fields. If in fact the findings of this study are overly positive as a result of the 'specialist' nature of many of the participants, then the gravity of the findings of this study is even greater.

The utility of the questions used to investigate teachers' curricular knowledge may be questionable. The concept of curricular knowledge involves not only a working understanding of the curriculum requirements – the main intent of the question used in the survey, but also includes more subtle components such as knowledge of available resources, programmes and instructional materials. The failure of the survey question to address these subtleties may have corrupted some of the survey findings relating to curricular knowledge.

This oversight was noted during phase one data analysis. Accordingly, any findings utilising those data relating exclusively to the tool in question remained tentative until qualified by additional, qualitative data. Qualitative data moderate the findings of the survey.

7.5 Recommendations for Further Research

The findings of this study offer some opportunities for further research.

1) This study made use of simple tools for measuring difficult to quantify entities such as professional science knowledge and Self-Efficacy. Though much more accurate tools are available, they are generally cumbersome and require considerable time and effort to implement.

The tools used in this study were more accurate than anticipated, and provided excellent direction for a follow-up phase of data collection. Developing a range of simple 'big picture' tools may give guidance to researchers in similar areas that are relatively 'new' areas of research.

2) Further research into the relationships investigated in this study needs to be undertaken. The findings of this study revealed a number of 'categories' of teachers based upon knowledge and efficacy scores. Further study of the knowledge – confidence relationships over a longer time scale and using more thorough and accurate instruments such as the RAND and TSE self-efficacy instruments used by Gibbs (1994) or the PSTE self-efficacy instrument used by De Laat and Watters (1994) though more difficult to manage and more demanding on the participants, could provide considerably more insight into these phenomena. Results from such study could enable teacher educators to adapt their pre-service and in-service teacher education programmes to better accommodate the requirements of their students.

7.6 The Significance of the Study

This study provides valuable and incipient data on the place of knowledge in earth science education. The results of this study may be applicable to science education in all disciplines. The findings of this study have significance in a number of areas.

This study takes place at a time when the implementation of science programmes in primary sand intermediate schools is a concern. A number of studies such as TIMMS (1994-1995), TIMMS-R (1998-1999), and Education Review Office, (2000, 2002) comment on the inadequate science subject matter knowledge and pedagogical content knowledge of New Zealand primary and intermediate teachers. Other studies (De Laat & Watters, 1995; Lewthwaite, 1999) identify a lack of teacher confidence as a major inhibiting factor in the effective implementation of science programmes.

This study originated from the question "what makes some science teachers more confident than others?" and in the process of addressing this question began an exploration of the influence of teachers' knowledge structures. A relationship between 'knowledge' and 'confidence' was found. It was found that these two factors have considerable influence on effective science programme delivery and are very closely related. This has major implications for pre-service and in-service teacher education programmes. This study has found that improving one of these problem areas (knowledge) will have considerable follow-on effects in teacher confidence.

7.7 Summary

During the course of this study the complex factors involved in effective earth science teaching have become apparent. Of these myriad influences it has become clear that the place of conceptual understanding in science teaching is one of critical importance.

Earth science, in fact all science is essentially conceptual in nature. Real science learning cannot occur if the concepts involved are not addressed effectively during the learning/teaching process.

Evidence in this study indicates that in many cases teachers do not possess the necessary conceptual understanding in earth science. Similarly the knowledge required to enable students to learn these concepts is also deficient in many primary and intermediate teachers.

It is the hope of the author that this study will in some way increase the awareness of the impact of maintaining a sound understanding of the subject matter when teaching earth science or science in general. The results of this study clearly show that the knowledge teachers need to possess is more than just a collection of abstract facts and that effective earth science teaching requires considerably more of a teacher than transmission of facts figures.

The discovery that professional science knowledge has such wide reaching influences and comes from sources can be manipulated is definitely positive. This finding alone is reason enough to consider that this study has been both purposeful and has practical applications.

APPENDIX A

LETTERS

Appendix A contains the two letters used to invite teachers to participate in phase one – the teacher survey and phase two – teacher interviews.

Massey University
COLLEGE OF EDUCATION

Technology Science and Mathematics Department
Massey University College of Education
Private Bag 11 035
Palmerston North

Dear Sir or Madam

I am currently conducting a masterate research exercise for the purpose of determining how teachers' knowledge relates to their confidence in teaching earth science topics.

I would like the opportunity to conduct a questionnaire survey with teachers from your school that have some science as part of their regular classroom programme. The questionnaire focuses on the following questions – **How confident are primary school teachers about teaching earth science?** And **What links exist between teacher confidence and their background knowledge and experience?** The survey should take approximately 25 minutes to complete. Permission for conducting this survey has been provided through my masterate supervisors and the College of Education Ethics Committee.

Results of this survey will contribute to the improvement of pre-service primary teacher education. When the survey is completed and the results are collated, I will give each school that responds an abbreviated report.

If you wish for any of your teachers to take part in this survey or you have any inquiries please complete and return the fax form attached to this letter or reply to a.b.haig@massey.ac.nz at the College of Education by June 14.

Thank you for your support in this matter.

Faithfully yours

Aidan Haig
Graduate Assistant
Masterate Student
Massey University
Palmerston North
(06) 350 5799 (8897)
a.b.haig@massey.ac.nz

Dr Brian Lewthwaite
Senior Lecturer
Research Supervisor
Massey University
Palmerston North
(06) 350 5799 (8850)
b.e.lewthwaite@massey.ac.nz

Dr Clel Wallace
Lecturer
Research Supervisor
Massey University
Palmerston North
(06) 350 5799 (8655)
r.c.wallace@massey.ac.nz

Aidan Haig
Department of Technology, Science and Mathematics Education
Massey University College of Education
Palmerston North
Fax: (06) 351 3472
Phone (06) 350 5799 extn 8897

Fax Reply Form

(Name of School)

____

Will/will not be participating in the survey on knowledge and confidence in teaching earth science.

The following teachers would like to participate:

(Names of teachers involved)

____

____

____

____

____

____

____

If you have any questions, please contact the school at:

(Contact details of school)

____

____

____

____

Massey University
COLLEGE OF EDUCATION

Technology Science and Mathematics Department
Massey University College of Education
Private Bag 11 035
Palmerston North

Dear Sir or Madam

Thank you for replying to the survey that was phase one of my research, the body of information that you contributed to has been extremely useful in aiding my studies so far.

As you may remember, you gave your consent to take part in further research in the area. This next stage in my research is intended to further develop and add depth to the trends revealed on phase one of the study.

Phase two of this study will involve a one-on-one interview that will explore ideas raised in the previous two data collection phases in more depth. This interview will take about 30 minutes to complete. You can have full confidence that your responses will be kept in confidence and will be used for research purposes only.

It is hoped that these interviews can take place in the late September. You can choose to participate in one, or both interviews and you may withdraw from the research at any time.

If you wish to participate, please reply before September 12th using the return form provided and we can arrange a time to meet. All information you give will be held in the strictest of confidence. At this time I would like to thank you for your time and your already considerable contribution to this research.

Faithfully yours

Aidan Haig
Masterate Student – Massey University
a.b.haig@masssey.ac.nz

APPENDIX B

THE TEACHER SURVEY

Appendix B illustrates the questionnaire used in phase one of the data gathering stage of the study. The First section provides general information concerning teachers' demographic details as well as some historical data in experiences with science and earth science. Section two gathers information of teachers' perceptions of science subjects, earth science and participants' perceived understanding of earth science topics. Section three makes use of a number of earth science teaching scenarios to determine participants' strength of efficacy belief in particular contexts. Finally the survey includes an invitation to participate in phase two and includes a cover sheet providing information in confidentiality and includes a consent form.

All participants received the same survey.

Massey University
COLLEGE OF EDUCATION

Professional Science Knowledge and its Impact on Confidence in the Teaching of Earth science

Teacher Survey

Aidan Haig
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Masterate Student
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Dr Brian Lewthwaite
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INFORMATION

My Name is Aidan Haig and I am currently a masterate student in science education at Massey University College of Education. I am currently undertaking a research project as part of my Master of Education thesis. This research is looking at how confident teachers feel about teaching science in the Making Sense of Planet Earth and Beyond strand of the *Science in the New Zealand Curriculum*. It also aims to relate teachers' perceptions of confidence to their background knowledge and experience. Little is currently known about how teachers' knowledge about teaching earth science and how teaching self-efficacy, relate to each other.

This study will be conducted in two parts. The first is a survey that uses the attached questionnaire. This questionnaire aims to find out how teachers feel about teaching earth science in primary schools. Your identity will remain confidential and completion of the questionnaire implies consent to this part of the study. The more people who participate in the survey, the more accurate a picture can be formed, so your participation is greatly appreciated.

As well as the questionnaire that you have received, Part Two of the study involves interviews with a smaller group of teachers. These interviews will take around 40 minutes and will be audio taped. **I would be grateful if you would offer to be one of the participants.** If you would like to know more, an information sheet is included at the end of this survey.

The purpose of this survey is to explore the following research question:

What knowledge do primary teachers possess regarding the teaching of earth science and in what ways does this knowledge impact on their confidence to teach it?

- Information gathered in this survey will be used in the writing of a master's thesis.
- Though participant confidentiality cannot be completely guaranteed, every effort will be made to ensure your anonymity.

This questionnaire has been prepared in consultation with the staff of the Research Committee, College of Education, Massey University, Palmerston North.

A word about "earth science"

In this survey, the term **"earth science"** will be used instead of "Making Sense of Planet Earth and Beyond", the strand of Science in the New Zealand Curriculum. It is intended to refer to all areas of the strand, including weather, oceanography, environment and astronomy as well as the geological areas of science that the term earth science is commonly associated with.

If you have any questions or require further information please contact my research supervisors or myself

Section A

Teacher Information

1. What year groups are you responsible for? Year. 1, 2, 3, 4, 5, 6, 7, 8

2. How long have you taught at this level?

   ____

3. Number of children on your class roll

   ____

4. Number of years you have taught

   ____

5. Are you Male/Female

6. How much earth science was included in the science that you studied at school?

   ____
   ____
   ____

7. What optional subjects did you study at secondary school level (history, biology)?

   ____
   ____
   ____

8. What academic qualifications do you hold, either partial or complete?

   ____
   ____
   ____

9. Comment briefly on how your pre-service teacher education has prepared you for teaching earth science.

   ____
   ____
   ____

10. Did you study earth science subjects at Teachers' College/College of Education?
    Yes/No

11. Have you studied earth science subjects at university level?
    Yes/No

12. Comment briefly on how useful this study has been to you in the teaching of science in Primary/Intermediate School.

    ____
    ____
    ____

13. What experiences have you had, either positive or negative, formal or informal, that you believe have contributed significantly to your scientific understanding and confidence to teach earth science in the classroom?

    ____
    ____
    ____

14. On a scale of 1-4 (1 = extremely difficult, 4= extremely easy) **how comfortable are you with teaching the following strands** of Science in the New Zealand Curriculum?

Living World – diversity of living things, their parts and functions of these parts, how these living things change and reproduce and how living things are interdependent and are influenced by their environment. ☐

Material World – how materials in our world (plastics, paper, metals, acids, etc.) are grouped according to properties, how their properties are related to their uses, how materials undergo changes and are formed and how our use of materials is effected by technology and effects our environment. ☐

Physical World – understanding physical science topics such as electricity, sound, light, magnetism and how these ideas are important to everyday life. ☐

Planet Earth and Beyond – understanding earth's place in space and the atmospheric and geological processes that have occurred and are occurring on planet earth – weather, geological history, astronomy. ☐

Scientific Skills and Attitudes – developing observational, measurement and classifying skills, recording information and making sense of collected information, reporting, planning and carrying out investigations. ☐

Science and Its Relationship to Technology – using items of technology to improve our understanding of scientific ideas – telescopes, microscopes; promoting fairtesting skills in children. ☐

Section B

Confidence and Knowledge in Teaching Earth science

Composition of Planet Earth

This includes subjects such as: rocks, soils, minerals, oceanography.

15. Is this component of the Making Sense of Planet Earth and Beyond strand regularly addressed in your science curriculum? Yes/No

(circle one on each line)

		Strongly Disagree	Disagree	Agree	Strongly Agree
16.	I have a sound scientific understanding of the materials and structure of Planet Earth.	1	2	4	4
17.	I can effectively explain the concepts of the composition of Planet Earth to students in a way that will develop their understanding.	1	2	3	4
18.	I can design class activities that develop students' understanding of the composition of Planet Earth.	1	2	3	4
19.	I know where the ideas of the Earth's composition fit into the curriculum.	1	2	3	4

20. Comments.

____

____

Processes that Shape Planet Earth

This includes subjects such as: Weather, erosion, plate tectonics, faulting.

21. Is this component of the Making Sense of Planet Earth and Beyond strand regularly addressed in your science curriculum? Yes/No

(circle one on each line)

		Strongly Disagree	Disagree	Agree	Strongly Agree
22.	I have a sound scientific understanding of the processes that shape planet Earth.	1	2	3	4
23.	I can effectively explain the concepts of the processes that shape planet Earth to students in a way that will develop their understanding.	1	2	3	4
24.	I can design class activities that develop students' understanding of the processes that shape planet Earth.	1	2	3	4
25.	I know where the ideas of the processes that shape planet Earth fit into the curriculum.	1	2	3	4

26. Comments.

____

____

New Zealand Geological History

This includes subjects such as: Geological time, changes in the local landscape, past and present life on earth.

27. Is this component of the Making Sense of Planet Earth and Beyond strand regularly addressed in your science curriculum? Yes/No

(circle one on each line)

		Strongly Disagree	Disagree	Agree	Strongly Agree
28.	I have a sound scientific understanding of New Zealand's geological history.	1	2	3	4
29.	I can effectively explain the concepts of New Zealand's geological history to students in a way that will develop their understanding.	1	2	3	4
30.	I can design class activities that develop students' understanding of New Zealand's geological history.	1	2	3	4
31.	I know where the ideas of New Zealand's geological history fit into the curriculum.	1	2	3	4

32. Comments.

____

____

Movement of planet Earth in relationship to other objects in the heavens

This includes subjects such as: Time as a position in space, planetary motion, phases of the Moon, stars and constellations.

33. Is this component of the Making Sense of Planet Earth and Beyond strand regularly addressed in your science curriculum? Yes/No

(circle one on each line)

		Strongly Disagree	Disagree	Agree	Strongly Agree
34.	I have a sound scientific understanding of astronomy concepts.	1	2	3	4
35.	I can effectively explain concepts of astronomy to students in a way that will develop their understanding.	1	2	3	4
36.	I can design class activities that develop students' understanding of astronomy.	1	2	3	4
37.	I know where the ideas of astronomy fit into the curriculum.	1	2	3	4

38. Comments.

____

____

Relevant Environmental Issues

This includes subjects such as: Guardianship of planet Earth, scientific perspectives on environmental issues.

39. Is this component of the Making Sense of Planet Earth and Beyond strand regularly addressed in your science curriculum? Yes/No

(circle one on each line)

		Strongly Disagree	Disagree	Agree	Strongly Agree
40.	I have a sound scientific understanding of current environmental issues.	1	2	3	4
41.	I can effectively explain environmental issues to students in a way that will develop their understanding.	1	2	3	4
42.	I can design relevant class activities that develop students' understanding of environmental issues and prompt them to take action.	1	2	3	4
43.	I know where the ideas of environmental issues fit into the curriculum.	1	2	3	4

44. Comments.

____

____

Section C

Earth science Unit Scenarios

Imagine that you are required to prepare and teach a unit for your class on the Solar System, exploring the spatial relationships between the Earth, Moon and Sun and their effects on planet Earth.

(circle one on each line)

		Strongly Disagree	Disagree	Agree	Strongly Agree
45.	I would choose to teach this unit to a class.	1	2	3	4
46.	I would enjoy teaching this unit.	1	2	3	4
47.	I believe my knowledge is adequate to teach the concepts involved in this topic	1	2	3	4
48.	I believe my student can gain a sound understanding of the concepts in this topic if I put in the necessary effort in teaching it.	1	2	3	4
49.	If a student asks a difficult question about this topic I could find a way to answer it.	1	2	3	4

50. Comment briefly on how you would approach the teaching of this unit.

____

____

____

Imagine that your class is about to do a unit on Earthquakes. It will explore the geological origins of earthquakes, faults, and the Richter scale.

(circle one on each line)

		Strongly Disagree	Disagree	Agree	Strongly Agree
51.	I would choose to teach this unit to a class.	1	2	3	4
52.	I would enjoy teaching this unit.	1	2	3	4
53.	I believe my knowledge is adequate to teach the concepts involved in this topic	1	2	3	4
54.	I believe my student can gain a sound understanding of the concepts in this topic if I put in the necessary effort in teaching it.	1	2	3	4
55.	If a student asks a difficult question about this topic I could find a way to answer it.	1	2	3	4

56. Comment briefly on how you would approach the teaching of this unit.

____

____

____

Imagine your syndicate group has asked you to plan and implement a unit on Weather that involves individual student investigations on major factors and patterns associated with weather and weather prediction.	Strongly Disagree	Disagree	Agree	Strongly Agree
	(circle one on each line)			
57. I would choose to teach this unit to a class.	1	2	3	4
58. I would enjoy teaching this unit.	1	2	3	4
59. I believe my knowledge is adequate to teach the concepts involved in this topic	1	2	3	4
60. I believe my student can gain a sound understanding of the concepts in this topic if I put in the necessary effort in teaching it.	1	2	3	4
61. If a student asks a difficult question about this topic I could find a way to answer it.	1	2	3	4

62. Comment briefly on how you would approach the teaching of this unit.

____

____

____

Your class is about to do a unit based on Fossils. Topics covered in such a unit could include, the fossilisation process, fossils as indicators of geological time and sedimentary processes.	Strongly Disagree	Disagree	Agree	Strongly Agree
	(circle one on each line)			
63. I would choose to teach this unit to a class.	1	2	3	4
64. I would enjoy teaching this unit.	1	2	3	4
65. I believe my knowledge is adequate to teach the concepts involved in this topic	1	2	3	4
66. I believe my students can gain a sound understanding of the concepts in this topic if I put in the necessary effort in teaching it.	1	2	3	4
67. If a student asks a difficult question about this topic I could find a way to answer it.	1	2	3	4

68. Comment briefly on how you would approach the teaching of this unit.

____

____

____

You are preparing a unit on a local environmental issue. The goal for the unit is to provide a scientific perspective on the issue and have students justify their personal involvement in any action they take.	Strongly Disagree	Disagree	Agree	Strongly Agree
	(circle one on each line)			
69. I would choose to teach this unit to a class.	1	2	3	4
70. I would enjoy teaching this unit.	1	2	3	4
71. I believe my knowledge is adequate to teach the concepts involved in this topic	1	2	3	4
72. I believe my student can gain a sound understanding of the concepts in this topic if I put in the necessary effort in teaching it.	1	2	3	4
73. If a student asks a difficult question about this topic I could find a way to answer it.	1	2	3	4

74. Comment briefly on how you would approach the teaching of this unit.

____

____

____

75. Are there any comments you would like to make regarding the earth science or the purposes of this questionnaire?

____

____

____

____

____

Thankyou for participating in this survey

\+ + + +

If you have any questions or comments contact:

Aidan Haig
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Massey University College of Education
(06) 355 9099 extn 8897
a.b.haig@massey.ac.nz

Or my Supervisors

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r.c.wallace@massey.ac.nz

Professional Science Knowledge and its Impact on Confidence in the Teaching of Earth science

Phase 2

Phase two of the study involves interviews with a smaller group of teachers. These interviews will take around 40 minutes and will be audio taped. **I would be grateful if you would offer to be one of the participants.**

Information tapes from these interviews will be transcribed and used in the writing of research results. A copy of the transcripts will be sent to you to confirm accuracy. Anyone involved in the transcribing process will be required to sign a confidentiality agreement. Your name will **not** be used during the writing process and every attempt will be made to ensure that no individual can be identified.

As a potential participant you have the right to:

- decline to participate;
- refuse to answer any question;
- withdraw from the study at any time;
- to ask questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- to be given access to a summary of the findings of the study when it is concluded;
- decline to have an interview (if you wish to participate in one) audio taped;
- ask for audio tapes to be erased, returned to you or allow any tapes to be kept at the completion of this project. If kept they would not be used for teaching or any other purpose than this research.

CONSENT FORM

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I understand I have the right to withdraw from the study at any time and to decline to answer any particular questions.

I agree to provide information to the researcher on the understanding that my name will not be used without my permission.
(*The information will be used only for this research and publications arising from this research project*).

I agree/do not agree to the interview being audio taped.

I also understand that I have the right to ask for the audio tape to be turned off at any time during the interview.

I agree to participate in this study under the conditions set out in the Information Sheet.

Signed: ....

Name: ....

Date: ....

APPENDIX C

THE TEACHER INTERVIEWS

Appendix C contains the framework used in the interviews of phase two of the data gathering stage of the study. The interviews investigate the recurrent themes and trends revealed during phase one. The questions consider the influences of background experiences on teachers' efficacy, teachers' perceptions of the value of different knowledge structures, teacher' efficacy beliefs in teaching earth science and enquire about any additional factors that may affect the delivery of earth science

Earth science

Which science subjects are most difficult to teach?

Why?

What is earth science to you?

For earth science which portions do you think are hardest to teach?

Why?

One of the results found in the survey was that a lot of teachers don't teach earth science at all. -Why do you think that is?

What makes earth science difficult to teach?

Which part of earth science is easiest/hardest to teach? Why?

Why would you choose/avoid teaching Astronomy?

Why would you choose/avoid teaching Geological History?

Background

What Science did you learn in school?

What kind of experiences do you have in science/earth science?

Do you think these helped your limited you in any way?

How do you think this has affected your confidence in teaching earth science?

Do you think Men are better science teachers than women?

How well did teachers' college prepare you for teaching science?

Knowledge Frameworks

What special talents define a good science teacher do you think?

What things are most important for a teacher to understand when teaching earth science at primary level? (referring to PSK)

How important is knowledge of the subject matter?

What does a sound understanding of a topic involve?

Do you think that it is difficult for some teachers to turn what they know into something their class will understand?

How important are general pedagogical skills in all this?

If you have to teach an earth science topic that you nothing about, what do you do?

If you are going to teach a unit on an earth science topic and your prior assessment shows that your students have almost no background on the topic, what action would you take?

Efficacy

How confident do you feel as a general teacher?

What subjects do you think you are best at teaching?

How come?

How confident are you at teaching science, and more specifically earth science?

How come?

Many teachers feel more confident teaching earth science topics where their knowledge was strong, why do you think that is?

A lot of teachers in the survey would only choose to teach subjects that they enjoy and avoid ones they think are hard. What do you think of that?

If you are explaining a difficult concept to you students and they 'just don't get it' what do you do?

What would you do if you had to teach an earth science topic that you knew absolutely nothing about?

BIBLIOGRAPHY

Appleton, K. (1992). Discipline knowledge and confidence to teach science: Self-perceptions of primary teacher education students. *Research in Science Education, 22*, 11-19.

Appleton, K., & Kindt, I. (1999). Why teach primary science? Influences in beginning teachers' practices. *International Journal of Science Education, 21* (2) 155-168.

Austin, L. (2001). Generalising general science. *New Zealand Science Teacher, 97,* 31-35.

Baker, R. (1994). Teaching in primary school science: What knowledge do teachers need? *Research in Science Education, 24*, 31-40.

Bandura, A. (1977). Self-efficacy: Towards a unifying theory of behaviour change. *Psychological Review, 84,* (2), 191 – 215.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory.* Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran (Ed.), *Encyclopaedia of human behaviour* (4) 71 –71. New York: Academic Press.

Bandura, A. (1997). *Self efficacy: The exercise of control.* New York: W.H. Freeman & Co.

Barker, M. (2000). Learning theories in science teaching – Hindsight or master plan? *New Zealand Science Teacher 94.* 32-39.

Bell, B., Jones, A., & Carr, M. (1995). The development of the recent national New Zealand science curriculum. *SAMEpapers 1995.* Hamilton: Waikato Print

Bell, B., & Baker, R. (eds.) (1997). *Developing the science curriculum in Aotearoa New Zealand.* Auckland: Longman.

Bell, J. (1993). *Doing your research project: A guide for first time researchers in education and social science* (3rd. ed). Buckingham: Open University Press.

Black, P., & Aitkin, J., M. (eds.) (1996). *Changing the subject: Innovations in science mathematics and technology education.* London: Routledge.

Black, P. & Buckridge, J. (1990). Geological education: a letter to the Geological Society of New Zealand. *Geological Society Newsletter*: August.

Bouma, G. D. (2000). *The research process*(4th ed.). Melbourne: Oxford University Press.

Brown, J. D. (2000). *What issues affect Likert-scale questionnaire formats?* Retrieved October 4, 2002. From http://www.jalt.org/test/bro_7.htm

Clandinin, D. J., & Connelly, F. M. (eds.). (1995). Teachers' professional knowledge landscapes. New York: Teachers College Press.

Clark, J. (1997). *Educational research: Philosophy, politics, ethics.* Palmerston North: ERDC Press.

Codd, J. A. (1998). *Educational reform and the abandonment of trust: An ethical problem.* A paper presented to an educational policy and practice seminar, Massey University College of Education, 14 July 1998.

Cohen, L., Manion, l. & Morrison, K. (2000). Research Methods in Educations. London: Routledge Falmer.

Dagher, Z. R. (1995). Analysis of analogies used by science teachers. *Journal of Research in Science Teaching, 32* (3), 259-270.

De Laat, J., & Watters, J. J. (1995). Science teaching self-efficacy in a primary school: A case study. *Research in Science Education, 25* (4), 453-464.

Drever, E. (1995). *Using semi-structured interviews in small-scale research.* Glasgow: Scottish Council for Research in Education.

Drew, C. J., Hardman, M. L., & Weaver-Hart, A. (1996). *Designing and conducting research: Inquiry in education and social science.* Utah: Allyn and Bacon.

Education Forum. (1994). *The relationship between science & technology in the New Zealand curriculum. A paper by Edgar W Jenkins, University of Leeds.* New Zealand: Author.

Education Forum. (1995). *Science in the New Zealand curriculum. A review by Peter Kelly, University of Southampton.* New Zealand: Author.

Education Review Office. (1996). *Science in schools – implementing the 1995 science curriculum.* Wellington: Education Evaluation Reports.

Education Review Office. (2000). *In time for the future. A comparative study of mathematics and science education.* Wellington: Education Evaluation Reports.

Education Review Office. (2002). *Science now. Science education for years 1 to 8.* Wellington: Education Evaluation Reports.

Ellis, J. D. (1995). *Intervening in the professional development of science teachers: The Colorado Science Teaching Enhancement Program.* Interim report of the formative evaluation of CO-STEP. Colorado Springs: Author.

Eisner, E. W. (1979). *The educational imagination.* New York Macmillan.

Garden, R, A. (Ed.). (1996). *Science performance of New Zealand Form 2 and Form 3 students.* Research and international Section. Wellington: Ministry of Education.

Garland, R. (1991). The mid-point on a rating scale: Is it desirable? *Marketing Bulletin,* (2), 66-70.

Gibbs, C. J. (1994). *Teacher efficacy, orientations towards children and self-esteem: The effects of student teaching practice.* Unpublished Thesis, Massey University, Palmerston North.

Gibson, S., & Dembo, M. (1984). Teacher efficacy: A construct validation. *Journal of Educational Psychology, 76* (4), 569 –582.

Ginns, I. S., & Watters, J. J. (1995). An analysis of scientific understandings of preservice elementary teacher education students. *Journal of Research in Science Teaching, 32* (2), 205 – 222.

Gooday, M., Payne, F., & Wilson, J. (1993). *Primary student teachers' scientific understanding of scientific knowledge and their attitudes towards science.* Aberdeen and Dundee: Northern College.

Grimm, J. G., & Yarnold, P. R. (1995). *Reading and understanding multivariate statistics.* Washington: American Psychological Association.

Grossman, P.L., Wilson, S. M., & Shulman, L. S. (1989). Teachers of substance: Subject matter knowledge for teaching. In Reynolds, M, C. (Ed.). *Knowledge base for the beginning teacher.* Oxford: Pergamon Press.

Haig, B. D. (1995). Grounded theory as scientific method. Retrieved October 5 2002 From http://www.ed.uiuc.edu/EPS/PES-yearbook?95_docs/haig.html

Harlen, W. (1997). Primary teachers' understanding in science and its impact in the classroom. *Research in Science Education, 27,* (3), 323-337.

Harlen, W. (2000). The teaching of science in primary schools (3rd ed.). London: David Fulton.

Harlen, W., Holroyd, C., & Byrne, M. (1995). *Confidence and understanding in teaching science and technology in primary schools.* Edinburgh: Scottish Council for Research in Education.

Hayward, B. W., & Lee, D. (1990). *Re earth science tutors for trainee teachers. Letter to New Zealand teacher training institutions.* Lower Hutt: Author.

Hoskin, P. W. O. (2000). The state of earth science in New Zealand Secondary Schools. *New Zealand Science Teacher 95*, 6-10.

Kempa, R. R., & Orion, N. (1996). Students' perception of cooperative learning in earth science fieldwork. *Research in Science & Technological Education 14,* (1). 33-41.

Leavitt, F. (1991). *Research methods for behavioural scientists.* California: Wm. C. Brown Publishers.

Lee, D. (1992). *Letter to the Ministry of Education* concerning the draft of *"Science in the National Curriculum".* Dunedin: Author.

Lee, O. (1995). Subject matter knowledge, classroom management, and instructional practices in middle school science classrooms. *Journal of Research in Science teaching32* (4). 423-440

Lewthwaite, B. (1999). Teacher perceptions on factors influencing the implementation of Science in the New Zealand Curriculum. *NZ Science Teacher 90,* 14 – 18.

Lewthwaite, B. (2001). *The development, validation and application of a primary school science curriculum implementation questionnaire.* Unpublished doctoral dissertation, Curtin University, Perth.

Lewthwaite, B.E.; Stableford, J. & Fisher, D. (2001). Enlarging the focus on primary science education in New Zealand. In R.K. Coll (Ed.),*SAMEpapers* 2001, (pp. 213-237). Hamilton, New Zealand: Centre for Science and Technology Education Research, Waikato University.

Maddux, J. E. (1995). Self-efficacy, adaptation and adjustment: Theory, research and application. New York: Plenum Press.

Matthews, M., R. (1995). *Challenging NZ science education.* Palmerston North: Dunmore Press.

Ministry of Education, (1991). *The draft science curriculum.* Wellington: Learning Media.

Ministry of Education, (1993). *Science in the New Zealand Curriculum.* Wellington: Learning Media.

Ministry of Education (1993a). *The New Zealand Curriculum Framework.* Wellington: Learning Media.

Morrison, K. (1989). Training teachers for primary schools: the question of subject study. *Journal of education for teaching, 15* (2), 97-111.

Munro, A. (1999). *The long and rocky road: A look at earth science education in New Zealand schools, 1970 – 2003.* Paper presented to the Geological Society of New Zealand annual conference.

New Zealand Qualification Authority. (2001). *Practicing teacher education. Unit standard* – 8740. Wellington: New Zealand Qualification Authority.

O'Neill, A. (ed). (1996/97). Curriculum reform. Development issues in Aotearoa New Zealand: An editorial introduction. *Delta* 48 (2), 49 (1) 127 –140.

Orion, N., King, C., Krockover, G. H., & Adams, P.E. (1999). The development and status of earth science education: a comparison of three case studies: Israel, England and Wales and the United States of America Part II. *Science Education International, 10,* (3). 19-27.

Pardhan, H., & Wheeler, A. (2000). Taking 'STOCK' of pedagogical content knowledge in science education. *School Science Review 82*, 81-96.

Pjares, F. (2002). *Overview of social cognitive theory and of self-efficacy.* Retrieved April 28, 2002.
From http://www.emory.edu/EDUCATION?mfp/eff.html

Pjares, F. (2002a). *Self-efficacy beliefs in academic contexts: an outline.* Retrieved May 8, 2002.
From http://www.emory.edu/EDUCATION?mfp/eff.html

Poole, M. (1995). *Beliefs and values in science education.* Philadelphia: Open University Press.

Print, M. (1993). *Curriculum development and design* (2^{nd} ed.) Australia: Allen &Unwin.

Raudenbush, S. W., Rowan, B., & Cheong, Y. F. (1992). Contextual effects on the self-perceived efficacy of high school teachers. *Sociology of Education, 65* (2), 150-167.

Reynolds, M. C. (ed.). (1989). Knowledge base for the beginning teacher. New York: Pergamon Press.

Riggs, I. (1995) *The characteristics of high and low efficacy elementary teachers.* Paper presented at the annual meeting of the National Association of Research in Science Teaching, San Fransisco.

Riggs, I.., & Enochs, L. (1990). Toward the development of an elementary teacher's science teaching efficacy belief indtrument, *Science Education, 74,* 625-638.

Rotter, J. B. (1975). Some problems and misconceptions related to the construct of internal versus external control of reinforcement. *Journal of Consulting and Clinical Psychology, 43* (1), 56 –67.

Salkind, N. J. (1991). *Exploring Research* (3rd ed.). New Jersey: Prentice Hall.

Schwarzer, R. (1996). *Generalized perceived self-efficacy.* Toronto, Canada: York University.

Schwarzer, R., & Jerusalem, M. (1993). *The general perceived self-efficacy scale.* Retrieved March 21, 2002.
From http://www.york.ca/faculty/academic/schwarze/engscal.htm

Sclove, S, L. (2001). *Notes on Likert Scales.* Retrieved October 4, 2002. From: http://www.uic.edu/classes/idsc/ids270sls/likert.htm

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher,15,* 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57,* 1-22.

Skamp, K. (1989). General science knowledge and attitudes towards science and science teaching of pre-service primary science teachers: Implications for preservice units. *Research in Science Education, 19,* 257-267.

Skamp, K. (1991). Primary science and technology: How Confident are Teachers? *Research in Science Education, 21* 290-299.

Skamp, K (ed.). (1997). *Teaching primary science constructively.* Sydney: Harcourt Brace.

Solomon, J. (1983). Messy, contradictory and obstinately persistent: a study of children's out of school ideas about energy. *School Science Review, 65,* 225-233.

Solomon, J. (1994). The rise and fall of constructivism. *Studies in Science Education, 23,* 1–19.

Symington, D., & Hayes, D. (1989). What do you need to know to teach science in the primary school? *Research in Science Education 19,* 278-285.

Taylor, A. M. (2001). Governance and management under Tomorrow's Schools: Dualism or separatism? Unpublished Thesis, Massey University, Palmerston North.

Tilgner, P. G. (1990). Avoiding science in the elementary school. *Science Education, 74*(4), 421 – 431.

Tosun, T. (2000). Beliefs of preservice elementary teachers towards science and science teaching. *School Science & Mathematics, 100* (7), 376-384.

Trend, R. (2000). Conceptions of geological time among primary teacher trainees, with reference to their engagement with geoscience, history and science. *International Journal of Science Education 22,* (5), 539-555.

Tschannen-Moran, M., Woolfolk-Hoy, A. & Hoy, W. K. (1998). Teacher efficacy: It's meaning and measure. *Review of Educational Research, 68,* 202-248.

Vallender, G. D. (1997). *A study of earth science education in New Zealand.* A report for the Royal Society of New Zealand. Christchurch: Author.

Verdon, A. J. (1988). Teaching tomorrow's earth scientists. *Geotimes*: December.

Walker, M., & Chamberlain, M. (1999). A Brief overview of the Third International Mathematics and Science Study (TIMMS) *The Research Bulletin 10* 41-55.

Wellington, J. (2000). *Educational research: Contemporary issues and practical approaches.* New York: Continuum.

Williamson-McDiarmid, G., Lowenberg-Ball, D., & Anderson, C. W. (1989). Why staying one chapter ahead doesn't really work: Subject-specific pedagogy. In Reynolds, M, C. (Ed.). *Knowledge base for the beginning teacher.* Oxford: Pergamon Press.