Influences on the science teaching self efficacy beliefs of Australian primary school teachers

A thesis submitted for the degree of

Doctor of Philosophy

of

The Australian National University

by

Merryn Clare McKinnon

Centre for the Public Awareness of Science
Faculty of Science
Canberra

November, 2010
Declaration

This thesis is an original work. None of the work has been previously submitted for the purpose of obtaining a degree or diploma in any university or other tertiary education institution. To the best of my knowledge, this thesis does not contain material previously published by another person, except where due reference is made in the text.

Merryn C McKinnon

November 2010
Acknowledgements

Firstly profuse and grateful thanks to the teachers who volunteered to be a part of this research, and who stuck with me for the duration. Without you, there would not be a thesis. Thank you.

To the indefatigable Dr Rod Lamberts, supervisor and sounding board, who provided coffee, support, solid advice and a good dose of reality when I needed it, even when I kept making the PhD process harder to supervise by moving countries and having a baby in the middle of it. He kept the faith, even when mine faltered. Thank you Roderick, could not have done this without you.

To the staff and students of the Shell Questacon Science Circus who collected surveys for the pilot study and allowed me to borrow their workshop materials, and to Bettina Payne and Jenny Dettrick for their assistance during the trial phase. To Cindy Chambers for keeping the papers coming and Ilze Groves for her support, advice and some darned handy references in the early stages.

To the staff and students of CPAS who provided thoughtful and insightful feedback in the formative stages of this process, especially Associate Professor Sue Stocklmayer who provided experience, wisdom and eagle-eyed editing at crucial times. It has been a pleasure to be associated with such a supportive and collegial group who actually make research seminars enjoyable!

Associate Professor David McKinnon at Charles Sturt University, my knight with shining STEBI statistics. Your advice was invaluable and saved me from possible PhD purgatory. Thank you for being so willing to help someone you just met at a conference. I am indebted.

To my colleagues at Questacon who supported my efforts, tolerated my disappearances and the piles of black tubs of ‘every day materials’ in the office, and generally made work feel less like work.

Last but not least, thanks to my family. To my mother Kerry for providing transcribing services, babysitting and always being the encouraging force. To my husband Ryan for constantly supporting, encouraging, wanting to understand my research and for bringing coffee when I needed it most. To my daughter Addison, for helping me realise that there is more to life, I can do more things simultaneously than I think, and for making me want to be the kind of person she can be proud to call Mum.
Abstract

The science teaching self-efficacy beliefs of primary school teachers are influential on teaching practice. The purpose of this research was to determine if informal education institutions, such as science centres, could provide professional development that influenced the self-efficacy of pre-service and in-service primary school teachers, and to what extent this was influenced by their science background, years of teaching experience and external, environmental factors. Participants were also asked if places such as science centres had a role to play with, and for, teachers.

A cohort of eight final year pre-service teachers and 13 in-service teachers (six from one New South Wales (NSW) school and seven from one Australian Capital Territory (ACT) school) completed a series of four one-hour workshops and were surveyed immediately before, immediately after, four months after and 11 months after the workshops. Surveys and semi-structured interviews were used in the data collection.

The results of this research showed that four hours of science centre produced, professional development workshops were capable of increasing the science teaching self-efficacy of all but three participants, with observable results for at least 11 months after the completion of the workshops. The ACT in-service cohort showed the greatest overall gains in self-efficacy. The pre-service cohort showed greatest gains in confidence in, and enjoyment of, science teaching. The school environment of the in-service participant cohorts was a major determining factor of how their increased self-efficacy influenced their teaching practice, with positive and negative consequences.

This thesis clearly demonstrated that the science education experienced by teachers in this study was highly influential in their own development of perceptions and beliefs about science that they, in turn, take to the classroom. This was just as applicable to newly graduated teachers as it was to those who have been teaching for over 20 years. Participants identified a role for science centres as a source of inspiration, support and training for teachers in order to help them teach science more effectively.

This project showed that the informal education sector could enact positive reforms within science education, but only if the context in which teachers must operate is taken into account and reform efforts adapted accordingly. The informal science education sector could be the key to achieving long lasting reform in science education where other, formal measures have failed.
Table of Contents

Declaration ...................................................................................................................................... iii
Abstract ......................................................................................................................................... v
Table of Contents ......................................................................................................................... vi
List of Figures ................................................................................................................................. ix
List of Tables ................................................................................................................................ xi
List of Tables ................................................................................................................................ xi
1. Introduction ............................................................................................................................... 1
   1.1 Background to the study ........................................................................................................ 1
   1.2 The research problem .......................................................................................................... 5
   1.3 The aim of this study ........................................................................................................... 6
   1.4 Overview of the thesis ........................................................................................................ 6
Chapter 2: The role of science education, teachers and teaching self-efficacy ......................... 8
   2.0 Science teaching and education in Australia ........................................................................ 8
   2.1 The status of science teaching in Australian schools .......................................................... 8
   2.2 Primary school teachers’ science training and self-efficacy ............................................. 21
   2.3 The development of the concept of self-efficacy and its application to teaching ................ 29
   2.4 Implications arising from the literature ............................................................................ 40
   2.5 How these implications are addressed in the current project ........................................... 41
Chapter 3: Formal and informal education and the role of professional development for teachers .............................................................................................................................. 43
   3.0 Different educational environments and their influences ................................................. 43
   3.1 Professional development for teachers ............................................................................. 43
   3.2 Formal versus informal education .................................................................................... 57
   3.3 Formal and informal education for teacher development .............................................. 65
   3.4 Implications arising from the literature ............................................................................ 70
   3.5 Development of research questions used in the current study ........................................... 73
Chapter 4: Research Design ......................................................................................................... 78
   4.0 Development and rationale of research design ................................................................... 78
   4.1 Development of method used to address the research questions ..................................... 78
   4.2 Pilot study ......................................................................................................................... 94
   4.3 Study design .................................................................................................................... 100
   4.4 Data analysis .................................................................................................................. 109
   4.5 Ethical considerations ...................................................................................................... 113
   4.6 Summary ....................................................................................................................... 113
Chapter 5: Results ....................................................................................................................... 115
Chapter 5: Presentation of findings from the current study

5.0 Presentation of findings from the current study .......................................................... 115
5.1 The study population — demographics, career choice influences and fears ....... 115
5.2 Research question 1: Did the workshops influence science teaching self-efficacy? ......................................................................................................................... 123
5.3 Research question 2: Differences between pre-service and in-service teachers . 139
5.4 Research question 3: Do the number of years of teaching experience cause differing effects and impacts? ...................................................................................... 151
5.5 Research question 4: The influence of previous science experiences .......... 156
5.6 Research question 5: The influence of the school environment .................. 159
5.7 Research question 6: Is there a role for informal science education? .......... 174
5.8 Summary of main findings .................................................................................. 180

Chapter 6: Discussion and Conclusions ......................................................................... 184

6.0 Putting the results in context ............................................................................... 184
6.1 Do science centre produced, short professional development workshops have any effect on teachers’ science teaching self-efficacy? ......................................................... 185
6.2 Do science centre produced, short professional development workshops affect pre-service teachers differently from in-service teachers? ................................................ 191
6.3 Do science centre produced, short professional development workshops have differing effects and impacts depending on a teachers’ teaching experience? ............ 193
6.4 Does an individual’s previous experience with science influence how they feel about science teaching? ................................................................................................. 195
6.5 Does the environment of the school influence the science teaching self-efficacy of the teacher, or how likely they are to teach science? ............................................. 198
6.6 Do teachers perceive that there a role for informal science education with teachers? ...................................................................................................................... 202
6.7 Limitations, recommendations for further research and overall conclusions .... 207

References ......................................................................................................................... 213

Appendix A: Modified Research Instruments ............................................................... 234
Science Teaching Efficacy Belief Instrument A (STEBI A) for in-service teachers 234
Science Teaching Efficacy Belief Instrument B (STEBI B) for pre-service teachers ........................................................................................................................................ 236
Science Curriculum Implementation Questionnaire (SCIQ) ................................... 238

Appendix B: Interviews - indicative areas of questioning ............................................. 241

Appendix B: Example of interview transcript .................................................................. 243

Appendix C: Workshop activities ................................................................................... 248

Appendix D: Participant information and certificate ..................................................... 253
Email to Prospective Participants (pre-service) .......................................................... 253
Information Sheet for Participants ............................................................................. 255
Certificate .................................................................................................................. 258
List of Figures

Figure 1: Model depicting theoretical relationship between professional development and student achievement (after Supovitz & Turner, 2000:965) ......................................................... 45
Figure 2: Expanded model depicting theoretical relationship between professional development and student achievement (after Supovitz & Turner, 2000:965) .......... 46
Figure 3: Flow chart showing evolution of study design in response to recruitment difficulties ..................................................................................................................... 103
Figure 4: Comparison of PSTE scores (range 13 - 65) of ACT in-service participants across the study period.......................................................... 125
Figure 5: Comparison of STOE scores (range 10 - 50) of ACT in-service participants across the study period.......................................................... 126
Figure 6: Graph showing most extreme cases of fluctuating PSTE and STOE scores in ACT in-service cohort.......................................................... 127
Figure 7: Comparison of PSTE scores (range 13 - 65) of NSW in-service participants across the study period.......................................................... 128
Figure 8: Comparison of STOE scores (range 10 - 50) of NSW in-service participants across the study period.......................................................... 129
Figure 9: Comparison of PSTE scores (range 13 - 65) of pre-service participants across the study period.......................................................... 130
Figure 10: Comparison of STOE scores (range 10 - 50 periods 1 - 4, due to omission of two items in STEBI A STOE) of pre-service participants across the study period...... 131
Figure 11: Comparison of confidence levels pre- and post-workshop of individuals in ACT in-service cohort.......................................................... 143
Figure 12: Comparison of confidence levels pre- and post-workshop of individuals in NSW in-service cohort.......................................................... 143
Figure 13: Comparison of confidence levels pre- and post-workshop of individuals in the pre-service cohort.......................................................... 144
Figure 14: Comparison of enjoyment levels pre- and post-workshop of individuals in the ACT in-service cohort.......................................................... 145
Figure 15: Comparison of enjoyment levels pre- and post-workshop of individuals in the NSW in-service cohort.......................................................... 146
Figure 16: Comparison of enjoyment levels pre- and post-workshop of individuals in the pre-service cohort.......................................................... 146
Figure 17: Comparison of mean scores of confidence and enjoyment immediately pre and post workshops for each participant group. 1 = not at all and 5 = extremely/ really. .................................................................................................................. 147
Figure 18: Comparison of overall mean PSTE and STOE scores for each ‘experience cohort’ for the entire study period. PSTE scale range 13 - 65; STOE scale range 10 - 50. .......................................................... 152
Figure 19: Comparison of PSTE scores of participants with 20+ years teaching experience across all sample periods. Score range 13 - 65 ........................................... 153
Figure 20: Comparison of STOE scores of participants with 20+ years teaching experience across all sample periods. Score range 10 - 50 ........................................... 153
Figure 21: Comparison of mean scores returned for professional support scale of the SCIQ by NSW in-service participants throughout study period, demonstrating high levels of variation in responses at an individual level. ................................................. 169

Figure 22: Comparison of mean scores returned for resource adequacy scale of the SCIQ by ACT in-service participants throughout study period, demonstrating consistency of responses at an individual level. ........................................................... 170
List of Tables

Table 1: Different stages of teacher progression according to level of experience, using discipline as an example of proficiency (Burry-Stock and Oxford, 1994) .........................24
Table 2: Five models of staff development for teachers (Peixotto and Palmer, 1994) after Sparks and Loucks-Horsley (1989) .................................................................53
Table 3: Summary of types of science centre impacts according to Garnett (2002). .....68
Table 4: Scales, item numbers and amendments made to the Science Curriculum Implementation Questionnaire (SCIQ) used in this study ..............................................88
Table 5: An overview of the indicative timings for each component of the study fieldwork, and the instruments used for each cohort. (STEBI = Science Teaching Efficacy Belief Instrument: STEBI A = for in-service teachers; STEBI B = for pre-service teachers; SCIQ = Science Curriculum Implementation Questionnaire) ..........109
Table 6: Overview of items included in efficacy belief and outcome expectancy scales, and reversed score items in the STEBI A and B instruments .....................................110
Table 7: Demographics of study population ..................................................................117
Table 8: Comparison of mean PSTE and STOE scores for each cohort at each sample period and as a mean for the entire study............................................................139
Table 9: Comparison of PSTE and STOE ranges, means and standard deviations from the STEBI A surveys using the in-service study cohort only, and then including the STEBI A data collected from the pre-service cohort at the final sample period (Period 4) ..................................................................................................................................140
Table 10: Overview of participants’ responses at the first interview (4 months after workshop completion) and final interview (10 months after workshop) of what aspects of teaching they felt most and least confident (conf) about. Numbers indicate total of participants choosing each factor. ........................................................................................................148
Table 11 Comparison of PSTE and STOE scores of participants with 15 - 20 and 4 - 6 years teaching experience across all sample periods .................................................154
Table 12: Comparison of overall change in mean PSTE and STOE scores for each teaching experience cohort ....................................................................................................155
Table 13: Factors identified by participants as most and least positive influences on their teaching career/training ..................................................................................159
Table 14: Comparison of means and standard deviations for each scale in the SCIQ from ACT in-service cohort across whole study period. ............................................163
Table 15: Comparison of means and standard deviations for each scale in the SCIQ from NSW in-service cohort across whole study period. .............................................165
Table 16: Means and standard deviations for each scale in the SCIQ from the pre-service cohort at the final sample period of the study ......................................................168
1. Introduction

1.1 Background to the study

1.1.1 Science and science teaching in Australian primary schools

Science receives very little teaching time in the primary classroom (Angus, Olney, & Ainley, 2007), limiting Australian school students’ exposure to the subject at an age when they are most receptive to science (Logan & Skamp, 2004). Science is failing to engage a wide range of students, and it is competing with a much larger range of subject choices in secondary school (Lyons & Quinn, 2010). Large numbers of students are opting to discontinue their studies in science during their secondary and tertiary years of education, leading to a decline in the number of students pursuing a career in the scientific field (Darby, 2005; Lyons & Quin, 2010; Palmer, 2007). The result is a predicted skills shortage of scientists, researchers, mathematicians and engineers across the country (ASTA, 2005). A greater problem is that of a scientifically illiterate Australia. As asserted by Laugksh (2000), citizens that are scientifically illiterate are ill equipped for life in a technologically advanced society.

The way science is taught in Australian primary schools is one identified cause of students’ disengagement in science (Palmer, 2008). Programs such as Primary Connections have been developed and implemented into Australian primary schools as a means of addressing these issues (Hackling, 2006). Primary Connections is a professional learning program for teachers, supported by curriculum resources with the ultimate aim of improving scientific literacy and student outcomes in science (ibid).

While programs like Primary Connections are making progress in improving the standard of science education in primary schools (Dawson, 2009), the current nature of the formal education system seems to be working against achieving reform; this is not a problem unique to Australia.

The science curriculum worldwide is criticised for being content heavy (Fensham, 2002) and school days are becoming increasingly crowded (Carnemolla, 2007), leaving little time for teaching science using hands-on activities. School science is being robbed of life and is not being taught in the manner that it was intended — as an exploratory subject with ample opportunity for experimentation (Greene, 2008). As a result science is failing to engage students. Studies of school science around the world are identifying the same problems (see for example Balfakih, 2003; Department for Business Innovation and Skills, 2009) Students are not engaged in science as the relevance of
science to their lives is not being illustrated (Science Alberta Foundation, 2007). In the international Relevance of Science Education (ROSE) study, students were found to believe that science was important, just not to them personally (Sjøberg & Schreiner, 2005).

Teachers are the greatest influence on student outcomes and achievement (Rowe, 2003). Yet many Australian primary school teachers feel under prepared to teach science and many lack the confidence to try (Goodrum, Hackling, & Rennie, 2001). Teacher training programs are not producing a new generation of scientifically literate or even science positive teachers. The reverse appears to be true, with primary school teaching seeming to specifically attract individuals who are afraid of science (Appleton, 2003). This is not to say that all Australian teachers are poor teachers of science; the author has personally been taught by, and observed, many highly capable teachers of science. But there are issues in science teaching which have been, and will continue to be, addressed in the literature.

Science education is not just a pipeline for future scientists and engineers. Teachers need to equip their students with scientific skills and understanding. It is important for the creation of a scientifically literate and engaged society, one that is capable of evaluating scientific information to make informed decisions about science related issues (Association for Science Education, 2008; Palmer, 2008). If teachers are unable to do this themselves, then they are not equipped to teach these skills to their students.

1.1.2 Professional development of teachers as a means of science education reform

Training teachers to have good science teaching practice will be the only way that long lasting improvement in student achievements in science will be seen (Tytler, 2003). The challenge lies in changing the beliefs of teachers about science and about their own abilities to teach science to achieve desired outcomes. Numerous studies have examined the beliefs of teachers in relation to science, specifically examining their science teaching self-efficacy and how this can be improved through the provision of professional development activities (see for example Enochs & Riggs, 1990; Wenner, 2001).

However, few studies have been conducted with pre-service teachers in their final years of their teacher training and as they progress to teaching in schools, a crucial and unique period for their belief formation and change (Luft, 2007). Fewer studies still have
examined the relationship between the process of learning to teach science with self-efficacy beliefs (Mulholland & Wallace, 2001). Researchers need to direct their attention to these early years of teaching in order to better understand the influences on new teachers, and how these influences manifest in teaching practice (Chan, 2008). Pre-service teachers and beginning teachers are considered an important part of science education reform (Hudson & Skamp, 2002) so a greater understanding of their belief formation and influences will assist in future reform efforts.

The most commonly identified means of influencing teachers’ beliefs, and ultimately their practice, is through the provision of professional development. A great deal is known about the factors that constitute effective professional development, but much less seems to be known about how to employ these in practice (Elmore & Burney, 1997 in McRae, Ainsworth, Groves, Rowland, & Zbar, 2001). There is growing recognition of the influence of the school environment on a teacher’s beliefs and practice (Lewthwaite, 2001). This influence is not always positive and could contribute to the avoidance or minimisation of science teaching, particularly in a new teacher (Luft, 2007). Conversely, a group of teachers from the same school undertaking professional development could provide a more supportive environment, leading to more effective and productive outcomes (Sato, Chung Wei, & Darling-Hammond, 2008).

The majority of professional development available in Australia tends to be short term or a singular offering (McRae et al., 2001). Much of the relevant literature argues that one-off professional development is incapable of achieving lasting results (Tytler, Osborne, Williams, Tytler, & Cripps Clark, 2008) and advocates longer term, sequential professional development for a collective of teachers (Desimone, Porter, Garet, Yoon, & Birman, 2002). Due to the time constraints on teachers, ongoing professional development rarely happens in practice (Hawley & Valli, 1999).

Irrespective of the duration or the format of professional development activity, measuring the impact in terms of teaching practice and student outcomes is extremely difficult, and often not quantifiable (McRae et al., 2001). When impacts have been successfully measured, the results for science based professional development are contradictory. Desimone et al. (2002) did not find any significant effects in relation to the duration of the professional development undertaken. Hilliard (1997) did not find the results of science professional development showed the same levels of success as those attained in other subject areas. In contrast, Perera (2010) found that science professional development workshops of one day duration were capable of facilitating
conceptual change in teachers. In the absence of other options, professional development and training of teachers are still seen as the best chances of achieving reform in science education (Smylie, 1996 in Supovitz & Turner, 2000).

The research presented in this thesis examines the beliefs of in-service and pre-service teachers, the latter as they complete their teacher training and begin teaching in schools. This research adds to the knowledge and understanding of the belief system of teachers, and in so doing helps teacher trainers and professional development providers to better understand the context, and constraints, within which beginning teachers work.

1.1.3 A role for informal science education organisations?

Science centres and museums are part of the informal education sector. Their main aim is to bring science and technology to the public and increase their enjoyment and excitement about science (Science Alberta Foundation, 2007). Informal science education institutions have the added ability to engage people in science and highlight its relevance to their everyday lives (Goodrum & Rennie, 2007). These institutions base their content on the constructivist approach to education, with an emphasis on hands-on activities, actively engaging the visitor in the learning process (So & Watkins, 2005).

Given the nature of informal science education, these institutions are well positioned to assist in enacting science education reform. Typically school visits to, or from, an informal science education provider are one-off and very brief. The effectiveness and positive impacts of these visits on students, and teachers, have been measured, however there is limited evidence of these impacts in relation to teacher professional development (Garnett, 2002). This could be attributed to the fact that the ability to measure impact is a key problem with any informal education program. Often the impact is not immediately, if ever, apparent, and consequently is rarely documented (ecsite UK, 2008a).

In a survey of their preferred characteristics of science based professional development, teachers overwhelmingly asked for it to be provided by an outside expert and to contain practical ideas and activities (Aubusson, Griffin, Sawle, & Vassila, 2010). The literature already shows that teachers consider places like science centres ‘experts’ (Finkelstein, 2005) and value the opportunities they present for their students in science, which they cannot provide in the classroom (Xanthoudaki, Tirelli, Cerutti, & Calcagnini, 2007). Partnerships between schools and informal education providers are capable of facilitating student engagement in science (Harris, Jensz, & Baldwin, 2005).
Stocklmayer, Rennie and Gilbert support this view, arguing that collaboration between the formal and informal education sectors “can result in an enhanced science education for students at school” (2010:1). However less is known about the usefulness of informal science education to teacher training (Palmer, 2007). The research described in this thesis addresses this knowledge gap.

Melber and Cox-Peterson (2005) found that teacher professional development conducted by a science centre did achieve positive outcomes for the teachers. Anecdotal evidence from professional development sessions run by a science centre, and attended by the author, indicated that there was potential for more significant involvement of science centres in teacher training. After participating in a two hour science workshop with activities using simple, everyday materials, teachers remarked “if only I’d done something like this when I was training to be a teacher!” These anecdotal comments were the catalyst for the current research project.

1.2 The research problem

Little is known about the impact of informal science education centres on professional development of teachers, or in teacher training (Astor-Jack, McCallie, & Balcerzak, 2007). Additionally, there is a limited understanding of the factors which influence the beliefs, and ultimately the science teaching self-efficacy, of pre-service and in-service teachers (Chan, 2008; Luft, 2007). Could these influences go beyond their teacher training and experiences as a teacher? Other external factors, such as the nature of the environment within which they work have been found to influence teachers’ self-efficacy beliefs (Lewthwaite, 2001), yet the importance of context to science teaching self-efficacy is yet to be fully understood. For example, do teachers’ previous experiences with science or the number of years they have been teaching also influence their beliefs and science teaching self-efficacy?

The nature of this research problem extends nationally and internationally, with each country having its own specific context and associated influences (Bursal, 2008; De Souza, Boone, & Yilmaz, 2004; Irez, 2006). While the current study positions itself within the larger body of work and in the international context, it specifically examines primary school teaching within Australia. Given the myriad informal science education institutions in Australia, each with its own specific area of expertise (for example an aquarium or a telescope facility), science centres are the focus of the current study. Science centres cover a broad range of scientific topics and phenomenon, and this will
be more relevant to the Australian primary school curricula, which vary between states and territories. The difficulty in quantifying the impact of a science centre is also a national and international issue in the informal science education field, thereby making this project relevant to teacher educators in the formal and informal fields.

1.3 The aim of this study

The aim of this study was to determine if short professional development workshops, developed by a science centre, can affect the science teaching self-efficacy of primary school teachers, and to identify to what extent this is influenced by external factors.

The research area dealt with multifaceted issues and could not be adequately addressed with one all encompassing research question. In order to deal with each factor identified in the literature, six research questions were developed. These were intended as a frame of reference, and this study was exploratory rather than experimental. The research questions can be categorised into two groups, teacher characteristics and environmental influences and beliefs, and were as follows:

**Teacher characteristics**

1. Do science centre produced, short professional development workshops have any effect on teachers’ science teaching self-efficacy?
2. Do science centre produced, short professional development workshops affect pre-service teachers differently from in-service teachers?
3. Do science centre produced, short professional development workshops have differing effects and impacts depending on a teachers’ teaching experience?

**Environmental influences and beliefs**

4. Does an individual’s previous experience with science influence how they feel about science teaching?
5. Does the environment of the school influence the self-efficacy of the teacher or how likely they are to teach science?
6. Do teachers perceive a role for informal science education institutions with teachers?

1.4 Overview of the thesis

Chapter 2 examines the nature of Australia’s primary science education problems. It describes the existing research into primary science teaching, teacher attitudes towards
science and the development and use of self-efficacy as a research tool. Chapter 3 provides an overview of the professional development tools used in an attempt to address the issues identified in Chapter 2 thus far, both in a national and international context. This chapter also addresses the known impacts and contributions of the informal education sector to the formal, with a specific focus on science centres and museums. The research questions arising from the literature in Chapters 2 and 3 are identified and outlined at the conclusion of Chapter 3.

Chapter 4 sets out the chosen research method, including justification of the different tools and techniques used based on prior research. The results of the study for each subject group are detailed and compared in Chapter 5. Chapter 6 discusses the results, placing them in the context of the larger body of research nationally and internationally. Conclusions of the study are drawn at the end of Chapter 6, where the limitations of the current study are addressed and final recommendations for future research provided.
Chapter 2: The role of science education, teachers and teaching self-efficacy

2.0 Science teaching and education in Australia

This chapter outlines the nature and breadth of the problems associated with the teaching of primary science and teachers’ perceptions of science in Australia. This initial overview of research describing the status and quality of science teaching in Australia, particularly within the primary school years, will provide the theoretical, social and political background of the issues involved.

The first section of this chapter provides an overview of the status of science teaching in Australian primary schools and the role that science plays in Australian society. Reference is made to the status of science teaching within the international context. The importance of teachers and the potential impacts they can have on students, and subsequently future generations, is discussed. Section 2.2 examines the training and self-efficacy beliefs of primary teachers, drawing on Australian and international findings. Section 2.3 reviews the development of self-efficacy research and outlines its applicability to the current research project. This final section also outlines some of the limitations and difficulties associated with research using teachers as participants.

2.1 The status of science teaching in Australian schools

2.1.1 The definition and purpose of science education

The Science Alberta Foundation defines science education as “the process or action of being educated about science, and the science knowledge and skills obtained through learning” (2007:12). Linn (2000) proposed four general goals of science education: making science accessible; making thinking visible; helping students to learn from each other and promoting lifelong science learning. An additional purpose of science education is as a means of training and recruiting future scientists — an expectation that is not shared by any other curriculum subject (Osborne & Dillon, 2008). The features of science education in the developed world have remained relatively unchanged through the 20th century and into the 21st — there is an emphasis on conceptual knowledge and the use of practical activities to illustrate principles, but these are not necessarily grounded in context (Tytler, 2007).
One of the fundamentally important outcomes of science education, and one which will be the focus of the present research, is to generate a ‘scientifically literate society’. Palmer defines scientific literacy as incorporating:

…an understanding of the nature of science as well as the concepts.

Scientifically literate people should have an interest in science and should know how to access information about science that will help them to make informed decisions about science-related issues in society (2008:168).

The Association for Science Education (ASE) in the United Kingdom further defines scientific literacy as “being comfortable and competent with broad scientific ideas, with the nature and limitations of science, with the processes of science and having the capacity to use these ideas in making decisions as an informed and concerned citizen” (2008:4). This is supported by Duschl who states that the goals of science education have changed to provide students with “an understanding of criteria for evaluating knowledge claims, that is, deciding what counts…” (2008:278). The concept of scientific literacy is fundamental to the purpose of science education in Australia, equipping students with the ability “…to understand more about science and its processes, recognise its place in our culture and society, and be able to use it in their daily lives” (Goodrum & Rennie, 2007:3).

This purpose echoes Laugksh (2000) who, based on a review of literature (published in English) pertaining to the concept of scientific literacy, asserts that if people are to live in a technologically advanced society then the members of that society will need to have reasonable levels of scientific literacy. The ASE (2008) identifies primary science in particular as having an essential role in the development of scientific literacy. In a study of science teachers in Turkey, Irez (2006) states that although science teachers have a central role to play in developing a scientifically literate society, research into the beliefs of pre-service and in-service teachers have found that teachers generally do not have a sound understanding of science themselves. A later study by Bursal (2008) found that Turkish teachers actually felt under prepared to teach science. This is reiterated in studies from across the globe as discussed in the following sections.

The extent of the problem is best shown through the Science and Society consultation conducted in the United Kingdom (UK), which collected 3,200 responses from business, education, media, policy-makers, scientists and the general public (Department for Business Innovation and Skills, 2009). The responses described a vision of science education:
…which produces scientifically literate and critically engaged citizens, and an inclusive, national workforce of critical thinkers able to adapt their skills to a changing society [through] skilled, enthusiastic, well-resourced and well-rewarded teachers [and] a practical-based science curriculum which places science in social, historical and global context (ibid:11).

This vision is in agreement with that of all other definitions about scientific literacy and the purpose of science education discussed in this section, so it appears to epitomise the common ideal. Yet in response to questions about the current status of science education, not one of these 3,200 consultation responses had a positive perception of the current science education system in the UK. In their development of the Australian School Science Education National Action Plan, Goodrum and Rennie identified that the focus for reforming science education must be directed at “…closing the gap between the actual and ideal pictures of science education” (2007:7). The ideal, it seems, is currently beyond our grasp.

What do these examples then imply about the level of scientific literacy in future generations? The literature is in agreement that teachers of science have an important role to play in developing a scientifically literate society. In contrast, very little appears to be known about how to ensure that this role is effectively fulfilled.

2.1.2 The philosophy of science education

Klopfer and Champagne (1990) defined two competing ‘philosophies’ for those within the science education system. The first, the ‘professionalists’, view science education with the main purpose of providing preparation for further science study for those students who will pursue careers in science and technology. The second philosophy is that of the ‘visionary’, which states that the purpose of science education is to provide a solid grounding in science, not only for careers, but for life. The view of the visionary then is that “the most important function of science education in schools is the development of a kind of literacy in science for everyone, whether the students are headed toward science careers or especially if they are not” (ibid:142). The ‘visionary’ philosophy of science is particularly pertinent in modern society.

The approach taken by science education practitioners, and education practitioners generally, is influenced by the beliefs held about the nature of knowledge, specifically if knowledge is believed to exist independently of the learner (realism) or if knowledge is simply a collection of ideas that are constructed by the learner (Hein, 1995). Learners
were viewed either as ‘empty vessels’, passive receivers of knowledge, or as being actively involved in the learning process (Nurrenbern, 2001). If the latter is true then education is not simply about the passive transfer of information from one mind to another as some believe (Bodner, 1986). Traditional views of knowledge held that our minds contain images which were copies of reality; information was accepted or rejected based on whether it ‘matched’ the copies in our minds or not and that was how knowledge was formed (Bodner, Klobuchar, & Geelan, 2001). This traditional view shaped the design of classrooms, subjects and student assessment for many years — classrooms were designed so students could only face the teacher (the sole source of knowledge) and students’ learning was assessed based on whether their responses matched the teacher’s (or not) (ibid). It could be argued that this still occurs in some educational settings today.

Jean Piaget pioneered the idea of people being active participants in the learning process. Piaget’s work was based on the belief that people construct knowledge around existing internal schemas, selecting and organising information from the myriad sensations around them and applying these new pieces of information to their mental scheme (Bodner, 1986; Hein, 1995). Pajares (1992) echoes Piaget’s work and defines knowledge as being fluid and in a state of evolution as it is continually interpreted and integrated into an individual’s existing schemata based on their experiences — knowledge is unique to the individual. This definition is sympathetic to constructivism, one of the prominent educational theories applied to science education.

Constructivism identifies the learner as having a central role in the learning process (Pines and West, 1986 in Tobin & Fraser, 1987). Hein extends this theory, stating that advocates of constructivism believe that “…learners construct knowledge as they learn, they don’t simply add new facts to what is known, but constantly reorganise and create both understanding and the ability to learn as they interact with the world” (1995:21). Constructivist approaches to education begin by accepting the perspectives of the learner. The learner’s ‘view’ is based on what they understand at that point in time, but this view is also capable of changing in light of new experiences which may give rise to new understanding (Mulholland, Dorman, & Odgers, 2004). The constructivist approach then, defines learning as having occurred “…when there is a connection between thought and experience” (Murphy, Murphy, & Kilfeather, 2010:2).

The role of the teacher then becomes more than simply transmitting information — they must become facilitators of student learning (van den Berg, 2001). According to Burry-
Stock and Oxford, a constructivist approach to education “…assumes that the students have a purpose for learning and that they are actively engaged in constructing meanings from their learning experiences…” (1994:272). This is supported by Howe and Stubbs (1996) who point out that teachers, as well as learners, must construct their own knowledge. There has been greater recognition of this fact in the intervening years. So and Watkins, in their discussion of approaches to develop constructivist teaching methods, state “in light of the advantages of constructivist views in enhancing pupils’ learning, such views are taken as referent of the better practice of teaching…” (2005:527). This reinforces the opinions of Burry-Stock and Oxford who said that “…if the goal is for students to understand, conceptualise, and apply new information…constructivism is a far more effective approach” (1994:274).

In an era where scientific and technological advances are prevalent and often relate to controversial topics, a scientifically literate society is important to ensure policy decisions (via a democratic process) are made based on sound and reasoned judgement. If members of society are unable to evaluate scientific information in the fields of, say, climate change or stem cell research, how can that same society vote to determine the position of the country in terms of adoption or development of technological advances in these areas? The need for science education is clearly not just about securing the scientists and researchers of tomorrow. It is also to enable a society to understand the implications of decisions that are made about the science and research which will ultimately shape the future. The author of this thesis subscribes to this democratic view of science education; one that equips society for active participation in discussion and decisions in the field. As such, while acknowledging that other view points as to the purpose and function of science education and science communication are in existence, this research will be presented from this democratic position.

2.1.3 Issues in attracting and retaining teachers in Australia

Before specifically discussing primary school teachers and science, it is necessary to describe some of the issues faced by the teaching profession generally. In Australian schools, attracting and training suitably qualified people into the teaching profession is of particular importance. In an overview of primary teacher education programs, Lawrance and Palmer (2003) found that the actual demand for teaching as a career is low, as is the status of teaching as a profession. This appears to be felt more in the secondary sector of education than the primary; the number of students studying to become primary school teachers is far greater than the number pursuing a career in
secondary school teaching (Commonwealth of Australia, 2006b). However, despite the number of primary teachers on waiting lists for permanent positions there are still areas which, for various socioeconomic or geographical reasons, struggle to attract teachers. Even if people are attracted into teaching as a career, the problem then becomes retaining these teachers. An Australian Education Union study of almost 1,300 beginning teachers showed that nearly two-thirds of respondents did not believe they would last more than ten years in the profession (Bellamy, 2007). This is similar to findings in studies of teacher attrition in the United States of America, which found that 50% of new teachers leave the profession in the first five years (Ingersoll, 2002 in Kern, Roehrig, & Luft, 2006).

In a Government enquiry into the training of teachers in Australian schools, and the suitability of these graduates to meet the demands of the job, a number of factors were identified which contributed to the attrition of new teachers. In terms of initial recruitment, the academic and personal suitability of student teachers was raised. One contributor noted that the low tertiary entrance scores of previous decades led to people who were barely literate and numerate to a year ten level themselves, being admitted into teaching degrees and who were now teaching literacy and numeracy to future generations (Commonwealth of Australia, 2006b). The tertiary entrance scores have increased since the 1980s and 1990s, however there are still concerns regarding the academic suitability of student teachers as the entrance score continues to be one of the most important determining factors for selection of students into undergraduate primary education courses (Ingvarson, Beavis, Elliott, & Kleinhenz, 2004). Teacher training programs are also heavily criticised as focusing too much on theory and not enough on the practical component undertaken in schools, which has attracted the attention of both the Federal Government in Australia and educational researchers alike (Murray, Nuttall, & Mitchell, 2008).

There is also a lack of support for the new teacher (via mentoring or other ongoing training) once they begin teaching in school. Many new teachers are simply ‘handed over’ from the tertiary training institution into the school system with little to no support and infrastructure to help them make that transition (Commonwealth of Australia, 2006a). Additionally, classrooms have changed with increasing demands on teacher time due to curriculum content (Carnemolla, 2007) and classroom and behaviour management (Commonwealth of Australia, 2006a). Studies of factors that influence teacher retention over the past decade have consistently identified the workload, salary,
disruptive pupils and the low status of the teaching profession as key reasons why teachers leave the profession, particularly in the early years (Kyriacou & Kunc, 2007; Watson, 2006).

Each of these factors should also be balanced by the fact that many students who begin teaching programs cannot articulate precisely why they want to teach in the first place (Commonwealth of Australia, 2006a). When all of these factors are combined with the need to teach subjects that they are not familiar with, like science, it is reasonable to assume that new teachers may soon find themselves feeling ‘lost’ and dissatisfied with their teaching experience and consequently leave the profession.

2.1.4 The role of science education for a nation

In an address to the Federation of Australian Scientific and Technological Societies (FASTS), the then Minister for Science, Education and Training, Julie Bishop, identified that the foundations of science and innovation lie within the Australian education system, particularly within its schools (Bishop, 2006). Bishop added that the potential for Australia to have a knowledge-based economy and society could only be realised if these strong foundations in science, technology and mathematics be put in place through solid teaching of these subjects throughout all stages of schooling. This ‘call to arms’ came at a time when the Government was faced with a shortage of science, engineering, technology and mathematics teachers and graduates that they could no longer ignore or attribute to normal cyclical trends.

Bishop stated that the teaching of science in primary school is a vital issue to address, as “…it is here that lifelong attitudes to science are often formed” (2006:1). Interestingly, Appleton notes that primary teaching seems to attract those “…who fear science rather than those who love it” (2003:21). Thus one of the most crucial periods for effective science education to be taking place, is actually hampered by the very resource put in place to facilitate the process.

An audit conducted by the Australian Science Teachers Association (ASTA) was conducted in 2005 to examine the provision of science, engineering and technology (SET) skills to Australian students to meet the future research and industry needs of the country. In the face of declining enrolments in SET subjects the audit also examined the supply and demand for SET graduates, and identified barriers to a scientifically literate Australian society. The audit, which drew on the work of Goodrum, Hackling and Rennie (2001), found that, in the primary area “…little or no science is really being
taught because the majority of teachers in this sector of schooling are not qualified in science, and do not feel confident to teach science and maths” (ASTA, 2005:9). This is not a new finding. In 1996, Stevens and Wenner published a paper which asserted that “general agreement exists that lack of such a background in science knowledge significantly contributes to hesitancy and possible inability to deliver effective science instruction in classroom settings” (1996:1). These studies indicate that there is an inherent problem in Australian primary science, and one which has been compounding for at least the last decade.

2.1.5 Primary school teachers and science avoidance

Studies involving primary school teachers, in particular measuring their confidence, competence and self-efficacy with science teaching, have shown that many primary school teachers simply lack each of these characteristics (Appleton, 2002; 2003; Hackling & Prain, 2005; Yates & Goodrum, 1990). The lack of confidence has a flow on effect with teachers shying away from teaching science (Stevens & Wenner, 1996). Self-efficacy beliefs of teachers can also contribute to how they approach science and science teaching. Their belief in what the outcome will be ultimately affects their behaviour. If a teacher does not believe that they have the necessary knowledge and skill to achieve a desired outcome, such as positive learning outcomes for students in science subjects, then they have a weak commitment to teaching that subject (Bandura, 1977).

This concept is applicable to the survey findings of Angus, Olney, Ainley, Caldwell, Burke, Selleck and Spinks (2004) who found that primary school teachers (grades kindergarten to year 6 — up to year 7 in Queensland) across Australia were spending an average of 41 minutes per week on science. This is the equivalent of 2.7% of total teaching time. In a recent study of a similar nature conducted for the Australian Primary Principals Association, Angus et al. (2007) found that science was largely still not being taught, with results showing that science had about 3% of total teaching time devoted to it. This is in comparison to English (38%), Mathematics (18%), Health and Physical Education (11%) and the Arts (8%). These results were gathered from over 600 teachers and principals from 160 schools representing each state and territory and each sector of the education system (government and non-government schools). These results are comparable to a study conducted in Bay Area schools in California in the United States of America, where 923 primary school teachers representing approximately 70% of the Bay Area participated (Dorph, Goldstein, Lee, Lepori, Schneider, & Venkatesan, 2007).
Despite policies and initiatives to support science education, of the surveyed elementary teachers who are responsible for teaching science, 80% reported spending an hour or less per week on science, with 16% of teachers not teaching science at all. The authors of this study acknowledge that the respondents were more likely to be engaged in teaching science than not; hence the results may actually present “…a more favorable picture of the status of science education in the Bay Area than what actually exists” (ibid:4).

A study by Goodrum et al. (2001) examined the status and quality of teaching and learning in Australian schools (primary and secondary) and found that of 204 teachers surveyed, 17% lacked the background they felt necessary to teach science. This is corroborated in a study conducted by Harris, Jentz and Baldwin (2005) who found that 23% of senior secondary science teachers surveyed, had not studied beyond first year university level science. Yet these teachers are responsible for steering senior high school students through final year exams. In the lower grades, the demographics are more dire. Ten percent of respondents taught years 7 and 8, and of this ten percent, which largely comprised early career teachers, 23% did not have any kind of science background at all. A further 12% had studied science at first year university level only (ibid).

Notwithstanding the policy focus, the programs, the science teacher associations and networks, science still does not appear to be considered a priority subject area. The focus is remaining firmly on numeracy and literacy which many teachers still seem to believe can only be taught through English and mathematics (ASTA, 2005). This is an internationally shared perspective, with the ASE in the United Kingdom arguing that the study of science is not only beneficial for the development of scientific literacy, but that science itself is a “strong vehicle for the development and application of literacy and numeracy in relevant contexts” (2008:1). Yet science does not appear to be used for this purpose.

2.1.6 The science curriculum

School curricula are often criticised for overwhelming teachers with the sheer volume of what must be taught (Rennie, Goodrum, & Hackling, 2001). There is also an ongoing need for the content of the science curriculum to be continually updated, keeping pace with progress in the various fields, to ensure that the content continues to be relevant to students, which places an added burden on teachers (Millar & Osborne, 1998; Rennie et
Ellison (2008) states that teachers should not be expected to use the teaching resources and strategies of yesteryear to prepare the students of today. Yet teachers and researchers alike contend that this is precisely what is happening as teachers stick with what is familiar, ‘safe’ and comfortable, focussing on the content that needs to be taught within increasingly crowded school days and curricula (Carnemolla, 2007; Hewson, Tabachnick, Zeichner, & Lemberger, 1999b). For all the agreement between the authors in the literature, no-one appears to be forthcoming with any real, long lasting solution. This implies that the situation is not an easy one to address, and given the multiple facets and factors involved, it is highly likely that there will not be a ‘one size fits most’ solution available (Johnson & Marx, 2009).

Fensham (2002) argues that there is a tendency worldwide for the science curriculum to be ‘content heavy’, concerned more with the retention and recitation of facts instead of actively engaging students in the process and experience of science. The British Association for the Advancement of Science supports this, saying that “school science fails to convey the ways in which science is relevant to everyday life and affects all of us” (in Science Alberta Foundation, 2007:16). Greene (2008) wrote that science education is robbed of life when all that is focussed on are the recitation of facts and gaining competency in technical detail. Science should be about exploration and discovery, driven by a desire to know how things work and why things happen — not a dry collection of context free facts which hold little meaning. However, as described by Sadler, Chambers and Zeidler (2004 in Pouliot, 2010), the science curriculum alone is not the defining characteristic of science education. How it is interpreted and used is also critical.

The use of interactive, hands-on activities and a constructivist teaching approach has been advocated as a way of better engaging students in science, but in an overcrowded curriculum and minimal time allocated to science lessons, this approach is rarely used in practice (Preston, Mules, Baker, & Frost, 2007). For many teachers, the use of such activities causes fear and uncertainty, leading them to avoid teaching the subject in this way, or altogether (Helsing, 2007). In contrast, a defined curriculum with clearly prescribed activities can create greater assurance for the teacher in knowing what must be taught and creates a sense of organisation. At the same time this highly organised approach also closes the curriculum scope, limiting opportunities for student involvement and exploration beyond what is prescribed, which negatively impacts
student initiative (Suarez, Pias, Membiela, & Dapia, 1998). This shortcoming in the science curriculum is another contributor to the decline in interest of students in science.

2.1.7 Student attitudes towards science

An international study of student attitudes towards, and interest in, science entitled Relevance of Science Education (ROSE), found that although most of the students surveyed believed that science and technology was relevant to the needs of society, they did not wish to get a job in science themselves (Sjøberg & Schreiner, 2005). This was particularly pronounced in the more developed countries (ibid). Although Australian students were not participants in the ROSE study, evidence of a decline in Australian students’ interest in science is provided by the Third International Mathematics and Science Study (TIMSS) replication study in 1999 (Martin, Mullins, Gonzales, Gregory, Smith, Chrostowski, Garden, & O'Connor, 2001). The 14-year-old Australian students surveyed had the worst attitudes to science in comparison to all of the English language speaking students in the whole study. There are decreasing numbers of Australian students who continue with studies in science subjects and a declining number of students who choose a career in a scientific field (Darby, 2005; Palmer, 2008). This is also seen in mathematics which saw the number of final year high school students studying advanced level mathematic subjects drop 40% between 1997 and 2003 (Lawrance & Palmer, 2003).

Logan and Skamp (2004) found that many students in their study did not hold positive attitudes towards science. The decline in positive attitude begins in late primary school and becomes increasingly evident during secondary school. This suggests that negative attitudes towards science can be formed early on in a student’s education, and are likely to be compounded as schooling progresses. The way in which science is taught in schools is one identified cause of this trend of declining interest in the sciences (Palmer, 2008). As discussed previously, the literature shows that Australian primary school teachers do not feel competent in science teaching. So science is not taught in an interesting, engaging manner — if it is taught at all — and students are not being engaged in the subject. This is supported by Rennie et al. (2001:469) who state that “…students’ engagement in learning is at its greatest when they are taught by enthusiastic and competent teachers”.

Research has shown that students strongly identify the teacher as one of the key influences on the level of engagement (Darby, 2005). A student’s beliefs and values
about learning in science can also be influenced by their experiences in actually learning science in school — especially the manner in which it is taught (Palmer, 2008). Thus if a student’s only experience with science in school is a boring, irrelevant one, then this will shape their perception, belief and expectation about science in the future. In the same way, a student who has had positive experiences with science, including interesting hands-on activities that make the phenomena relevant, understandable and enjoyable, would be more likely to have a positive, more receptive attitude towards science and a greater willingness to do more (Holstermann, Grube, & Bögeholz, 2010).

Personal interest in a subject can be manufactured through repeated positive exposures to situational interest (Palmer, 2004). Situational interest is defined by Schraw, Flowerday and Lehman as “…temporary interest that arises spontaneously due to environmental factors such as task instructions or an engaging text” (2001:211). Therefore, if a student has repeated experiences with science that are engaging, thought provoking and stimulating, then it can be hypothesised that a student could form a personal interest in science as a result of these repeated positive ‘situational interest’ exposures. The teacher then, has an even greater responsibility for not only educating their students with the appropriate information, but they must also do so in a manner which assists the student in forming this personal interest — or if nothing else, a passing situational interest.

2.1.8 The role and influence of teachers on students

Good quality teachers with access to continuous professional training, in combination with relevant, up to date knowledge and skills in science are “…the foundation of any formal science education” (Osborne & Dillon, 2008:9). Supovitz and Turner (2000) proposed that superior teaching in classrooms will translate to better levels of student achievement. Professional development could provide an opportunity for teachers to improve their knowledge in the specific discipline they teach which could quite possibly give rise to better student outcomes (Darling-Hammond, 2000 in McRae et al., 2001).

A commissioned report on the elements of successful student outcomes, which included the views of primary teachers, states that:

…teacher influences on learning outcomes are, at the very least, sufficiently significant as to be measurable. As the learning process involves primarily teachers and students, anything which affects either party would logically impact on learning outcomes (Price Waterhouse, 1995:67).
A study by van Manen (1999 in Darby, 2005) takes this further by asserting that any action the teacher does or does not make has significance for students.

This assertion is balanced somewhat by the findings of Leigh (2007) who examined student test score gains in literacy and numeracy. He found that the age and experience of a teacher were positively related to students’ test score gains rather than their actions. Teachers cannot help their age or experience and nor should they be held responsible for any inherent influence these factors may have on their students’ performance. Leigh’s study did not examine test scores in science, so these findings may not be as applicable in a science teaching context, as the near endemic lack of confidence in science teaching in Australia seems to suggest (see Appleton, 2003; Goodrum et al., 2001). Interestingly, a study of the science teaching self-efficacy beliefs of teachers in India found that the more experience a teacher had, the lower their confidence in their students’ ability to achieve desired outcomes in science (De Souza, Boone, & Yilmaz, 2004). This suggests that perhaps experienced teachers not only lack confidence in their own science teaching abilities but also believe that their students are incapable of doing well in science. Perhaps this is one potential explanation for why teachers minimise or avoid science teaching.

Irrespective of their age or experience, teachers who are enthusiastic about a topic are more likely to have students who see the intrinsic value in a subject and are more motivated to become engaged in it (Holstermann et al., 2010), thereby enhancing student outcomes (Palmer, 2007). This opinion is supported by Tytler et al. who identified that:

…teachers are central to engaging students’ interest. They are, after families, the most important sources of information about science, technology, engineering and mathematics (STEM) work and the thinking underpinning STEM disciplines… (2008:144).

It almost becomes a catch-22 situation as to get an enthusiastic teacher, they arguably need to have positive feelings towards the subjects they are teaching which, in science, is often hard to find.

The quality of a teacher is of vital importance to student achievement as illustrated in a study conducted by Rowe (2003) of 270,000 final year high school students in Victoria, Australia over a six year period. The study findings indicated that there was “significantly more variation within schools than between schools” signifying that the
quality of teaching was the most important source of variation in determining student achievement. Rowe states that after taking into account all other sources (such as gender, social backgrounds and differences between schools) the largest difference in student achievement is found between classes. That is, the most important source of variation in student achievement can be attributed solely to the quality of the teacher. The findings from this study are further corroborated by Russell Tytler who concludes:

For promoting change in school science, we can focus our attention on any of a number of different elements in the mix that impacts on student learning. Ultimately, however, it is the teacher who impacts directly on student learning (2003:290).

A teacher’s perception of science, and thus their subsequent enjoyment of and confidence in the subject, is influenced by their own educational experience, even as back as far as their own days as school students. Stevens and Wenner (1996) found that pre-service teachers’ experiences in science, when they were high school students themselves, had far greater impact on their overall perceptions and belief of science teaching than their teacher training course work. Thus, it could be inferred that a teacher’s input at an early stage of schooling will influence their students’ perceptions and attitudes in adult life. This reinforces the importance of teachers portraying subjects like mathematics, science and technology in a positive way.

Lawrance and Palmer (2003) argue that the task to engage students in the sciences at a young age must be centred on primary and secondary school teachers. Even teachers themselves identify that mathematics and science are not taught in ways that encourage people to become a mathematics or science teacher (Commonwealth of Australia, 2006b). Therefore, there is an even stronger demand for teachers to receive training of the highest standard so that they can fulfil the requirements for the development of a scientifically literate, and a scientifically positive, society.

2.2 Primary school teachers’ science training and self-efficacy

2.2.1 How an individual’s educational experiences shape their perceptions of science

The array of courses available to students studying to become teachers in Australia is vast with a diverse number of approaches and options. In an overview of primary teacher education programs, Lawrance and Palmer (2003) found that there was a large degree of innovation in the development of courses and programs. Despite this, for
students enrolled in a typical four year undergraduate degree, the minimum amount of science, technology and mathematics subjects that a student teacher must cover is approximately 10% of their overall program.

Science is not a popular option among teaching students, with many teacher trainees opting to enrol in other, non-science programs that were already well over-supplied (Lawrance & Palmer, 2003). This has largely contributed to the skills shortage Australia faces in attracting suitably qualified teachers of science and mathematics (Commonwealth of Australia, 2006b; Harris et al., 2005). This teacher shortage has at least two consequences for Australian schools. The first is that the highly qualified teachers of science and mathematics will be greatly sought after and are likely to be recruited into selective and/or private schools; and the second is that this demand for the highly qualified teachers will result in other teachers in other classes and schools being required to teach subjects in which they have not been formally educated and equipped to teach (Lawrance & Palmer, 2003).

Darling-Hammond (2000) argues that the most consistently negative predictor of student achievement is the number of teachers who hold less than a minor educational qualification in the fields that they teach. Thus the prevalence of teachers with little to no scientific educational background is likely to yield poor student achievement in science. Ultimately, the shortages in teachers who are well qualified and equipped to teach science will have flow on effects to the greater Australian population. As more school students complete their education with few motivating experiences to encourage them to engage in science, either as a student or a member of the public, the creation of a scientifically engaged society will be all the more challenging.

Many studies have shown that teachers hold strong perceptions and beliefs about teaching even before they enter the classroom, irrespective of their background or training (Friedrichsen & Dana, 2003; Schwarz & Gwekwerere, 2006). Settlage (2000) postulates that the attitudes pre-service teachers will have towards science will largely be determined by the quality of their own experiences as learners of science. Thus the nature of the problem is cyclical. If primary and high school teachers are not providing positive science learning experiences, then their students will develop less than positive attitudes towards science. Jones (2008) argues that any of those students who then enter the teaching profession will be bringing these less than ideal attitudes to their teaching, and subsequently to their own students. In a study of Australian teacher training programs at 35 institutions, Palmer (2008) found that only a third of the programs
included in the study were actively working to achieve attitudinal change in primary teacher education students. Even with awareness of the problem, the cycle of producing teachers with negative attitudes towards science continues.

Unless this cycle is broken by teacher training and professional development that actively works to change the attitudes of pre-service and in-service teachers towards science, and injects ‘science positive’ teachers into the school environment, it will perpetuate. This is supported by Palmer who believes that “…for pre-service primary teachers, changing negative attitudes towards science teaching so they are more positive will have the greatest educational impact…” (2006b:667). This is further supported by Hanuscin, Akerson and Phillipson-Mower who believe that “one of the most influential experiences that teachers have is being a learner in science themselves…” (2006:913).

If a student enjoys a learning experience and is stimulated, then this will strengthen their interest in the subject (Holstermann et al., 2010). Therefore an interested science student could translate to an interested science teacher, who may be more motivated to engage their students in science. De Souza et al. suggest that we leave the teaching of science to “…only those who are motivated to make a difference in the science classroom” (2004:850). The Queensland Government in Australia already appears to be making these steps, announcing that 100 specialty science teachers will be provided to primary schools to attempt to engage students in science before they transition to high school (Howells, 2010).

Even specialist science teachers will require ongoing training and support, and the need for effective training of future generations of teachers still remains. This is supported by Jones who says that access to professional development, in combination with science resources, “…should not be limited to professional development of practicing teachers, but also needs to be a fundamental part of pre-service teacher preparation” (2008:65). One way of achieving this would be to re-examine the nature of teacher training and to ensure that ongoing training in science is provided to teachers throughout their career.

2.2.2 The transition from pre-service to beginning teacher

Early science experiences are only a part of the factors influencing pre-service teachers. For many, the transition between being a pre-service and an in-service teacher is a period characterised by a focus on ‘self’ and survival (Marso & Pigge, 1989). This focus evolves as the teacher gains further experience. Greenwood draws on the work of Norman (1982 in Greenwood, 2003), proposing that teachers can be classified in stages
according to their level of teaching experience. Pre-service and first year teachers are in the first stage which involves the accrual of information and the gathering of knowledge that can assist them in developing and improving their classroom performance. Teachers in the second stage — generally after one year of teaching — have restructured their knowledge into a more organised system. However this more organised system may not represent the most efficient practice. Greenwood argues that it isn’t until after two or more years of teaching that a novice teacher is starting to develop their knowledge in a way that is efficient and allows their teaching processes to become more natural and automatic.

Burry-Stock and Oxford (1994) put forward a more detailed path of progression for teacher education. They describe a framework as shown in Table 1:

**Table 1: Different stages of teacher progression according to level of experience, using discipline as an example of proficiency (Burry-Stock and Oxford, 1994)**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Characterised by:</th>
<th>When applying discipline, teachers will:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novice</td>
<td>Skill development</td>
<td>Lack the experience to be flexible with rules</td>
</tr>
<tr>
<td>Advanced beginner</td>
<td>Importance of broad skills and use of more sophisticated rules</td>
<td>Use the situation to determine which disciplinary rules are applied</td>
</tr>
<tr>
<td>Competent teacher</td>
<td>Coping with problems and students using hierarchical decision making process</td>
<td>Consciously choose goals and rules based upon the situation. Feel a sense of personal responsibility for outcomes</td>
</tr>
<tr>
<td>Proficient teacher</td>
<td>Thinking analytically but intuitively organising and understanding the task</td>
<td>Examine their experiences, deliberately consider alternatives and feel a sense of responsibility for the outcome</td>
</tr>
<tr>
<td>Expert teacher</td>
<td>Fluid performance - do not need to stop to deliberate when making certain decisions</td>
<td>Know by feel and familiarity what action to take</td>
</tr>
</tbody>
</table>

This framework provides slightly more nuance to the progression of a teacher’s level of competence. Burry-Stock and Oxford used discipline as an example of how a teacher’s level of competence can be measured. If one were to apply this same framework at a subject level basis however, the classification may not be as neat. An expert teacher
may exhibit novice teacher behaviour when it comes to teaching subjects, like science, that they are unfamiliar and uncomfortable with. This is discussed further in the next section of this chapter.

Unfortunately, for many pre-service and in-service teachers, their beliefs and subsequent practice do not reflect the current theory and advocated approaches to science education (Keys & Watters, 2006). Stevens and Wenner (1996) propose that a lack of science knowledge greatly contributes to hesitancy to teach science, possibly to the extent of being unable to provide effective science experiences in the classroom.

This is supported by a study of the practices of pre-service chemistry teachers in Turkey, which found that the teachers’ perceived lack of content knowledge was identified as a barrier to their use of the effective teaching techniques advocated in their training program (Uzuntiryaki, Boz, Kirbulut, & Bektas, 2010). This could also be compounded by a lack of role models in science teaching.

Skamp (1995) found that the negative ethos of supervising teachers towards science was detrimental to pre-service teachers, occasionally negatively influencing their decision to enter the teaching profession. Skamp’s study was limited due to the small sample size, yet similar findings were reported by Mullholland and Wallace (2001) who found that the low status of science in the primary school curriculum often meant that there were not any positive role models in science to assist pre-service and beginning teachers. A later study by Hudson and McRobbie (2003) found that 20 percent of the mentors given to pre-service teachers did not model a science lesson, and just under half (47%) of the pre-service teachers were not certain whether their mentors were interested in science or not. This indicates a need for some form of quality control or rigorous selection process for potential mentors of pre-service teachers, particularly those who will provide a positive role model for science.

For some beginning teachers, the juxtaposition of their beliefs and their practice are a source of confusion. Brickhouse and Bodner (1992) found that many beginning teachers experienced a conflict between their own perceptions and beliefs about science teaching, and how they actually presented science in the classroom. This was also observed in a small study of in-service teachers which observed that while teachers adopted the jargon, such as hands-on, to describe their teaching practice, their adoption of hands-on teaching approaches were superficial at best (Furtak & Alonzo, 2010). In essence, they were talking the talk, but not really walking the walk.
The literature appears to suggest that it is almost as though the teachers know how it should be done, but the actual practice and delivery of it gets lost in the overall demands of classroom management, their own perceptions of science and their self-assessed ability to teach it. This is supported by Hudson (2006) who examined the differences in perceptions of knowledge of science between second and third year education students. The study showed that the third year students believed that they had a far greater prior knowledge for teaching science in primary schools than their second year counterparts, despite both cohorts having completed the same amount of science methodology courses. Statistical analysis revealed that both the second and third year cohorts felt better equipped to plan and implement the necessary practices — the pedagogy — for teaching in science, which in turn influenced their perception of their prior knowledge of science. Hudson proposed that the information and ideas the third year students may have gleaned from other core curriculum areas and experiences may have been incorporated into their theoretical framework for developing and delivering science subjects, thereby making them feel more comfortable in the experience and subsequently as though they had greater prior knowledge. As succinctly summarised by Raizen and Michelson “knowing science and knowing how to teach it are two different things” (1994:82).

2.2.3 Pedagogical content knowledge as an indicator of teaching proficiency

The development of teaching pedagogy and subject knowledge are both important to the development of a teacher. Referred to as pedagogical content knowledge, or PCK, it is defined by Shulman (1986) as involving “…the blending of content and pedagogy into an understanding of how particular content knowledge is organised, represented and adapted to the diverse interests and abilities of students, and presented for instruction” (in Reitano, 2004:20). However, Park and Oliver (2008) propose that Shulman’s definition can be interpreted differently by individuals in different groups. For example an educational researcher may use a different interpretation of the nature of PCK to that used by a teacher, thereby creating a variety of meanings of PCK.

Park and Oliver (2008) identified that a teacher’s development of PCK was not simply reliant on them acquiring new knowledge. They assert that teachers are knowledge producers, not knowledge receivers — their PCK is influenced by the knowledge that they acquire, and then how that knowledge is applied and their reflection on that knowledge use in practice. Park and Oliver are arguing that teachers receive knowledge and this does result in positive influences, but “…the most powerful changes result from
experiences in practice” (ibid:278). This viewpoint appears to support the constructivist view of learning. Teachers acquire knowledge, but it is what they do with it and how they use and interpret it which ultimately shapes how the knowledge is retained (scaffolded in existing internal schemata) and manifests. Ultimately, irrespective of the interpretation of PCK used, a teacher with highly developed PCK will not only know the subject matter, but will also have a sound understanding of how to convey this information effectively and efficiently to learners.

PCK is an important determinant of teacher behaviour. This is supported by Park and Oliver (2008) who concluded that the efficacy of a teacher is linked to their PCK. Therefore PCK could also be applied as an indicator of competence in a subject; a teacher is competent in a subject if they are able to teach a subject based on student centred outcomes; less competent if they are exhibiting a teacher centred approach.

Reitano (2004) found that PCK is an important part of effective teaching, be it for a novice or an experienced teacher. Reitano drew on work completed by Sanders, Borko and Lockard (1993) who found that experienced teachers, when asked to teach in a subject area outside of their field of expertise, often resorted to teaching behaviour similar to that exhibited by novice teachers. Typically more time and effort was expended in the planning and preparation of the class, rather than on the development of the content knowledge structure and adapting the lesson to fit with the background knowledge of the student. Reitano observes that “there is a transition from teacher-centred to student-centred outcomes as an indicator of competence [of the teacher]” (2004:43). If an experienced teacher does not have PCK in a subject, then they will tend towards novice teacher behaviour. But, teaching outside of an area of familiarity can also have a positive effect. Teaching in a field outside of their comfort zone is a way for teachers to extend their professional expertise and re-energise their teaching by taking on a new challenge (Department of Education Science and Training, 2003).

2.2.4 Perceived barriers to teaching science

Previous sections have discussed how teachers’ confidence and prior science experiences can limit the amount, and quality, of science they teach. Time and resource availability are also often named as barriers to science teaching, but this is not always the case (Keys, 2005). Appleton and Kindt (2002) conducted a study involving beginning teachers in a regional area of Queensland, Australia, examining the status of science and conducting an inventory of the science teaching resources available in
schools. They found that in a number of schools, while not necessarily overtly stated, science was a lower curriculum priority in comparison to subjects like mathematics or English.

One commonly occurring comment from participants in Appleton and Kindt’s study was the difficulty in accessing the resources required to teach science in class. Interestingly, this comment was made by teachers who were working in schools that had more than adequate resources available, both in terms of equipment and source books of ideas and activities. Through further investigation, Appleton and Kindt were able to identify that many of the teachers interviewed, even those committed to hands-on instruction of science, felt that the time required to find and gather all of these resources and then plan the class was the major stumbling block. As a result, many of those teachers involved in the study allowed themselves to be limited by these perceived difficulties and remained in a ‘default’ teaching strategy where they felt comfortable. As science teaching in these schools was not perceived as important, and no school science teaching policy was in place, many of the teachers inferred that they were able to devote a minimal amount of teaching time to science, or avoid it altogether if they so wished.

There were nine student teachers used in Appleton and Kindt’s study, from a potential cohort of 20, selected due to their high academic performance in the science education component of their teacher training. Appleton and Kindt chose to use the good performers in science education, arguing that they would be more likely to attempt to teach science. Therefore the population used in their study is possibly more science positive than could be considered accurately representative of the greater beginning teacher population. Despite their purported positive attitudes towards science, many of the participants were able to actively avoid science teaching, citing reasons such as time and resource availability as stumbling blocks. If a science averse, beginning teacher were in the same situation, with little additional impetus from the school environment to teach science, then it would be even easier for these beginning teachers to neglect science teaching altogether.

A scenario such as this allows teachers who are not confident to teach science to focus on building their teaching skills in areas where they feel more comfortable. However, these teachers do not apply those skills to the areas of personal discomfort — like science. It can be reasoned then, that these teachers will always approach science teaching as a novice, focussing on their own outcomes instead of the students, as described in Reitano (2004). This supports a study done by Zeichner and Tabachnick
(1981 in Greenwood, 2003) who wrote that the culture of the school environment and the influence of the cooperating teachers (who were supporting the beginning teachers) were major contributors to the ‘dilution’ of the skills and practices that the beginning teachers were taught during their pre-service education.

Appleton and Kindt (2002) concluded that were many different factors that worked together to ultimately influence teachers’ perceptions of their science teaching ability. While personal belief and confidence certainly play a part, their own science experiences and their school environment also influenced their development as a science teacher. This is further supported by Howitt (2007) who found that the influences of pre-service primary teachers’ confidence in their ability to teach science is highly variable and individual in nature. Thus it can be concluded that addressing only one factor will not address the issue in all teachers. Each factor has a role to play and needs to be addressed in any professional development or teacher training. The advent of the concept of self-efficacy in teaching goes some way to developing a means of predicting teacher outcomes. The current project examines the interactions between science teaching self-efficacy and external factors, contributing to the understanding of these interactions covered in the existing literature.

Teachers’ beliefs and perceptions of science can be influenced by a number of factors, beginning when they are students themselves. Previous science experiences can create negative attitudes towards science which around two thirds of teacher education programs are not addressing or attempting to change. Teachers feel uncomfortable with their level of science content knowledge and under prepared to teach science. Their teaching practice and beliefs do not match the current educational theory or advocated science education approaches. When coupled with schools that do not place high priority on science as a subject area, and a lack of science positive role models, negative attitudes towards and beliefs about science will perpetuate, unless action is taken. The next section will look at how the beliefs of teachers are formed, and identify possible areas for remediation.

2.3 The development of the concept of self-efficacy and its application to teaching

2.3.1 Beliefs of teachers

From the literature it is evident that the knowledge and background of teachers is an important determinant of the status and quality of science teaching. The beliefs of the
teacher also have a great influence on their performance, or as de Laat and Watters put it, that belief systems of teachers are “powerful predictors of teacher behaviour” (1995:455). Unless the beliefs of teachers about teaching are addressed and acknowledged in any attempted reform efforts, enduring change in the classroom or within science education itself will not be achieved (Lumpe, Haney, & Czerniak, 2000; Pint'o, 2004).

According to Bandura (1997) an individual’s beliefs can indicate the basis of, and rationale for, the decisions people make throughout their lives. Smith and Neale (1989) propose that teachers have strong beliefs about what science is, and thus how it should be taught. Teachers hold beliefs about their profession and practice, including how students learn; their own abilities and confidence to perform specific tasks (self-efficacy); and their abilities to effect positive outcomes with their students (teaching efficacy) (Lumpe et al., 2000; Pajares, 1992). This is supported by Schraw et al. (2006) who found that a learner’s beliefs and attitudes affect their learning and behaviour. For a pre-service or beginning teacher, this is particularly important as the beliefs they form about their science teaching ability are likely to shape the kind of science teacher they become. Beliefs have often been confused with other concepts such as attitudes, knowledge and values (Lumpe et al., 2000). Nespor (1987 in Pajares, 1992) distinguishes between belief systems and knowledge systems. Whereas knowledge systems are open to evaluation and are malleable subject to experiences and the acquisition of additional knowledge, beliefs are less disputable, more inflexible and less open to critical examination.

The earlier a belief is formed the harder it is to change (Pajares, 1992). This has implications for any reform efforts in science education. If a reform initiative requires a comprehensive change to the beliefs or practices of a teacher, this is likely to generate fear and uncertainty as teachers find their beliefs challenged and are left unsure as to what is expected of them (Munthe, 2003 in Helsing, 2007). However, newly acquired beliefs are more susceptible to re-examination and change (Pajares, 1992). Pre-service teachers tend to be more positive and unrealistic in their expectations and abilities while completing their teacher training, and these beliefs can change rapidly once they begin teaching in schools (Swars & McMunn Dooley, 2010). Therefore, the beliefs of pre-service and beginning teachers about the nature of their profession, and in their abilities, are arguably more easily altered than the same beliefs held by experienced teachers. This is supported in a study by de Laat and Watters (1995) which found the efficacy
beliefs of pre-service teachers to be dynamic and possible to change — subject to experiences and context. This study used 10 participants with a range of teaching experience. Further work needs to be conducted in the same area to examine if the trends are more widely applicable.

The context of an individual's beliefs plays an important role. The beliefs of teachers must be examined in the context of the school environment in which the teacher is operating. This includes the available resources, support from administration, the principal and other teachers (Luft, 2007; Lumpe et al., 2000) and the perceived constraints imposed by the climate of the school or classroom itself (Pint'o, 2004). De Laat and Watters state that to examine teacher practice in isolation from a teacher’s beliefs about their own efficacy, science and their knowledge of science will “...result in an incomplete picture” (1995:460).

2.3.2 The development of the teaching self-efficacy concept

Bandura defines teaching self-efficacy as “...a teacher’s personal beliefs about their ability to teach and their ability to produce positive outcomes for children” (1995 in Appleton and Kindt, 2002:44). Tschannen-Moran, Woolfolk Hoy and Hoy (1998) distinguish self-efficacy from other conceptions of self, such as self-esteem, as it pertains to a specific task. It “...has to do with self-perception of competence rather than the actual level of competence” (ibid:210).

There were two different strands that emerged from the first examination of self-efficacy of subjects. The first was developed by Rotter (1966) and was centred around the so called ‘Locus of Control’. Locus of control grouped people into two categories: those who believed that they could influence or affect an outcome (an internal locus of control) and those who believed that the achievement of a desired outcome would be determined by external, environmental factors (an externally oriented locus of control). This initial work of Rotter was further developed and applied specifically to teachers by the RAND Organisation and defined as:

…the extent to which teachers believed that they could control the reinforcement of their actions, that is, whether control of reinforcement lay within themselves or in the environment. Student motivation and performance were assumed to be significant reinforcers for teaching behaviours (in Tschannen-Moran et al., 1998:202).
The second strand in the development of self-efficacy measures, based in social learning theory, was proposed by Albert Bandura. Bandura (1977) postulates that there are two central components to self-efficacy: ‘efficacy expectation’ which details the individual’s belief in their ability to achieve the desired outcome (behaviour); and ‘response/outcome expectancy’ which represents the belief that the achievement of the desired behaviour will have a desirable outcome.

Bandura identified four sources of efficacy expectations. These are mastery experiences, physiological and emotional states, vicarious experiences and verbal persuasion. Mastery experiences refer to a teacher’s successful achievement of a task. These mastery experiences are the most powerful providers of efficacy beliefs (Woolfolk Hoy & Burke Spero, 2005). The second source is physiological and emotional states — the level of anxiety or excitement that a teacher feels can either enhance (when experienced at moderate levels) or limit self-efficacy (Khourey-Bowers & Simonis, 2004). Vicarious experiences are those which allow teachers to watch and critique the practice of another teacher or educator. If the teacher watching strongly identifies with the practice being shown, and it is modelled successfully, then their efficacy will be positively affected. If the model being taught is unsuccessful then this will have a negative impact on efficacy (Woolfolk Hoy & Burke Spero, 2005). The final source Bandura identified is that of verbal or social persuasion which refers to the communication between individuals or groups about particular teaching practice or the provision of positive feedback from colleagues or students. This source of efficacy is very limited in terms of providing any enduring efficacy beliefs, but it can contribute to corrective changes in behaviour (Bandura, 1997).

Palmer (2006b) summarises Bandura’s findings, which show that teachers with high levels of self-efficacy are more likely to be committed to teaching, view learning problems of their students as something that can be overcome and devote more time to motivating, encouraging, guiding and praising students; in general their students have higher levels of achievement. In comparison, those teachers with low self-efficacy are discouraged by student difficulties, make little effort to motivate or guide the students and are likely to have a weak commitment to teaching the subject.

In a book published in 1997, Bandura compared his own strand of self-efficacy theory with that of the work stemming from Rotter’s internal/external locus of control. Bandura conducted research that provides data showing that the two approaches to measuring efficacy are not actually measuring the same thing. One is examining a
person’s perception of their own ability to produce certain actions (self-efficacy) whereas the other is examining a person’s beliefs about the ability of actions to affect outcomes (locus of control). The data used in Bandura’s study found that not only do the two concepts have little to no relationship with each other, but perceived self-efficacy is a strong predictor of behaviour while locus of control is typically weak (Tschannen-Moran et al., 1998). This is supported by Gencer and Cakiroglu who state that self-efficacy beliefs of teachers “…has emerged as one of the few teacher characteristics that consistently relates to teaching and learning over the past 25 years” (2007:664).

Numerous researchers have conducted studies into the theory of self-efficacy, particularly as it relates to science teaching. Gibson and Dembo (1984) developed the Teaching Efficacy Scale (TES), designed to measure general teaching efficacy, not subject specific efficacy. Enochs and Riggs (1990) modified their scale to develop the Science Teaching Efficacy Belief Instrument (STEBI). The first instrument they developed was specifically designed to measure the self-efficacy beliefs of in-service primary teachers (STEBI A). They later modified the STEBI A to develop a scale that could be used to measure the self-efficacy beliefs of pre-service teachers (the STEBI B). In both instruments, the questions were grouped according to Bandura’s postulated two factors contributing to efficacy: ‘expectation efficacy’ or ‘Personal Science Teaching Efficacy Belief’ (PSTE) and ‘response/outcome expectancy’ or ‘Science Teaching Outcome Expectancy’ (STOE).

Both strands of self-efficacy instruments have been used by researchers to identify features relating effective teaching outcomes and teacher efficacy, as will be discussed in the next section. Numerous efforts have also been made to make these instruments more rigorous, definitive and to narrow the scope of efficacy applicability (Tschannen-Moran et al., 1998). While these attempts have uncovered significant results as to the applications and inter-relationships involved in measuring efficacy, whether or not efficacy is able to be used as an overall general indicator or predictor of teacher behaviour “…has yet to be determined” (ibid:217). Studies have shown that the initial results obtained in the STEBI instruments could indicate where changes as a result of some intervention could be expected (Riggs, 1995; Roberts, Henson, & Tharp, 2001). For example teachers with initially low PSTE and high STOE scores would tend to show increased PSTE scores after an intervention, whereas their STOE would remain relatively stable. However the STOE scale has attracted criticism, as it is trying to
measure outcomes that are controlled by the environment, rather than the teacher themselves, which some argue greatly limits its applicability (Dellinger, Bobbett, Oliver, & Ellet, 2008). Therefore any study of teacher self-efficacy needs to take the context of the beliefs into account in order to maximise the usefulness of the results.

### 2.3.3 Context efficacy

A relationship between teacher efficacy and broader school level variables, such as the school climate and the behaviour of the principal, has been identified (Appleton & Kindt, 2002; Tschannen-Moran et al., 1998). While a positive level of self-efficacy is acknowledged as a necessary starting point for effective teaching, as discussed previously there are many factors which can contribute to the overall efficacy of a teacher and these must be taken into consideration.

Ford (1992 in Lumpe et al., 2000) criticised Bandura’s theory of outcome expectancy, arguing that simply focusing on the connection between a person’s actions and what they perceive the outcome will be is too limiting. Ford proposed the construct of context beliefs and specifically identified three contexts for educational context beliefs; the designed environment (i.e. buildings and physical resources), human environment (i.e. the students and other teachers) and the sociocultural environment (i.e. the policies and cultural norms) (ibid). Researchers have since produced results to support Ford’s construct, showing that a science teachers’ beliefs can be shaped by their environmental context (Lumpe et al., 2000). Other researchers have found that the school environment can also be associated with student outcomes, in particular student attitudes, aspirations and motivation to succeed in science (Pariso, 1991 and Plucker, 1998 in Huang & Fraser, 2009).

Therefore the school environment, and additional context variables, could have a great influence on the performance of students and teachers alike. Beginning teachers especially are likely to be unaware of the influences of the organisational, administrative and interpersonal environments of schools on their own beliefs and practice (O'Connell Rust, 1994). The measurement of beliefs alone limits the amount of information available from which to draw inferences, thus the “context-specific nature of beliefs becomes critical” to the validity and value of the study (Pajares, 1992:327). Some of the factors which constitute the school environment, such as resource adequacy and the priority placed on science within the school, are particularly influential and can
be “agents that overwhelm even the best intentions of beginning science educators” (Lewthwaite, 2001:90).

Bandura (1981 in Enochs & Riggs, 1990) had originally defined self-efficacy as a ‘situation specific’ construct. In response to the growing body of evidence showing the influence of environmental factors and overall context, Bandura (1997 in Lumpe et al., 2000) developed collective school efficacy which provided a broader view of efficacy more in line with Ford’s context beliefs. Chan defines collective teacher efficacy as “…the efficacy beliefs shared among teachers as professionals in a school [which] might be assessed through focusing on the group or on the individuals as members of the group” (2008:1058). The efficacy beliefs of a group of teachers within the same school, if they are shared, could have a profound effect — either positive or negative — on beginning teachers as they enter the teaching profession (Tschannen-Moran et al., 1998). In support of this, Woolfolk Hoy and Burke Spero (2005) found that the changes in self-efficacy beliefs of a first year teacher were related to the level of support that the teacher received from their school environment. Research is yet to comprehensively examine the influence of a school environment on the commitment of a new teacher in their first year (Weiss, 1999) and more studies on the impact of the context on the new science teacher, and vice versa, need to be conducted (Luft, 2007).

2.3.4 Use of self-efficacy as a research tool

Previous sections have detailed how an individual’s experiences can influence their confidence in teaching (and learning) a subject, as well as how they perceive a subject. A teacher may exhibit very high levels of self-efficacy in the teaching of English for example, but low levels of self-efficacy in the teaching of mathematics. Research examining factors that influence beliefs and practice of teachers in order to determine their success, has shown that many of these factors are not universally applicable and that a more consistent predictor of teacher success is self-efficacy (Scharmann & Orth Hampton, 1995). This is supported by Henson, Kogan and Vacha-Haase who acknowledge self-efficacy as one of the “...best documented attributes of effective teachers” (2001:404). Yet it is important to recognise that it is not appropriate to assume that high self-efficacy equates to effective teaching overall (Palmer, 2008).

Teaching self-efficacy has been shown to be strongly linked to learning outcome achievement (Ashton & Webb, 1986; Gibson & Dembo, 1984) and motivation (Midgely, Feldlaufer, & Eccles, 1989; Woolfolk, Rosoff, & Hoy, 1990) of both students
and teachers as well as general teacher enjoyment and persistence (Gibson & Dembo, 1984; Watters & Ginns, 1995). Enhancing self-efficacy is considered key to changing teachers’ practice (pedagogy), but some researchers argue that teachers need to be dissatisfied with some aspect of their teaching outcomes in order for real and lasting reform to occur (Southerland, Sowell, Blanchard, & Granger, 2010). Pedagogical discontentment exists in a balance with self-efficacy. If self-efficacy is too low then a teacher who is dissatisfied with their pedagogy will lack the confidence in their own ability that is needed to attempt a new practice; if self-efficacy is very high and there is no pedagogical discontent (irrespective of how effective their practice really is) then new practices will not be considered (ibid).

Ginns et al. (1995) drew on the work of Enochs and Riggs (1990) in their examination of the effectiveness of pre-service teacher training in science. They state that self-efficacy theory can be used as a predictor of previous science experiences: if pre-service teachers have negative beliefs about science and science teaching, these may have developed as a result of their own experiences of science as a learner. This underpins the later findings of many researchers (Hanuscin et al., 2006; Palmer, 2008; Settlage, 2000; Stevens & Wenner, 1996) as discussed in section 2.2. Ginns et al. (1995) acknowledged that pre-service training and courses in Australia have usually not achieved their desired outcomes — specifically to increase the science teaching self efficacy of the student teachers. They propose that one way of increasing the science teaching efficacy of pre-service teachers would be to include positive science experiences that are relevant.

Previous work by Wenner (2001) compared the self-efficacy beliefs in mathematics and science of pre-service and in-service teachers (both subjects measured in separate studies). Wenner found that experience tended to increase the expressions of personal teaching self-efficacy in both groups, with three exceptions. Pre-service teachers were more likely to report a greater level of confidence in their ability to explain mathematics and science; they were more welcoming of students asking science questions (although they were not confident of being able to provide the answers) and they believed that they would find better ways to teach science in the future. Overall, pre-service teachers almost seemed more optimistic about teaching science, and they were also “more willing to be accountable for student performance than were practicing teachers” (ibid:185). However, Wenner’s work did not extend to how the beliefs of these pre-service teachers changed once they became in-service teachers. For each of these
studies, these beliefs are a snapshot of that particular moment in time, not an indication of any enduring belief system.

In a study examining the durability of self-efficacy, results showed that high levels of self-efficacy were still present in pre-service teachers for a period of 8 – 11 months after an ‘intervention’, which consisted of a science course and teaching practicum (Palmer, 2006a). However, Palmer also notes that it is not unusual for one year to elapse between pre-service teachers finishing their science education subjects and finishing their teaching degree, which could erode any gains in self-efficacy that the science education subjects may have achieved. In an earlier study, Woolfolk Hoy and Burke Spero (2005) found that the self-efficacy of pre-service teachers increased after student teaching practicals but decreased in the first year of teaching proper. Further longitudinal studies are needed to examine this proposition.

As discussed earlier, the transition from pre-service to in-service status is a significant period of evolution for a teacher (Greenwood, 2003), with many teachers often rating their first year of teaching as “...the most demanding and stressful year they have experienced” (Ingvarson, Beavis, & Kleinhenz, 2005:11). Despite the variation of influences on pre-service teachers during this period, Marso and Pigge conclude that its effects are able to be generalised as “...concerns and attitudes toward teaching can change in a predictable way through pre-service training and into the initial years of employment as a teacher” (1989:34). This supports Ashton and Webb’s (1986) theory that teacher self-efficacy beliefs increase over time as teachers gain greater familiarity with their role and how it fits within the overall context of their school environment. Hence the results found within this type of research could be used to inform teacher education initiatives across the primary science spectrum.

There is a considerable body of research detailing changes in teacher self-efficacy, but comparatively little research has been undertaken to examine how these self-efficacy beliefs change at the different stages of a teacher’s career (Chan, 2008; Tschannen-Moran et al., 1998). In particular, studies of beginning teachers are required as this population differs from their pre-service and in-service colleagues. A beginning teacher’s development during this phase is unique in their overall development as a teacher and as a teacher of science (Luft, 2007). Additionally, there is very little research that has been conducted to directly link the process of learning to teach science with self-efficacy belief (Mulholland & Wallace, 2001).
Given the nature of beliefs, particularly those that are long held, it could be assumed that beginning teachers will show greatest variation in their beliefs in the early years of their teaching career, while more experienced teachers are likely to resist any change in their beliefs at all (Chan, 2008; Pajares, 1992; Tschannen-Moran et al., 1998). The influence of context on these beliefs cannot be ignored by researchers, as often the perception of the context in which a teacher operates may shape their belief structure, ultimately influencing their actions and thus the quality of teaching (Lumpe et al., 2000). In an eight month study of a school in New Zealand, Lewthwaite (2004) found that the school environment, and particularly the principal in their role as an instructional leader, influenced the quality and success of science curriculum delivery. For a beginning teacher in particular, an environment that is ‘anti’ science could have a profound influence on their formation of attitudes and ultimately their beliefs about science teaching.

Long term studies that follow pre-service teachers into their teaching careers are required to provide greater understanding about what happens to teachers’ beliefs over time, and how these beliefs can be influenced by external factors such as professional development and the context in which the teachers work (Appleton & Kindt, 2002; Lumpe et al., 2000; So & Watkins, 2005).

2.3.5. The challenges of longitudinal research with teachers

Researchers have consistently identified difficulties in attracting and retaining teachers for research, particularly longitudinal research. In her doctoral research examining the transition students make from pre-service to in-service teachers, Mulholland (1999) conducted a longitudinal study with three beginning teachers, using in-depth narrative and story telling. Lewthwaite (2005) studied a group of 12 teachers over a period of two years in his examination of science curriculum implementation in a school, using repeated surveys and interviews. Roehrig and Luft (2006) examined the different induction experiences of beginning teachers based on the nature of their pre-service training. Their study had a total study population of 16 (four from each program type) and used interviews, surveys and videos of lessons in the analysis. In these instances it could be argued that the richness of data and the longitudinal nature of the research compensated for the small sample sizes.

There is difficulty associated with using beginning teachers for any kind of research, let alone longitudinal studies, as:
...participating in research could be daunting and overwhelming...newly qualified teachers begin a career worried about surviving the first year, which leaves them with little enthusiasm for participating in a research study (Luft, 2007:533).

Watters and Ginns (2000) experienced the same problem in their study which began with a participant cohort of 154 students enrolled in the same Bachelor of Education (Primary) program. Each of these students was undertaking a science methods course as part of their degree. From the initial cohort, due to the logistical difficulties experienced by the researchers in implementing the end of course survey, only 22 students were surveyed. Similarly, Woolfolk Hoy and Burke Spero (2005) conducted a longitudinal study with an initial potential cohort of 53 students, 29 of whom were retained until the conclusion of the study.

Small sample sizes are limiting in terms of the types of data analyses that can be conducted and the generalisation of results. Judson and Lawson (2007) used two high schools to source their participants, leading to a total study sample size of 25 (n1 = 9, n2 = 16). They acknowledged the small sizes limited their ability to generalise from their results, but argued that the use of two different schools “…somewhat increase[d] the likelihood that results can be generalised” (ibid:493). Cantrell, Young and Moore (2003) conducted a study of factors influencing the science teaching efficacy of pre-service teachers. Their study design included three different groups of participants, but when it came to analysis and the ability to discern differences between groups they noted that a limitation of their study was that only twelve participants were in all three groups. To strengthen future results, they recommended the use of a longitudinal cohort study. This is fraught with its own problems as found by Palmer (2006a) who, from a potential sample size of 150, ended up with a useable sample of 55. Therefore any attempts to address these knowledge gaps, along with the existing gaps in knowledge of belief systems of teachers and how they change over time, must also endeavour to obtain results from within a challenging research population.

The use of one-off surveys would allow greater respondent numbers from within a teaching cohort. However a one-off survey would not capture the depth and richness of data that is sorely needed, particularly at the pre-service to beginning teacher phase. For any measure of the durability of self-efficacy or how beliefs change through time, a longitudinal study, with what will probably become a small cohort, must be used.
2.4 Implications arising from the literature

The role of science and science education in society goes beyond the attraction and retention of scientists and engineers. A scientifically literate and engaged society is required in order for Australia, and other countries, to progress in this era of expanding scientific knowledge and rapid technological development. Political powers see science and science education as one key component of the foundation upon which the future Australian economy will be built. Yet this foundation appears to be somewhat shaky due, among other things, to inherent weaknesses in the primary education system.

A teaching workforce that is not scientifically literate, not confident in teaching science and consequently not providing the exposure to science in a relevant, engaging manner has been identified by many researchers over the last decade (Angus et al., 2007; Appleton, 2003; Goodrum et al., 2001; Harris et al., 2005; Hewson et al., 1999b; Stevens and Wenner, 1996). As a result, future generations are not interested in science and the cycle of scientific illiteracy continues on a national, and international, level as identified by the TIMSS study (Martin et al., 2001), Australian Government committee inquiries (Commonwealth of Australia, 2006b) and international studies (Science Alberta Foundation, 2007; Sjøberg & Schreiner, 2005).

As outlined in this chapter, research has determined that teachers’ beliefs influence their practice; therefore any reform initiative employed within schools with the aim of improving the teaching of, and thus student outcomes in, a particular subject will need to be monitored taking the beliefs of the teachers into account. From the body of research into teachers’ beliefs, self-efficacy beliefs have been identified as one of the most consistent characteristics which can be used to evaluate teaching and learning, including predicting teacher behaviour (Gencer & Cakiroglu, 2007; Tschannen-Moran et al., 1998).

Numerous studies have examined the influence of different factors on teacher self-efficacy, such as previous science experiences either in school or elsewhere (Hanuscin et al., 2006), science methods courses during university teacher training (Palmer, 2006a), mentors (Luft, 2007) and continuing professional development (Desimone et al., 2002). While there have been many studies examining the acquisition of self-efficacy beliefs, the other important processes in belief change — generality, durability and resilience (as identified by Bandura, 1997) — are yet to receive the same level of
attention (Palmer, 2006a). This is supported by Chan (2008) who notes that studies of how efficacy beliefs change over the course of a teacher’s career are largely lacking. Beginning teachers in particular are largely an unknown quantity, and a better understanding of their beliefs and professional development process is needed now. The understanding and knowledge generated by such a study would be useful to science teacher educators, professional development specialists and policy makers alike (Luft, 2007). This is a difficult population to research given the existing demands on their time, and the ‘survival’ nature of their first year (Luft, 2007; Watters & Ginns, 2000). The beliefs of pre-, beginning and in-service teachers can all be influenced by the environment of the school in which they work, including the other teachers or perceived level of resources (Lewthwaite, 2001). The ‘collective efficacy’ of the teaching cohort at a school could also greatly influence the beliefs, and ultimately the practice, of beginning teachers (Tschannen-Moran et al., 1998). Therefore any studies examining the beliefs of teachers must also take the school environment into consideration.

2.5 How these implications are addressed in the current project

This research examines the beliefs of teachers transitioning from student to beginning teacher (as suggested by Luft, 2007) as well as the influence of external factors on beliefs (see Lewthwaite, 2001; Lumpe et al., 2000; So and Watkins, 2005). These external factors are also at work on in-service teachers, so an examination of how their school environment, teaching experience, and previous science experience influences their teaching practice also warrants attention. This project contributes to the existing knowledge about teachers’ self-efficacy beliefs and how they may, or may not, be influenced by external factors.

Studies spanning the last three decades have generated a list of factors that need to be addressed in order to rectify the declining interest in science of both teachers and students, yet the more recent research is still identifying the same problems and issues. It is almost as though it is known what has to be done to fix the problem, but the implementation is falling short. This implies that whatever solutions have been applied so far are either not solutions at all, or that there are additional issues limiting the effectiveness of any remedial actions taken. The context in which the factors are operating is still not being appropriately considered or addressed. A multi-faceted problem such as this may require looking beyond the traditional arenas of teacher
education and professional development, and requires a broad research method to adequately capture the interplay of contributing contextual factors.
Chapter 3: Formal and informal education and the role of professional development for teachers

3.0 Different educational environments and their influences

The previous chapter discussed the role of teachers in the creation of a scientifically literate society, and identified the challenges associated with achieving this goal. With declining student interest in science, and the largely ‘science averse’ beliefs of the current and next generation of teachers, the engagement of students in science faces the initial obstacle of getting primary school teachers to actually teach science in the first place. As described previously, studies have indicated that current teacher preparation programs offered in Australian higher education institutions are not creating teachers who are willing to teach science — the teaching of our teachers is falling short. If traditional, formal, means of education are not proving to be effective in addressing this problem, then can other sectors play a part? Could the involvement of institutions in the informal education sector, particularly those solely devoted to science education, be a part of the solution?

The first section of this chapter examines the role and function of professional development, its characteristics and its limitations. Section 3.2 provides an overview of the similarities and differences between the formal and informal education sectors. Section 3.3 looks at the impacts of informal science education, the challenges that exist in measuring these impacts, and in quantifying the effectiveness of informal science education institutions. Section 3.4 outlines the implications arising from the literature in this chapter, leading to a synthesis of the issues and knowledge gaps identified in this and the previous chapter in section 3.5. This final section also outlines the research questions that are examined in this thesis.

3.1 Professional development for teachers

3.1.1 The definition and purpose of professional development

Abell, Lannin, Marra, Elhlert, Cole, Lee, Park, Rogers and Wang define professional development (PD) as “…a term used to describe experiences aimed at improving teacher knowledge and practice” (2007:136). Lieberman’s (1995 in Supovitz & Turner, 2000) definition of PD incorporates the inclusion of opportunities to learn “from and with colleagues inside the school” (p591). Singh and Schifflette argue that PD is a “…dynamic process triggered by the need to improve, self-awareness and efficacy, but
continued and sustained by the efforts of others” (1996:157). Initial teacher training is intended to prepare teachers for the classroom, but continuing PD is important to help teachers gain new skills and confidence and sustain professional practice (Wellcome Trust, 2006).

The provision of professional development for teachers who [need to] teach science is well supported through research in the field. Supovitz and Turner (2000) proposed that superior teaching in classrooms — which will in turn translate in to better levels of student achievement — can be facilitated by the provision of high quality professional development. A study conducted by McRae et al. (2001), found that PD programmes were endeavouring to achieve something for students and not conducted just to meet external requirements. PD provides teachers with the opportunity to improve their knowledge; something particularly relevant to the needs of primary school teachers, many of whom are currently teaching subjects in which they have little to no academic background (Darling-Hammond, 2000).

The influence of teachers’ beliefs and confidence in their ability to teach science, as discussed in the previous chapter, is a key factor in influencing how teachers present science to their students. In a review of factors influencing student outcomes in science, Murphy, Beggs, Russell and Melton (2005) found that the most important factor influencing teacher confidence was that of their experience of professional development in science. Those who had participated in continuing PD in science were more confident in almost all aspects of science teaching, including the use of practical work and ensuring student engagement and understanding. This is supported by the Australian Science Teaching Association (2005) who argues that the quality of science teachers is heavily reliant on the provision of professional development that is targeted to the needs of the teachers and produces quantifiable gains in teacher performance. If teachers are better equipped with the necessary skills, knowledge and confidence to teach science, then logically this should also translate to better outcomes for students (Supovitz & Turner, 2000). This is further supported in the United Kingdom, where teachers identified teacher training as the top priority to address in order to realise a higher quality of science education (Hopkin & Sharp, 2008).

Professional development of a good quality is crucial to improving teacher confidence, and thus student performance in science. Yet, like belief systems, PD outcomes can be influenced by more than simply the individuals involved.
3.1.2 External influences on professional development effectiveness

The influence of the school environment, and the administrative and policy directions within which the school operates, can greatly impact on the effectiveness of any provided PD (Supovitz & Turner, 2000). Long standing research findings indicate that the school context is very important, to the extent that the “…pre-existing level of support for professional development in a school has a significant indirect effect on the outcomes of the programs” (Ingvarson et al., 2005:17). Singh and Schifflette (1996) propose that the interactions teachers have with their peers and other staff, such as school administrators, can not only influence the PD but can also be used as opportunities by the participating teachers for further learning and experimentation with new ideas. These theoretical interrelationships have been described graphically by Supovitz and Turner (2000:965) and are shown in Figure 1.

Figure 1: Model depicting theoretical relationship between professional development and student achievement (after Supovitz & Turner, 2000:965)

The science curriculum is particularly driven by external societal influences such as the rapid advancement of technology, the use of information and communications technology in the learning environment, and the social and ethical considerations that many of these emerging and evolving fields of science raise (Wellcome Trust, 2006). Schools and teachers are expected to maintain pace with these changes and promote and encourage the appropriate skills and abilities in their students accordingly (Pint'o, 2004). Therefore, to effectively apply Supovitz and Turner’s model to science teaching and PD, an additional external interrelationship is needed, which is that of societal influence based on technological progression (see Figure 2).
Figure 2: Expanded model depicting theoretical relationship between professional development and student achievement (after Supovitz & Turner, 2000:965)

PD for science educators, particularly primary school teachers, is in high demand. A study by Darling-Hammond (2000) found that of 5,803 primary teachers in the United States of America, 27.5% wanted more PD in science. Australian teachers want more PD to be offered on a sequential or ongoing basis, irrespective of topic (McRae et al., 2001). To be effective however, the PD must be targeted to the needs of teachers; both in terms of helping teachers keep abreast of the rapidly emerging new fields in science, such as nanotechnology and biotechnology, as well as producing tangible improvements to a teacher’s performance (ASTA, 2005; Wellcome Trust, 2006).

Irrespective of the importance of the external environments, it is the teachers themselves who have been shown to have the biggest impact on student achievement (Darling-Hammond, 2000; Department of Education Science and Training, 2000; Desimone et al., 2002; Rowe, 2003). In their review of research examining alternate sources and rationale for student achievement, Hawley and Rosenholtz concluded that:

In virtually every instance in which researchers have examined the factors that account for student performance, teachers prove to have a greater impact than program. This is true for average students and exceptional students, for normal classrooms and special classrooms (1984:3 in Supovitz & Turner, 2000).

Supovitz and Turner (2000) argue that clear linkages between professional development, the background of the teacher and environmental factors should be addressed by future research. They particularly advocate the use of long term studies,
examination of collective self-efficacy beliefs of participants and the influence of any ‘interventions’ on the outcome expectancy beliefs of participants. The current project addresses many of their suggested research areas.

3.1.3 The argument for ongoing professional development

As discussed in the previous chapter, teachers’ beliefs and attitudes about science play critical roles in how teachers approach the teaching of science. Ongoing professional learning opportunities for teachers are necessary to ensure the development and maintenance of an “effective teaching cadre” (Singh & Shifflette, 1996:145). In particular, continuing PD in science for primary teachers “…is probably the most important factor in bringing about improvements in primary science learning and teaching” (Wellcome Trust, 2006:16).

Continuing PD is just as important for beginning teachers, as it is during these early years of teaching that their beliefs about their abilities, and the subjects they teach, are the most malleable (Pajares, 1992). Generally the science experiences of beginning teachers are limited; usually a one semester methods course and infrequent science content subjects, which, when combined with student teaching, the experiences “…frequently…cancel each other out” (Yager, 2005:99). Continued exposure to science, and ways of effectively teaching science in the classroom, could be vital to improving the science teaching abilities of beginning teachers. Continuing PD is one means of achieving this. This is supported by the Wellcome Trust which, in a study of teachers’ perceptions of continuing PD, found “…clear evidence that teachers who had undertaken science professional development work were more confident to teach science” (2006:14).

PD that provides focus on content, provides opportunities for ‘hands-on’ work and is integrated into the day to day business of the school is “…more likely to produce enhanced knowledge and skills” (Garet, Porter, Desimone, Birman, & Yoon, 2001:9). This is supported by Tytler who, in a review of teacher professional learning intended to support a science curriculum initiative in Australian schools, concluded that any teacher support would need to allow for “resource development, and…local control and contextual variation” (2007:62). In order to achieve this, PD cannot simply rely on the dissemination of content; it must also allow teachers to experience science as learners themselves.
There are some who argue that PD, in its current formats, is ineffective. Tytler contends that in order for any truly successful reform in science education to occur, teachers need to form “…a new set of beliefs about the nature and purposes of science education. Also required is a new set of teaching and learning skills…These are significant changes, beyond the reach of simple content delivery models of professional development” (2007:60). Kahle and Boone (2000) similarly state that PD workshops used in isolation (particularly the short term, after school variety) offer “little potential to initiate and sustain the change required for professional growth in science education” (p104). This is further upheld by Tytler et al. who found that the typically short term nature of any intervention (PD or otherwise) in primary schools means that any gains or reforms tend to be lost once the intervention “…has run its course and other priorities take over” (2008:62).

As will be discussed in greater detail in a later section, a large study examining the nature of PD offered in Australia identified the one-off type of PD as the predominant form (McRae et al., 2001). Presumably, this could have been due to the time constraints faced by teachers and the difficulty associated with attracting and retaining participants to longer term PD. This is also a consideration for external PD providers for whom ongoing PD represents an ongoing cost, hence small numbers of participants would not make this an economically viable option.

Continuing, long term PD is largely considered beneficial and a necessary component of successful PD. Authors such as Tytler assert that “there is thus almost universal agreement amongst science education researchers that long term professional development…is necessary to support significant teacher development” (2007:190). However in measuring the effectiveness of PD based on student performance, Kennedy (1998 cited in Supovitz & Turner, 2000) found that there was little relationship between student performance in science and the duration of PD undertaken by the teacher. Desimone et al. (2002) also did not find any statistically significant effects for the duration of PD undertaken. It could be that ongoing PD is the more effective model for most subjects; it is merely science that is problematic for teachers, irrespective of the duration of PD undertaken. This is verified by Hilliard (1997) and Loucks-Horsley (1996 in Hartshorne, 2005) who found that results of PD in primary science did not show the same levels of success as those attained in other subject areas. In contrast, Perera (2010) found that science workshops based on constructivist principles, of one day in duration, were capable of facilitating teachers’ conceptual change. This indicates
that the use of constructivist principles in professional development warrants closer examination.

3.1.4 Barriers and opportunities for professional development as an agent of reform

Teachers themselves can also be sceptical of the success of any PD initiative. Darby (2008) states that veteran teachers, who have seen numerous reforms come and go, tend to wait for a new reform to pass; they don’t even attempt to modify their teaching practice until they can be certain that the new reform was going to stay. This corroborates findings of an earlier study by Hudson and Skamp (2002) who attest that reform in Australian primary science education to date has not been successful due to the tendency of many primary teachers to not change their teaching practice. Hudson and Hudson (2006a) provide further insight, identifying the sheer number of educational reforms that have come and gone, which have helped to make many teachers and schools resistant to change. Why implement any new reform when it will not result in an enduring change? Additionally, teachers take pride in developing their own programs, and asking them to change their methods, in effect telling them what they are doing is incorrect, can be demoralising (Wagner, 2001) and increase resistance to reform.

The beliefs of teachers about teaching must be taken into consideration as well (Lumpe et al., 2000). It is the teachers in schools who must enact any reform change, and this is often a labour intensive process requiring curriculum revision and adopting new methods of assessment. The role of the teacher, and their beliefs, must be acknowledged in any reform if enduring changes are to be achieved (ibid).

Hudson and Skamp (2002) advocate the education of pre-service teachers as being a necessary part of primary science reform. PD alone cannot influence the practice of a pre-service or beginning teacher. Interactions with students in the classroom setting is “the most powerful source of information in knowledge acquisition of pre-service teachers” (Jones & Vesilund, 1996 in Reitano, 2004:3). Therefore any PD will lack any real impact or meaning until pre-service teachers see how it works in the classroom. The beliefs of these pre-service teachers about teaching will also influence their practice (Schwarz & Gwekwerere, 2006), which again will limit the success of any reform initiative unless these beliefs are acknowledged and addressed. This is endorsed by
Howitt who states that “learning to teach science is a process of re-evaluating and re-forming existing ideas, beliefs and values” (2007:44).

Where PD can arguably have a great impact is on the development of a pre-service teacher’s skills, specifically by influencing what these new teachers consider ‘safe’. Appleton and Kindt (2002) propose that if a new teacher’s experience with science is largely limited to books and recitation of facts, then this is familiar and therefore safe. If their experience with science is centred around hands-on activities and developing new understandings — as well as seeing children develop new understandings — via those activities then this kind of science teaching will seem ‘safe’ and thus the default approach to science in the classroom.

Other factors such as the school environment and the support of other teachers will naturally influence the development of these teachers as well. But if science can largely be experienced as something interactive and enjoyable, rather than something to be feared, this can only have a positive impact. This is upheld by Preston et al. who believe that “graduate teachers entering the profession with effective science pedagogy and positive attitudes should translate into enhanced teaching and learning of science in primary schools” (2007:32). Posnanski (2002) states that there is a need to identify the connections that exist between PD interventions, teacher background and external, environmental factors. He proposes that further study in this area could include collection and analysis of longitudinal data and research on the collective self-efficacy of teachers participating in PD (ibid). The current project uses Posnanski’s suggested research areas to examine the impacts of PD on both pre-service and in-service teachers in an attempt to contribute to the development of successful reform strategies in primary science teaching.

There are many demands placed on schools and teachers, driven and shaped by the changing values and patterns of society (Pint'o, 2004). PD is often hailed as the answer to the educational priorities of schools. However, the effects of PD on teachers, students and/or schools is often not, and occasionally never, apparent (McRae et al., 2001). This is possibly another reason why there are many detractors of PD. Despite the debate surrounding the effectiveness of PD for teachers, “…it is still seen as the best bet for changing teaching practices, because alternative methods…have fared no better” (Smylie, 1996 in Supovitz & Turner, 2000).
3.1.5 Characteristics of professional development

According to Gardner there is not one single method which embodies effective teaching so “teachers must pursue a variety of models…” (1993:208). Similarly, there is not one particular model of PD that is effective in all contexts. It may be unreasonable to assume that “…broadbrush policies and guidelines for effective professional development will ever emerge” (Guskey, 2003:749). The complexity of the characteristics, such as the school environment and prevailing organisational or individual attitude towards PD, influence PD effectiveness and prevent prescriptive models from being developed (ibid). A ‘one size fits all’ PD is not a realistic solution, or expectation (Johnson & Marx, 2009).

There is an emerging consensus in the profession about the characteristics of ‘high quality’ PD which includes active learning opportunities (hands-on/constructivist approach), PD of an extended duration, and the collective participation of teachers from the same school or grade (Desimone et al., 2002). Despite the regular identification of these characteristics in the literature, the extent of the importance and impact of these characteristics on teacher performance and student achievement is relatively uncharted (ibid). In particular, studies extolling the virtue of constructivist teaching approaches tend to be descriptive rather than empirical; more empirical work needs to be done to support the claims of constructivist pedagogy (Carter & Wheldall, 2008).

Hawley and Valli (1999) proposed design principles for effective professional development. Effective PD must include involving the teachers as learners; running the PD as a school based activity; and as part of a comprehensive change process. The PD must be collaborative, information rich and provide opportunities for the teachers to develop a theoretical understanding of the knowledge and skills to be used. The PD must also be driven by the goals and standards for student learning and performance. Finally the PD must be continuous and supported, including follow up and support from outside of the school. Despite producing this comprehensive list, Hawley and Valli conclude that “…few of these principles are common to professional development programs in schools…and the cases where most, much less all, of the principles are being implemented simultaneously are rare indeed” (1999:45).

The Inservice Teacher Education Project Committee (1988) outlined similar principles of good practice for PD in Australia over a decade earlier. They had a greater focus on collaboration, not only between the teachers undertaking the PD but also between the
stakeholders of the PD, including collaborative leadership and support from the school principals. This reinforces the importance of the school environment to the effectiveness of any PD intervention.

Louden (1994) provides an overview of best practice in PD, from the actual planning through to implementation and application. During the planning stage Louden advocates bringing together teams of classroom teachers, and teachers who will be committed participants. The program must be flexible enough to accommodate the needs of individual teachers and must be relevant to the needs and interests of the teachers. The PD must be facilitated by a knowledgeable leader, have user-friendly resources, school executive support, and the involvement of teachers drawn from both a similar and diverse range of settings. The PD must also be run in comfortable surroundings. The PD should provide opportunities for active engagement, make optimal use of the time available, model exemplary practice, and use a variety of presentation styles. Finally, the PD should reward teachers in some way for being involved, create feelings of excitement or empowerment, and involve planned follow up. This is not an exhaustive account of all components in Louden’s list, but a snapshot of what was identified as best practice.

McRae et al. (2001) note that many of the ideas in this list are consistently recurring throughout the literature; a sentiment that is echoed by Banilower, Heck and Weiss (2007). They state that while there does appear to be an “emerging consensus as to the elements of effective professional development based on the wisdom of practice, empirical evidence to support these ideas is scarce” (ibid:390). Rightfully, they suggest that future research needs to investigate the most effective PD approaches, taking into account the contextual factors and influences.

In many ways, the list of characteristics of effective PD appears to be founded upon common sense; almost to the point of being intuitive. If this was the case, if it does appear to be that simple, then why does effective PD still seem to be eluding the teaching profession? As summarised by Elmore and Burney “…while we know a good deal about the characteristics of good professional development, we know a good deal less about how to organise successful professional development so as to influence practice…” (1997:2 in McRae et al., 2001).
3.1.6 Models of professional development delivery

Sparks and Loucks-Horsley (1989 in Peixotto & Palmer, 1994) described five models of PD for teachers, which are summarised in Table 2. The training model, which is typically characterised as short term is the most used model of the five, with Peixotto and Palmer referring to it as “greatly overused [although] remains valid when used appropriately and integrated with a variety of other approaches” (1994:365). In a review of the nature of PD conducted in Australia, McRae et al. (2001) found that the main formats of PD were workshops or seminar discussions and attending conferences. These align with Sparks and Loucks-Horsley’s training and individually guided models respectively. One-off workshops were the most commonly cited form of PD, supporting Peixotto and Palmer’s ‘overused’ standpoint of the training model.

Table 2: Five models of staff development for teachers (Peixotto and Palmer, 1994) after Sparks and Loucks-Horsley (1989)

<table>
<thead>
<tr>
<th>Model</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individually guided models</td>
<td>Teacher identifies a need and tries to address this need through a variety of formal and informal procedures. Examples include reading articles in professional journals, talking with colleagues or undertaking a course.</td>
</tr>
<tr>
<td>Observation/assessment model</td>
<td>Characterised by feedback from supervisors, peers and others. Teachers can self assess but greatest benefit achieved when outside observations are used i.e. asking a colleague to observe a lesson and provide feedback.</td>
</tr>
<tr>
<td>Involvement in a development/improvement process</td>
<td>Teachers working with others will acquire skills and improved abilities by their participation. For example a group of teachers developing performance assessments for a subject.</td>
</tr>
<tr>
<td>Training</td>
<td>Workshops or institutes specifically designed to develop teachers’ knowledge and skills. Typically short term and focus on one area such as improved design of scoring criteria for assessment. The most extensively used model.</td>
</tr>
<tr>
<td>Inquiry</td>
<td>Teachers working individually or in groups and becoming involved in active research. Teachers identify a problem and conduct the research through to drawing conclusions and making recommendations.</td>
</tr>
</tbody>
</table>
McRae et al. found that PD offerings were predominantly one-off and occasionally followed up (2001). One-off workshops tend to be offered by external organisations, such as specialists in a particular area (e.g. science, music or health) or the state or territory Department of Education providing PD on new processes for assessment or curriculum change. Despite being the predominant mode of PD delivery, the one-off model is often criticised for being exactly that — one-off. Teachers feel that one-off activities have less impact and that more could be achieved with PD activities that are sequential or ongoing (ibid).

Hoban (1997) identifies three different models of PD which are founded upon knowledge about teaching: the outside-in, inside-in and inside/outside models. The outside-in model utilises outside experts and resources that teachers can use in their own practice. Hoban identifies several strengths of this model. It can provide new ideas which may be beyond a teacher’s experiences; it is efficient in delivery — teachers can gather in the one spot and receive all the necessary information in a short time; and this style of PD can also provide positive reinforcement of teachers’ existing practice and beliefs. The weaknesses associated with this type of model are the limited opportunities for follow up as well as the external, possibly negative, influences of the school context which are not taken into consideration in this model of PD delivery (ibid).

Inside-in models of PD require reflective practice by the teacher, the strengths of which include teachers taking responsibility for their own learning, and valuing the knowledge they have acquired within their own context (ibid). The same factors which provide the strengths of this model also provide the limitations. Teachers “…interpret their experiences based on the way they already frame their practice. This is more likely to occur if teachers work in isolation and do not collaborate with other teachers to provide them with alternative perspectives” (ibid: 10).

Hoban’s final model of PD is the inside/outside model. This combines characteristics of the two models discussed previously. The teachers can draw upon their own ideas and experiences as well as those of others to allow alternative perspectives, creating a community of learners who can discuss ideas and practice. The strength of this model is that it allows collaboration between practitioners, which can also lead to long term involvement of all participants, thereby providing PD that is regular and ongoing. The time and effort required to establish such a practice is a limitation of this model (ibid). In an already time poor profession, very few teachers would be able (or perhaps willing) to commit so much time to such an exercise. Yet the strength of collaboration and
sharing by teachers is echoed by many other authors (see for example Penlington, 2007; Sato et al., 2008).

Davis (2003) proposes that teacher educators should view PD through a knowledge integration perspective. That is, “…science teacher educators first need to identify…teachers’ foundational ideas about teaching and science, and then promote knowledge integration processes including adding, linking, distinguishing and reconciling ideas” (ibid:42). The process of adding ideas is influenced by working with other teachers. Multiple perspectives can help create clarity that may not have been present before. Teacher interactions, collaborative efforts and their influence in PD has become an increasing focus in education research.

A recent survey found that primary science teachers in New South Wales, Australia, have strong preferences for the type, delivery and content of the PD they receive (Aubusson et al., 2010). The teachers surveyed voted overwhelmingly (93% of 173 respondents) for collaborative, school based PD. They consistently identified the inclusion of practical activities and preferred that the PD was delivered by an expert. The remainder of this chapter will discuss collective and collaborative PD, with section 3.2 introducing a possible source of science ‘experts’.

3.1.7 Collective professional development

In a review of different PD structures, Penlington (2008) found that teachers engaging in dialogue with each other is a core component of many professional learning models. Penlington proposes that dialogues that occur within groups that have an “established rapport and trust” (2008:1314) and occur over time, are likely to be more effective and productive than discussions occurring between different teachers on an ad hoc basis, where the same level of trust does not exist. Therefore, it could be surmised that continuing PD offered to the same cohort of teachers within a school setting over time could prove more effective than simply offering PD to teachers from a group of schools who are unfamiliar with each other.

Additional studies support Penlington, and outline the benefits of such ‘collective participation’ as including the opportunity for the participants to discuss the PD experiences outside of the actual PD itself, provide support and encouragement to each other, as well as the likelihood that they have shared resources, curriculum and assessment requirements (Garet et al., 2001; Sato et al., 2008). Teachers within the same school may also teach the same students, so students’ needs can be discussed
across grades and classes. The final advantage of collective PD is that of its potential to enact, and sustain, change over time. Even as some teachers leave, or new ones join, a faculty, there will be members from the original PD cohort who remain and can thus sustain the practice.

The benefits of collective PD also applies to beginning teachers with Watson, Steele, Vozzo and Aubusson finding “…interactions with colleagues and the school community [to be] a significant feature of the transition to science teaching…that facilitated ‘learning on the job’” (2007:149). This supports the earlier findings of Appleton and Kindt (2002) who observed collegial interaction to be an important influence on the establishment of teaching practices, including science. They also found that for the ongoing PD of some teachers, these interactions with colleagues sustained their importance. So and Watkins (2005) identified a lack of sharing and discourse between teaching colleagues as a barrier for beginning teachers. Participants in their study lamented the lack of discussion about teaching approaches which inhibited their ability to develop more student oriented teaching skills. So and Watkins proposed the use of mentors in the early years of teaching as a potential means of addressing this shortfall.

A mentoring teacher can be a powerful influence, positive or negative, and their beliefs and teaching styles “…can significantly influence the direction of a prospective teachers’ development” (Hewson et al., 1999b:381). A shared experience in collective PD could either enhance a positive, or mitigate a negative influence of mentoring teachers.

Collective participation in PD can develop a “shared professional culture” (Hewson, Tabachnick, Zeichner, Blomker, Meyer, Lemberger, Marion, Hyun-Ju Park, & Toolin, 1999a:254) which Cochran-Smith and Lytle (2001 in Penlington, 2008) contend should be a focus in order for PD to be effective, rather than the traditional aim of skills transmission. This is supported by Judson and Lawson who state that “this type of collective gathering around a particular area of professional interest gives members a sense of identity…which will actually mediate a teacher’s response to reform efforts” (2007:491). At the time of writing their report, Garet et al. had found “little research…available on the effects of collective approaches to professional development, but there is some evidence that it can be effective in changing teacher practice” (2001:8). Similar gaps and potential have been identified in the knowledge about beginning teachers with Bianchini and Cavazos stating that “…more research is needed
to understand how interactions among preservice teachers within a professional community influence the learning process” (2007:606).

Formal education institutions are not the only source of knowledge and expertise (Rudd, Sutch, & Facer, 2006). From the literature discussed it appears that PD which uses resources external to the school environment, as well as communities of teachers themselves, could be one means of enhancing the effectiveness of PD. Potential external providers of ideas and resources identified through the literature are informal science education institutions, such as science centres and museums (Lawrance & Palmer, 2003), particularly given their focus on the provision of hands-on experiences (Melber & Cox-Peterson, 2005).

3.2 Formal versus informal education

3.2.1 The differences (and similarities) between formal and informal education

Before discussing how informal science education providers can contribute to the professional development of teachers, it is necessary to define the difference between formal and informal learning. Dierking, Falk, Rennie, Anderson and Ellenbogen (2003) define informal learning as that which occurs outside the realm of formal learning, traditionally in schools. Crane (1994 in Kelly, 2000) defines an informal learning environment as “any setting outside the traditional classroom that provides opportunities for interaction and exploration yet does not mandate learner participation” (p763). Types of informal learning sources include science centres, museums, zoos and aquariums, books, television or the Internet. There is growing recognition of the important role these can play in supporting the learning of science, technology, engineering and mathematics which are typically considered part of the formal learning remit (Falk, Randol, & Dierking, 2008). From these definitions it can be surmised that it is the setting, rather than the process, which creates the distinction between the ‘formal’ and ‘informal’.

A Staff Work Paper by the Commission of the European Communities defines formal learning as “[taking] place in education and training institutions, leading to recognised diplomas and qualifications” (2001 in Briede & Peks, 2005:15). The paper then incorporates a definition often missing in other research, distinguishing between non-formal learning and informal learning. Non-formal learning “takes place alongside the mainstream systems of education and training and does not typically lead to formalised certificates” (ibid:15). The paper defines informal learning as an innate supplement to
day to day living, with the key difference between it, formal and non-formal as any learning that occurs is not necessarily intentional “…and so may well not be recognised even by individuals themselves as contributing to their knowledge and skills” (ibid:15). Briede and Peks (2005) consider both informal and non-formal education to have even greater influence on the development of competence than formal education.

Harington (2001) provides a summary of the characteristics of formal and informal science learning. Where formal learning is compulsory, assessed, teacher led, curriculum centred with tightly structured outcomes, informal learning is almost the polar opposite with learner led and centred, unstructured, unassessed social activity giving rise to unintended and often unmeasurable outcomes. McManus (1992) succinctly states that, in every sense, informal education is entirely free choice. Semper (1990) argues that the natural curiosity of children is reduced by the formal education system and Bresler (1991 in Harington, 2001) proposes that the very foundation of science education — curiosity — is best developed via informal education. Thus it could be inferred that for effective science education, both formal and informal learning are necessary.

The Jenkins report identifies the aims of formal science education as “…to prepare the most talented pupils [at science subjects] for science at university and beyond; and to develop ‘‘scientific literacy’…for all pupils” (British Association for the Advancement of Science, 2005 in Science Alberta Foundation, 2007:19). It is possible that informal science education can work to achieve these aims, while it “also attempts to bring real-world science to the general public…and has as one of its key aims increasing interest and excitement about science in general” (Science Alberta Foundation, 2007:19). This is confirmed by McClafferty (unpublished 1999 in Harington, 2001) who, in defining the characteristics of contemporary science and technology centres, found that learning, play and exploration with the aim of popularising science were the foundations of the mission statements of all of these centres.

Falk and Dierking (2000) developed a Contextual Model of Learning which describes free choice (informal) learning as being influenced within three interrelated contexts: personal, sociocultural, and physical. Personal context factors consist of the individual’s motivation and expectations, both of which affect what an individual does and learns within an informal learning environment. Their interest influences what they choose to interact with, and their prior knowledge and experiences affect what meaning and
knowledge they take away from an experience. In informal learning environments, an individual has free choice and control over what they learn, how and with whom.

Falk and Dierking (2000) define sociocultural factors as referring to the different groups and the nature of the culture and society within which free choice learning is taking place. As well as being influenced by one’s own peers and family, the learning of an individual can also be affected by someone external to these groups, but who is perceived to be a knowledgeable source, such as a teacher or facilitator. The physical context refers to the advance preparation of the learner; for example, knowing what to expect, where to go, and the general ‘administration’ of a visit. The setting in which the learning is to take place is also important, the design and architecture contributes to the comfort levels of the learner. If a learner feels comfortable within the environment and feels confident in their ability to navigate that environment, then their learning outcomes are enhanced (Falk & Storksdieck, 2005). Finally, any “…experiences occurring after the visit frequently play an important role in determining, in the long term, what is actually “learned” in the [informal setting]” (ibid:746).

Wellington (1990 in Science Alberta Foundation, 2007) adopted a slightly different approach to that of Falk and Dierking (2000), stating that informal science education works within three domains, namely: affective, cognitive, and psychomotor, and claims that “the affective area is much neglected in traditional, formal science and education” (in Science Alberta Foundation, 2007:19). Therefore it is possible that the programs delivered by informal science education institutions may affect or engage with students in a different way than a traditional science lesson in a classroom setting.

A survey conducted on the role of informal science institutions in the United States of America found that “informal science institutions do indeed provide infrastructure for science education, contributing in significant ways to the teaching of science in the nation’s schools” (Inverness Research Associates, 1996:18). This is confirmed by Melber and Abraham (1999 in Scottish Science Advisory Committee, 2003) who also suggest that the combination of the formal and informal approaches to education would yield the most effective science education program. This is further endorsed in a national strategy document designed to engage Australians in science (Commonwealth of Australia, 2010). The current study examines how informal learning institutions can contribute to the formal education sector, using science centres as an example.

Science centres (as well as other centres of informal learning) have been generally acknowledged in the research literature as playing a vital role in improving student
outcomes in science (Anderson, Lucas, Ginns, & Dierking, 2000), and even influencing academic career choices (Salmi, 1998). Less is known about “precisely what mechanisms are involved in successful science centre learning, and what it is about these experiences that my be contributing to such gains” (DeWitt & Hohenstein, 2010:454), however our understanding of these processes and outcomes has improved greatly over the last few decades (Stocklmayer et al., 2010). What still remains relatively unknown is the role and effectiveness these institutions can play in teacher education (Palmer, 2008). This echoes an earlier call for more research in this arena by Lawrance and Palmer (2003) who advocate an examination of the usefulness of informal institutions and the impact of these experiences in teacher education programs. Martin reiterates this stance, stating that “thinking at the interface between two learning systems, where museums and schools may want to work together, has not yet been captured” (2004:S76). The current study explores the potential for science centre involvement in teacher education, both for pre-service and in-service teachers.

### 3.2.2 Defining science centres and ‘hands-on’.

A science centre is broadly defined as:

…any institution providing access to the public for the purpose of popularising science and using an exhibition as at least one of its tools…Science centres aim to explain science and technology to non-experts. They typically use interactive exhibits, involving their visitors in active experimentation… (Persson, 2000a:10)

Smith (1997) describes informal education as being driven by conversation, actively engaging participants through exploration and taking place in any setting. Of these factors, the most pertinent is that of the active engagement of the participants. Many science centres have adopted a ‘hands-on’ approach, where the majority of objects and articles on display can be touched, manipulated and explored. It is this process of exploration that provides science centre visitors with the opportunity to direct their own learning experience. By actively engaging with scientific concepts, objects and phenomena, participants are able to make connections between the theory and the real world application of science.

Hands-on is defined by Kelly as:

…investigative experiences that include more than mere concept verification.

Hands-on is the embodiment of inquiry in which learners utilise their
explorations and manipulations to formulate new ideas and concepts and perhaps develop and initiate their own investigations (2000:758).

The term hands-on is often used interchangeably with ‘interactive’, which is not necessarily correct. As defined by Rennie and McClafferty (1996) hands-on requires physical involvement by a user, whereas interactive activities are those which respond to input from a user and require some further user response. The crucial differentiation between the two is that interactive infers some two way response between activity or exhibit and the user. In comparison, hands-on “…does not necessarily mean ‘minds-on’…but this does not mean that the hands-on aspect is not important” (ibid:58).

Hands-on activities are an important component of constructivist theory of education. By engaging in hands-on enquiry, teachers are constructing ideas and knowledge through personal experience with the subject and are active participants in the learning process (So & Watkins, 2005). Constructivist based professional development allows teachers to “learn about science and science teaching with the same methods and strategies as students should learn science in schools” (Posnanski, 2002:190). Constructivist PD could provide a model of how science should be taught using an inquiry oriented manner, reclaiming the crucial aspects of investigation and experimentation that typify how science should be experienced, which have been lost to text books and recitation of facts (Greene, 2008). What must be avoided however, is teachers believing that the provision of hands-on activities in isolation from the development of scientific inquiry skills or content knowledge, is enough to constitute effective learning for the students (Talanquer, Novodvorsky, & Tomanek, 2009).

‘Hands-on’ approaches to science are important sources of self-efficacy, particularly for beginning teachers (Palmer, 2006b). Science methods courses that used hands-on activities in pre-service teacher education were found to positively affect and enhance student teachers’ self-efficacy (Schoon & Boone, 1998; Watters & Ginns, 2000) as they provide an opportunity for the student teacher to have a successful experience in understanding scientific concepts using everyday materials. This could then be translated to a successful experience in teaching science to a child. Both of these situations provide an important mastery experience, as defined by Bandura (1977) and discussed in Chapter 2, which is one of the most powerful sources of self-efficacy for teachers (Woolfolk Hoy & Burke Spero, 2005). Nye and Thigpin assert that “direct and concrete experiences where the learner applies what is being learned are essential

This active learning approach has been found to enhance the effectiveness of professional development activities with in-service teachers as well (Desimone et al., 2002; Garet et al., 2001). This is supported by the findings of Perera (2010) who observed groups of teachers becoming empowered by the hands-on process to the point of experimenting with the prescribed activities and developing their own demonstrations. In essence “the teachers became confident enough to play around with the science” (in Wetheral, 2008:4). This typifies the position of Hawkins (1965 in Rennie & Williams, 2000) who identifies play, or unguided exploration, as the beginning of real learning.

3.2.3 Hands-on science: education or simply entertainment?

In a study of characteristics that pre-service teachers use to define a good primary science teacher, Skamp found that one of the most common perceptions among his participants was that a “good science and technology teacher [uses] ‘experiments’ and not just telling and writing” (1995:406). Additionally, they make science fun (ibid). One of the key strengths of science centres is their ability to make science fun, relevant and engaging for visitors. Indeed, detractors of science centres criticise them for being too entertaining at the expense of education (Rennie & Williams, 2002) with some accusing science centres of trivialising the learning of science by focussing instead on visitor entertainment and enjoyment (Rennie & McClafferty, 1996).

Solomon and Thomas take a rather extraordinary position by considering hands-on science in general to be in the same realm as “science magic shows…designed to amuse and enhance the public’s enjoyment of science, although these are undoubtedly important for making science knowledge seem more accessible and fun for children” (Solomon & Thomas, 1999:62). They contradict themselves later in their paper however by stating that “at all levels of learning, motivation and arousing curiosity appear more important than the science content…This provides an effective foundation for a continuing lifelong interest in science” (ibid:85). Surely if children find science accessible and fun they would be motivated to engage with it more? In which case, could it not be argued that hands-on science could actually be a facilitator of motivating students to engage with science, to become scientifically literate, or even potentially pursue a career based on their interest, rather than an impediment to science learning?
Howard Gardner supports this viewpoint, stating that “…schools have become increasingly anachronistic, while museums have retained the potential to engage students, to teach them, to stimulate their understanding, and most important, to help them assume responsibility for their own future learning” (1993:199). The practices used by informal science education providers are capable of fostering an individual’s continued interest in science, and as such these informal education practices should be employed to guide science education reform (Perera, 2010).

Solomon and Thomas’ opinions are in stark disagreement with the other literature in the field. Bredderman (1982 in Haury & Rillero, 1994) conducted a review of research on hands-on science programs that spanned 15 years, involving more than 57 studies, 13,000 students and 1,000 classrooms. In comparisons between hands-on classrooms against those who were textbook or traditional (i.e. hands off), students in hands-on classrooms exhibited significantly higher science process skills, and increased learning and achievement in science content.

Aside from improving science process skills, hands-on science providers, such as science centres, can achieve attitudinal change towards science in their visitors (ecsite UK, 2008a), including increased student enthusiasm for the subject (Tytler et al., 2008). This is reinforced in Stocklmayer et al. who state that from both sustained and some short interventions from informal science education providers, there is evidence that “…informal experiences can radically influence a student’s interest in science” (2010:27). Beyond the impact on student attitudes, science centres can be useful vehicles for enhancing public engagement with science (Persson, 1999). The House of Lords in the UK in 2000 endorsed “…science centres as a principal influence on the relationship between science and society” (Rennie & Williams, 2002:708). Increased public engagement with science could also ultimately boost scientific literacy (Miller, 2002).

3.2.4 Informal and formal education partnerships

One of the ways by which science centres achieve enhanced public engagement with science is by forming partnerships and linkages between the community and the science sector. These partnerships can yield a range of activities and initiatives including exhibitions, touring education programs and public events such as talks, debates and themed weekends.
These partnerships and ‘bridges’ are an integral part of science centres’ and museums’ operations and mandate. The impacts from such partnerships can go beyond simply creating public awareness — they can be effectively used in the formal education sector. For example, science centres can provide schools with access to specialists and resources they may not already have (Finkelstein, 2005), particularly in regional, rural and remote areas. This could take the form of scientists working with teachers, students, or both, in the classroom and providing a tangible experience for the students as to what a scientist does and the kind of career opportunities available. In the National Action Plan for science education in Australia the authors claim that:

…effective science education will bring school science and the out-of-school science community much closer together. This is a powerful way to enhance science learning because it shows students that science has demonstrable relevance and value to them…and to use science in their life outside school (Goodrum & Rennie, 2007:28).

The importance of these partnerships was highlighted at the Australia 2020 summit where the development of ‘science and mathematics connections’ through these means was seen as a way of improving science and mathematics education, particularly in primary schools (Australian Government, 2008). Yet Griffin and Symington (1997) found that the majority of teachers do not have an adequate understanding of how to use places like museums as valuable informal learning resources. As a consequence, valuable opportunities could be missed as teachers do not know what they can ask informal educators for, and science centres and museums do not appear to be effectively marketing themselves to teachers in this way (Phillips, Finkelstein, & Wever-Frerichs, 2007). In the Australian context, a potential inhibitor to the effectiveness of science centres in making inroads to schools is the sheer number of science education stakeholders, each trying to work in the same arena with little to no coordination between them (Goodrum & Rennie, 2007).

The role of science centres and their importance to the ongoing education, progression and development of society has been noted by researchers worldwide (for example Johnson, 2005; Miller, 2002; Salmi, 2000; Ucko, 2003). What is less known is the usefulness of informal learning centres to teacher education (Lawrance & Palmer, 2003; Palmer, 2007). There is very little by way of published research on PD in informal institutions, particularly informal science education institutions (Astor-Jack et al., 2007). This is a key gap in the literature, and in the knowledge and understanding, of
how the interplay between formal and informal education can be used for best effect. Hofstein and Rosenfeld recommended that “future research in science education should focus on how to effectively blend informal and formal learning experiences in order to significantly enhance the learning of science” (1996:107 in Anderson, Lucas, & Ginns, 2003).

3.3 Formal and informal education for teacher development

3.3.1 Informal science education and teacher professional development

The differences between informal and formal education are a strength of any collaboration between the two educational approaches (Xanthoudaki et al., 2007). Experiences in science centres and museums can help teachers gain ideas for further class work (ibid) and provide access to expertise (Finkelstein, 2005). Rather than comparing the two educational approaches, Rennie and McClafferty believe that “don’t compare, complement” (1995:181) is an appropriate motto for examining how the two can work in tandem.

While science centres and museums can engage students in science and enact some attitudinal change (ecsite UK, 2008a; Jarvis & Pell, 2005; Rennie & McClafferty, 1995), there is a growing realisation of the role that they can play in providing adults with the same opportunities (Rennie & Williams, 2002). St John and Perry describe science museums as providing “…an array of resources that help people not only to learn science, but also, more broadly, to develop long-term relationships with the content, phenomena and issues of science” (1993:59). As well as inspiring and motivating students to engage with science, it is possible that informal institutions could also have positive effects on teachers. Jarvis and Pell identify this as a challenge for the informal science education sector stating “the challenge for science museums is how to enthuse and inspire the reluctant teacher” (2005:79).

Many science centres around the world conduct programs specifically for teachers, which can range from one off workshops to ongoing PD, teacher training and residential science ‘boot camps’ (Bischoff & Read, 2005; ecsite UK, 2008b; Finkelstein, 2005; Persson, 2000b). The Exploratorium in San Francisco, United States of America (USA), runs a well known teacher institute, which caters for in-service and pre-service teachers and runs workshops, continuing PD and “summer institutes” (Exploratorium, 2009). The Liberty Science Center in New Jersey, USA, runs an alternate route certification program for science teachers (Liberty Science Center, unknown).
Discovery Centres in the United Kingdom also offer continuing PD programs and resources for teachers (ecsite UK, 2008b), the value of which was given attention in a House of Commons Science and Technology Committee inquiry where every submission (44 in total) emphasised the important role these centres played “in supporting schools and the science curriculum” (ecsite UK, 2008b:14). Science centres and museums have been found to “change dispositions and readiness for school science (both in teachers and in students)” (The Center for Informal Learning and Schools, unknown:1), as well as support teachers in advanced study and conceptual development (ibid).

In a position statement on informal science education, the National Science Teachers Association in the United States declared that “…informal science learning experiences offer teachers a powerful means to enhance both professional and personal development in science content knowledge and accessibility to unique resources” (1998:17 in Melber & Cox-Peterson, 2005). This is reaffirmed by the Science Alberta Foundation (2007) which, in a literature review of informal science education activities and impacts, found that professional development activities offered by these institutions had the potential to not only influence teachers, but also the students they teach.

However Phillips et al. (2007) found that informal science institutions do not seem to be “pioneering a route into the classroom” (p1505) and as a result are underutilised as a PD resource. Nor are the effects and influences of informal education PD widely disseminated in the literature (Melber & Cox-Peterson, 2005). Lawrance and Palmer recommended that “although there has been study on the effects of informal learning experiences for school pupils, studies of their usefulness in teacher education are still needed, and the impact of these types of experiences in teacher education programs should be further explored” (2003:86).

There is growing recognition that the development of an effective teaching cadre is necessary for student engagement in science and that one of the ways that this can be achieved is by partnerships and collaborations between schools and other, external sectors such as industry, government and informal educators (Harris et al., 2005; Lawrance & Palmer, 2003; Rennie et al., 2001). Teachers themselves perceive that external providers of PD add greater “…credibility, effectiveness and relevance…” (Commonwealth of Australia, 2006b:54).

This is supported by the research of Rodrigues, Marks and Steel (2003) who found that partnerships between schools and subject specialists created an improved knowledge
base and pedagogical content knowledge for the participating teachers. Collaborative PD efforts can also help teachers change more than just their professional practice; it can also provide enhanced self-esteem, job satisfaction and motivation (Darby, 2008). One of the key challenges of demonstrating the impact of informal science education activities is that the impacts are difficult to quantify, particularly in the short term.

3.3.2 Impacts of informal education: Impact defined and how it is measured

Much of the research examining the impacts of informal education has been concerned with learning outcomes. To measure learning, first it must be defined. Typically learning is considered to be the acquisition of new information, facts and ideas (Falk and Dierking, 1993 in Ferguson, 1996). Instead of the standard definition of learning, the term ‘affective learning’ has been used and is considered more appropriate for science centres (ecsite UK, 2008a). Affective learning refers to the “generation of strong emotions and the changing of visitors’ attitudes” (Roberts 1993 in ecsite UK, 2008a:4). This is more in line with the constructivist approach taken in science centres, where the focus is on the learner, rather than the subject which is to be learned (Hein, 1995).

The very nature of science centres means that visitors will often be exposed to phenomena and ideas that they may not have seen before, and this exposure will influence how further related ideas and phenomena are constructed into knowledge by the visitor (Anderson et al., 2000). Hawkey (2004 in Johnson, 2005) describes learning as a process of people actively engaging in experience in order to make sense of the world they live in. The learning may develop or deepen skills, knowledge and ideas and effective learning is exhibited by a change and a desire to learn more (ibid). In order to measure change however, the ‘baseline’ of the visitor needs to be known, as well as how the change manifests over time (Research Councils UK, unknown).

The evidence for learning outcomes is rarely, if ever, seen at the same time as the visit to the science centre (Johnson, 2005). It is more usual that a later event or experience will provide “…the context within which the learner sees the relevance of the science centre experience and makes sense of it” (ibid:1). The scale of time over which a learning outcome from a science centre visit could take to become measurable usually infers a lengthy and expensive evaluation, which is beyond the means and scope of the majority of informal education institutions (Research Councils UK, unknown). As a result, evidence of impact in informal education is rarely documented (ecsite UK, 2008a).
A small cohort of science centres internationally undertook a study in an attempt to collate information about science centre impacts in order to quantify the value of science centres (Garnett, 2002). This study qualified impact as “the effect or influence that a science centre has on…the group of people and organisations that the science centre considers to be its clients or potential clients” (p2). The report was able to categorise the impacts of science centres into four domains: personal, societal, political and economic. The definition of each of these impacts is summarised in Table 3.

Table 3: Summary of types of science centre impacts according to Garnett (2002).

<table>
<thead>
<tr>
<th>Impact</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal</td>
<td>The change that occurs in an individual as a result of their contact with a science centre</td>
<td>Science learning; changed attitudes to science; increased professional expertise; personal enjoyment</td>
</tr>
<tr>
<td>Societal</td>
<td>The effect that a science centre has on groups of people, organisation, and on the built and natural environment</td>
<td>Local/regional/international tourism; community partnerships; youth employment; community leisure activities; environmental restoration</td>
</tr>
<tr>
<td>Political</td>
<td>The influence of a science centre on government policies and priorities. Its impact on all levels of Government</td>
<td>(no examples provided)</td>
</tr>
<tr>
<td>Economic</td>
<td>The direct and indirect effect the science centre has on employment and the local economy</td>
<td>Income to the science centre and its community from visitors; science centre expenditure; job creation for staff and outside providers</td>
</tr>
</tbody>
</table>

Requests for reports and studies, published and unpublished, on the impacts of the centres on their communities, yielded 180 reports from centres and researchers alike. The key results of the study found that 87% of the reports detailed personal impacts, with societal impacts (9%) and economic impacts (4%) documented far less. None of the submissions provided evidence of a political impact; this may not be information
that centres are willing or able to share. From all reports detailing personal impacts, the majority dealt with science learning in science centres, and “very few…on the professional development of teachers” (*ibid*:4).

The existing research into learning in museums has shown that learning occurs at different levels (Persson, 1999) and varies between individuals, although enjoyment of the visit is usually the common finding (Rennie & McClafferty, 1995). This enjoyment of a visit is crucial for teachers as well. Jarvis and Pell (2005) found that the personal interest of teachers is an important determinant of how students will respond to science, and a visit to a science centre. In their study one teacher was inspired by the visit, leading him to show tangible enjoyment and enthusiasm for the subject which was readily apparent to his students. As a result, they showed greater attitudinal gain and positivity towards science in contrast to the students of a fellow teacher who patently disliked science (*ibid*).

The findings of Jarvis and Pell, while based on one teacher, are reinforced by an evaluation into the impacts of science learning centres in the UK which found that primary school educators in particular were “most likely to report positive impacts” (GHK, 2008:64). These impacts were particularly seen in personal motivation, subject knowledge and confidence in the classroom. An earlier study, which conducted in-depth surveys with 450 teachers, found that the teachers expected their students to exhibit affective learning after a science centre visit. Reviews of the research into impacts of science centres have shown that “…evidence for affective learning is significant and indicates that science…centres do have powerful emotional impacts upon their visitors and can have a lasting impact upon their attitudes” (ecsite UK, 2008a:6).

Affective learning then, is easy to attribute to science centres. However isolating the impact of a science centre visit from the range of other experiences an individual has greatly limits the ability of researchers to measure and quantify the impacts and outcomes of science centres. Some, such as Rennie and Williams (2002), argue that the measurement of learning and what knowledge science centre visitors leave with is addressing the wrong issue. This follows the earlier sentiments of Falk and Dierking (2000) who believe that evidence of learning in museums and science centres does exist, but researchers, museum professionals and the public have been asking the wrong questions and using the wrong methods to attempt to find it.

The practicality of attempting to measure the potential impacts of science centres is a process with inherent difficulties. Schauble, Leinhardt and Martin state that:
…learning effects of a museum visit may have a very long ‘cycle time’, sometimes emerging years after the encounter occurs. These features make museum learning very difficult to track with the methods and approaches familiar to most researchers (1997:3).

Additionally, they identify a weakness in the methods used by researchers in this area — notably that research into museum learning usually employs tools used to measure school learning. As previously discussed, museum (informal) and school (formal) learning are different and thus the methods used to measure one are unlikely to produce the most reliable results for the other. The logistical difficulties associated with long term studies, as well as the absence of a clear theoretical model for how science centres can influence behaviour and attitude are all limiting factors to studies in this area (Dierking, Burtnyk, Büchner, & Falk, 2002).

3.4 Implications arising from the literature

3.4.1 Knowledge gaps in defining effective professional development

Professional development continues to offer the best hope for teacher reform and improved outcomes in science education (Smylie, 1996 in Supovitz & Turner, 2000). A great deal is known about the characteristics of effective professional development (Desimone et al., 2002), yet it should not be assumed that just because it is known it is automatically incorporated into practice (Hawley & Valli, 1999) or that a ‘one size fits all’ prescriptive policy for effective PD will emerge (Guskey, 2003; Johnson & Marx, 2009). As a result, it seems that there are many different PD offerings available to teachers, with limited levels of success.

Many researchers highlight the importance of social interaction, community participation and active involvement of students in the learning process (Falk & Dierking, 1992; Wenger, 1998). This also applies to adult learners, such as teachers, with collaboration by teachers identified as a key component of effective PD for both beginning (Appleton & Kindt, 2002; Watson et al., 2007) and in-service teachers (Garet et al., 2001; Penlington, 2008). Studies on the impacts of the external environments, mentors and other teachers have been conducted (Hudson & Skamp, 2002), but there is a need for further research with pre-service teachers to better understand how learning communities, and their environments, can influence their practice (Bianchini & Cavazos, 2007).
For all that is known about what makes PD effective, there is little empirical evidence in the literature (Banilower et al., 2007; Melber & Cox-Peterson, 2005). Any attempt to measure the effectiveness of PD must take into account the external environmental factors (Garet et al., 2001; Tytler, 2007) and the background of the teacher themselves (Posnanski, 2002). From the literature reviewed, it appears that few researchers have attempted to address all of these factors in one study. Yet this is consistently recommended as an area for further study due to the inherent gaps in understanding for both pre-service and in-service teachers.

From the evidence that does exist regarding the effectiveness of PD, the results are mixed. While many researchers have found that one-off, short term PD is ineffective for improving the standard of science education (Tytler et al., 2008), others have found that the amount of time and PD devoted to improving science education will still yield less success than that exhibited in the teaching of other subjects (Hilliard 1997; Loucks-Horsley, 1996 in Hartshorne, 2005). Obviously, PD in science is still missing the mark, but this may not be due to the nature of the PD itself so much as other external factors which are stymieing any advances PD may make. Further study is needed to examine the effects of science PD, but also to take into account the beliefs and background of the teacher as well as the external influencing factors, such as the school environment.

3.4.2 A potential role for the informal education sector?

As discussed in this chapter, expertise and knowledge is not something that need only reside within the walls of formal education institutions (Rudd et al., 2006). It is not realistic to expect teachers to ‘do it all’ in science in an era of such rapid technological and scientific advancement. Many formal educators are now looking to form collaborations with specialists from outside the school sector to help them achieve the desired educational outcomes for their students (Commonwealth of Australia, 2006b). This gives strength to a model of PD advocated by Hoban (1997), the inside/outside model, which uses a community of learners (the teachers) and an external organisation to provide resources, ideas and new perspectives. The external provider need not be a part of the formal education community. This model does have an intensive resource load on participants, and often represents an investment of significant time and money that many schools and teachers could baulk at. It is worth attempting to identify some models of best practice in order to ascertain if the investment of resources will indeed yield the desired effects.
Informal education institutions have an increasingly important role to play in the support of the formal education sector, particularly science centres and museums. While some claim that science centres are doing more entertaining than educating (Solomon & Thomas, 1999), other researchers have found that science centres are capable of producing positive impacts and affective learning outcomes in their visitors, irrespective of age (Anderson et al., 2000; ecsite UK, 2008a). Science centres have also been shown to greatly facilitate learner engagement and thus positively influence subsequent learning (Darby, 2005; Phillips et al., 2007). For many science centres and museums the emphasis is on making science accessible and fun; ultimately aiming to make people feel positive about science, rather than intimidated. Professional development programs offered by science centres employ the same techniques, with positive outcomes for the teachers who participate (Melber & Cox-Peterson, 2005), which translates to positive science experiences for their students. Perhaps science centres can help teachers where traditional PD has struggled?

Actually witnessing the learning that occurs in the science centre setting is difficult. Sometimes an individual visiting a science centre may not even recognise that they have indeed actually learnt something themselves (Briede & Peks, 2005). Quite often it is a later event that will provide the context for the information learned in the science centre, and it may only be then that the visitor makes sense of it (Johnson, 2005). As Johnson argues, this should actually be considered one of the key strengths of the science centre as a visit could equip the visitor with a ‘database’ of resources upon which to draw throughout life. However in terms of measuring the impact of science centres, the challenge then lies in not only identifying learning, but trying to measure something which could actually be unmeasurable (Harington, 2001).

The evidence of science centre impact is available (Garnett, 2002), but scarce in many domains, particularly related to the impacts of science centre PD programs on teachers (Astor-Jack et al., 2007). The hands-on approach of science centres is regarded as a key contributor to the effectiveness of PD for teachers (Desimone et al., 2002; Garet et al., 2001; Schoon & Boone, 1998; Watters & Ginns, 2000). However little is known about the effectiveness of science centres in teacher education (Lawrance & Palmer, 2003; Martin, 2004; Palmer, 2008), and more research is required to better understand how to blend formal and informal education to best effect (Hofstein and Rosenfeld, 1996 in Anderson et al., 2003).
If science centres have the capacity to contribute to the professional development of teachers to engender a positive approach to teaching science, then surely they can contribute a great deal to the formal education sector. It could be argued that this would ultimately extend to society through the creation of science positive and scientifically literate students and teachers. Trying to provide evidence of this would necessitate a shift in focus from ‘learning’ per se, to that of the beliefs of teachers and how they are influenced by their colleagues and environment.

3.5 Development of research questions used in the current study

3.5.1 Why science education is a problem for Australian primary schools

Chapter 2 outlined the role of science education for Australia and the current status of science in Australian primary schools. Research examining the perceptions of pre-service, beginning and in-service teachers has found that, within each group, there is a significant fear of science and a lack confidence in teaching it (Appleton, 2003; Goodrum *et al.*, 2001; Hackling & Prain, 2005; Stevens & Wenner, 1996). This is irrespective of whether they have been teaching for twenty weeks or twenty years. This suggests that somewhere in their training, or even in their own experiences as a science learner, the experience was not positive. This has had a detrimental effect on how they perceive science today. Their beliefs and attitudes towards science have been shaped by their own experiences; as they will now go on to shape those of their current and future students.

The teaching of science is not simply a means of creating future scientists and engineers. Science education is vital for ensuring the scientific literacy of a society, equipping people with the skills and ability to make valid, informed decisions about the kind of technological and scientific advances they, as a society and a country, wish to embrace during this rapidly evolving technological age. Yet despite increased focus from all levels of government and the teaching profession itself, the status of science continues to decline in Australian schools, with diminishing numbers of students pursuing further studies and careers in the science, engineering and technology industries. Science education continues to under perform. Educational reform, innovation and improvement is imperative, but its success is based on teacher change (Rennie *et al.*, 2001). To improve the status and quality of science education, and ultimately scientific literacy in society, the status and quality of science teaching must be addressed, beginning with the teachers themselves.
Schools and teachers face a formidable task, trying to keep abreast of a subject in which they may already have little experience or just inherently dislike. Science is rapidly evolving and becoming more advanced — primary teachers are expected to keep pace, along with all the other subjects in the curriculum they are expected to teach (Pint’o, 2004). Numerous institutions offer specialised PD to update teachers’ knowledge about the new content or come in to the school to work with the students, however this tends to be short term (Goodrum & Rennie, 2007) and not always entirely appropriate for the needs of the teachers. They are getting some exposure to the new information, approaches and ideas, but these short term experiences are doing little to influence their own skills and beliefs in their own abilities to successfully teach science and achieve desirable outcomes.

3.5.2 Making professional development work: issues to consider

As discussed in this chapter, PD is regarded as one of the best ways to address current limitations in science education (Smylie, 1996 in Supovitz & Turner, 2000). The need for continuing PD is not only for in-service teachers, but is considered necessary for pre-service and beginning teachers as well; it is only through the education of the next generations of teachers that reform can be achieved (Hudson & Skamp, 2002; Preston et al., 2007). Extensive research has identified the characteristics required for effective PD (Desimone et al., 2002; Hawley & Valli, 1999; Hoban, 1997), yet the implementation is either non-existent or fails to achieve the desired reform (Darby, 2008). Traditional PD approaches are failing to consistently achieve the desired results in science teaching, even when they are succeeding in other subject areas (Loucks-Horsley, 1996 in Hartshorne, 2005).

Collaborative PD has been shown to greatly enhance the success and outcomes achieved by teachers (Garet et al., 2001), including beginning teachers (Watson et al., 2007). In particular, communities of learners from within the same school environment can be especially effective as they already have an established rapport and trust, which has been shown to make group work more effective (Penlington, 2008). Additionally, having an established group working together to achieve mutually desirable goals has been observed to mediate the response to reform efforts (Judson & Lawson, 2007).

PD which involves organisations external to the school environment is advocated by researchers (Hoban, 1997) and teachers alike (Aubusson et al., 2010; Commonwealth of Australia, 2006b) as it allows new ideas and perspectives to be applied, and provides an
opportunity for teachers to hear from specialists in an area they have to teach. It also allows the teachers, as a community of learners, to reflect on the practice as a group and work together to achieve the best possible results. The challenge with this model is to ensure it is enduring and affordable (both in time and resources), and that it takes the context in which the teachers must work into account. This project will examine the enduring effects of PD based on the inside/outside model.

The school environment has been consistently identified as a factor that needs to be taken into consideration when examining the beliefs of teachers (Lewthwaite, 2001; Lewthwaite & Fisher, 2004). The ease of accessing resources to teach science and the status of science as a subject within a school can all affect how a teacher perceives science and ultimately their beliefs (ibid). These beliefs can also be influenced by their colleagues. The collective efficacy of the teaching cohort could profoundly shape the beliefs of beginning teachers (Tschannen-Moran et al., 1998). There is a need for further research on the influence of the school environment, including the beliefs of other teachers, on beginning teachers (Luft, 2007; Weiss, 1999).

A range of needs and knowledge gaps has been identified in the literature. Firstly, teachers are still unwilling or unable to teach science, irrespective of whether they have twenty years of teaching experience or are just starting in the profession. Despite a range of reform initiatives, including varying models of professional development, little headway appears to have been made. Further research requires a big picture approach, examining the background of pre- and in-service teachers, their perceptions of science and their beliefs and, importantly, how these beliefs change over time. The use of a long term study can contribute to the understanding of how, when and if teachers’ beliefs can be influenced.

3.5.3 The research questions explored in this thesis

The research described in this thesis used efficacy beliefs as one of the key measures of teacher intent and practice, examining teachers already working in schools and those who are making the transition from pre-service to beginning teacher. The inclusion of pre-service and in-service teachers in this research contributes to the understanding of the general applicability of efficacy among teacher groups. The study design employed in this project also addressed the knowledge gaps regarding the resilience and duration of self-efficacy beliefs of teachers.
Aside from the teachers themselves, the use of PD as a means of reform warrants further examination. Drawing on the collective PD models, combined with the use of external providers, the use of informal education organisations was identified as a potential means of contributing to reform in science education. Science centres and museums exist to communicate science to the wider public, raising their awareness by making science fun, accessible and increasing the motivation of visitors to engage with the subject (Persson, 1999). Many teachers express fear of, and negativity towards, science therefore the use of science centres, which have been shown to positively influence attitudes towards science (see Anderson et al., 2000), could contribute to achieving the desired reform in science education.

The constructivist, hands-on approach used by science centres has been shown to positively affect visitors to the centre (Darby, 2005; Garnett, 2002; Phillips et al., 2007). Science centres are also well regarded as sources of professional development for teachers, providing access to ideas, resources and expertise, and capable of increasing teacher confidence (Finkelstein, 2005; Melber & Cox-Peterson, 2005; Xanthoudaki et al., 2007). Combining known characteristics of effective PD (Garet et al., 2001; Hawley & Valli, 1999), with informal science education PD could create a program that may have some impact on teachers, and subsequently their science teaching.

The aim of the current study was to determine if science centre produced, short professional development workshops were capable of influencing the science teaching self-efficacy of primary school teachers, and to identify the extent to which this was influenced by external factors. Specifically, this study addressed the following two groups of research questions:

**Teacher characteristics**

1. Do science centre produced, short professional development workshops have any effect on teachers’ science teaching self-efficacy?

2. Do science centre produced, short professional development workshops affect pre-service teachers differently from in-service teachers?

3. Do science centre produced, short professional development workshops have differing effects and impacts depending on a teachers’ teaching experience?
Environmental influences and beliefs

4. Does an individual’s previous experience with science influence how they feel about science teaching?

5. Does the environment of the school influence the self-efficacy of the teacher or how likely they are to teach science?

6. Do teachers perceive a role for informal science education institutions with teachers?

The following chapter will outline the methods used in the current research, including justifications for the choices of instruments that were made.
Chapter 4: Research Design

4.0 Development and rationale of research design

Chapters 2 and 3 outlined the existing knowledge and research surrounding primary school teachers, their perceptions of science and how various professional development programs have been employed to attempt to improve the teaching of science in primary schools. One of the crucial points arising from the literature discussed in Chapter 2 was the importance of obtaining a context-specific understanding of the belief structure of teachers, as well as how these belief structures may change over time. A key point raised in Chapter 3 was the limited data in existence of the role and impact of informal science education institutions on teacher education and professional development. Each of the preceding chapters identified gaps in the existing knowledge of how to improve the status and quality of science teaching in Australian schools. The review of the literature identified areas requiring further research in order to strengthen and consolidate the understanding of the development of teachers at different stages of their careers, and to validate or improve upon the research instruments employed in these areas. The research questions addressed in this thesis are based on these identified needs.

The purpose of this chapter is to describe the design of the research presented in this thesis. Section 4.1 discusses and justifies the instruments and methods used, and limitations of these are identified. Section 4.2 provides an overview of the preliminary work conducted to ensure the validity and viability of the proposed workshops and research approach with the intended teacher cohorts. Section 4.3 provides an overview of the final study design and implementation, including the challenges of attracting and retaining teachers for the purposes of research. Finally, section 4.4 discusses the analysis of the data.

4.1 Development of method used to address the research questions

4.1.1 Brief review of the aim and research questions of the current research

The aim of the current study was to determine if science centre produced, short professional development workshops were capable of influencing the science teaching self-efficacy of primary school teachers, and to identify the extent to which this was influenced by external factors. It did this by addressing the following research questions:
Teacher characteristics

1. Do science centre produced, short professional development workshops have any effect on teachers’ science teaching self-efficacy?

2. Do science centre produced, short professional development workshops affect pre-service teachers differently from in-service teachers?

3. Do science centre produced, short professional development workshops have differing effects and impacts depending on a teachers’ teaching experience?

Environmental influences and beliefs

4. Does an individual’s previous experience with science influence how they feel about science teaching?

5. Does the environment of the school influence the self-efficacy of the teacher or how likely they are to teach science?

6. Do teachers perceive a role for informal science education institutions with teachers?

These research questions were designed as a frame of reference only, making this exploratory rather than experimental research. The professional development referred to in the aim and research questions took the form of four workshops on basic scientific principles. The workshops, described in greater detail in a later section, employed a hands-on, constructivist approach with the emphasis on participants having the opportunity to build confidence through successful interactions with scientific experiments and practice.

4.1.2 Research method: A mixed method approach

The study of beliefs is difficult to conduct via an empirical investigation due to the vast range of beliefs of, and influences on, individuals; and the study of educational beliefs is no less challenging (Pajares, 1992). Educational beliefs can range from individual perceptions of ability to achieve or influence outcomes, to beliefs about subjects. It is the specific nature of these beliefs that actually makes this area of research possible as: …researchers have learned enough about specific types of beliefs to make their exploration feasible and useful to education…Clearly when specific beliefs are carefully operationalised, appropriate methodology chosen, and design thoughtfully constructed, their study becomes viable and rewarding (Pajares, 1992:308).
Given the range of factors examined in this research, no single instrument would have provided the necessary scope — therefore a number of instruments were used. Kagan (1990) supports this approach, arguing that no one single instrument is able to capture the complexity of teachers’ knowledge.

As summarised by Bazeley (2004), the difference between qualitative and quantitative analyses have been defined:

…on the basis of the type of data used (textual or numeric; structured or unstructured), the logic employed (inductive or deductive), the type of investigation (exploratory or confirmatory), the method of analysis (interpretive or statistical), the approach to explanation (variance theory or process theory), and for some, on the basis of the presumed underlying paradigm (positivist or interpretive/critical; rationalistic or naturalistic).

Quantitative ‘purists’ in educational research believe that the researcher should remain emotionally detached and uninvolved with their research subjects and should try to test their theories and hypotheses empirically (Burke Johnson & Onwugebuzie, 2004). The data collected should be considered time- and context-free (Nagel, 1986). In contrast qualitative ‘purists’ believe that context and the interaction between researchers and the objects of the study and the consideration of the context is vital to understanding the full picture (Burke Johnson & Onwugebuzie, 2004). The debate about which of these two methods is more appropriate for educational research has been long argued and divisive, leaving some graduates with the impression that they must use one method or the other, not both (ibid). There was even an ‘incompatibility thesis’ which claims that the two methods cannot and should not be mixed (Howe, 1988).

Throughout the literature examining teachers’ efficacy beliefs the debate appears to continue. Ross (1994) advocates the use of rich, qualitative analysis for research on teacher efficacy and professional development programs to ensure that the different contexts are examined fully. In comparison, Watson et al. (2007) deemed qualitative methods as the most appropriate approach for providing an in-depth understanding of teacher beliefs. In contrast, Mulholland et al. (2004) argue that while qualitative studies provide relevant details, they do not actually demonstrate any significant change in attitudes or beliefs from within a study cohort. They state that the studies which have done this have been quantitative analyses, often using the Science Teaching Efficacy Belief Instrument (STEBI) developed by Riggs and Enochs (1990).
Within the last two decades there has been a shift towards using the two methods in tandem. In their study of the influence of a staff development program on teacher efficacy, Singh and Schifflette (1996) used both a survey instrument and formal interviews. They assert that the combination of qualitative and quantitative research methods allows for the provision of different perspectives and helps confirm pre-existing findings. This is supported by Palmer (2004; 2006a) who used multiple data sources as a means of ‘cross checking’ any identified trends. The adoption of both qualitative and quantitative research methods allows collected data to be measured and revealed through “different lenses” (Salzman & Newman, 2002:7). This is considered to be a mixed methods research approach which is formally defined as “the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study” (Burke Johnson & Onwuebuzie, 2004:17). The current study employs a mixed method research approach using both surveys and semi-structured interviews to capture the broad range of issues, maximise the depth of understanding and ‘cross check’ any identified trends.

4.1.3 Triangulation or data integration?

The practice of using more than one method to examine a phenomenon is often called triangulation. Triangulation is defined by Denzin as “the combination of methodologies in the study of the same phenomenon” (1978:291). It was initially envisaged as the use of:

…parallel (or otherwise duplicated) studies using different methods to achieve the same purpose, with a view to providing corroborating evidence for the conclusions drawn, i.e. as a technique of validation (drawn from the concept of triangulation in surveying) (Bazeley, 2004:3)

Triangulation is “typically perceived to be a strategy for improving the validity of research and evaluation findings” (Mathison, 1988:13). In particular, triangulation was seen as a means of mitigating or even overcoming associated problems of bias and validity in research (Blaikie, 1991). Webb, Campbell, Schwartz and Sechrest (1966), first developed the idea of triangulation for use in social science research by claiming that all research methods are biased. Using more than one method enables a less biased interpretation of the results overall. This was supported by Denzin (1989) who advocated the use of multiple methods as a means of overcoming the personal biases from the use of a single method.
There are four different types of triangulation defined by Denzin (1978): 1) data triangulation which uses more than one person, one time and one place; 2) investigator triangulation — using more than one researcher in a study; 3) theory triangulation; and 4) methodological triangulation which uses multiple methods to examine a phenomenon. This latter type is often incorrectly used “loosely as a synonym for mixed methods…” (Bazeley, 2004:4) instead of acknowledging its original purpose as a technique of data validation (Denzin, 1978).

The use of triangulation as a means of minimising bias has been contested in the literature, with Fielding and Fielding stating:

Theoretical triangulation does not necessarily reduce bias, nor does methodological triangulation necessarily increase validity. Theories are generally the product of quite different traditions, so when they are combined one may get a fuller picture, but not a more “objective” one. Similarly, different methods have emerged as a product of different theoretical traditions, and therefore combining them can add range and depth, but not accuracy. In other words, there is a case for triangulation, but not the one Denzin makes (1986:33).

As stated in an earlier paragraph Denzin (1989), in the third edition of his book, backed away from the use of triangulation as a means of validation, but upholds its use as a means of overcoming personal bias.

Some authors contend that using multiple methods is not in itself a claim to triangulation; that there is a difference between the outcome of using multiple methods and the process by which these methods are inter-related (Moran-Ellis, Alexander, Cronin, Dickinson, Fielding, Slaney, & Thomas, 2006). Greene, Caracelli and Graham (1989) identified three ways of employing mixed methods; none of which incorporated triangulation per se. One of the ways identified was that of using mixed methods to garner a better breadth and depth of data and thus understanding of the topic being researched (Greene et al., 1989). This is the case in this current study, where qualitative and quantitative data are being used in tandem to provide a more complete picture. Some researchers would call this triangulation, by virtue of the fact that more than one research method is being used (Moran-Ellis et al., 2006). However the use of the qualitative data in this research project follows the line of thinking held by Jick who states that “qualitative data and analysis function as the glue that cements the interpretation of multimethod results” (1979:609).
Moran-Ellis et al. rather claim that a more accurate view of research using mixed methods is one of integration; specifically that which:

…involves the generation of a tangible relationship among methods, data and/or perspectives, retaining the integrity of each, through a set of actions clearly specified by the research team, and that allows them to ‘know more’ about their research topic (2006:51).

The current study used qualitative and quantitative data to allow a greater depth and breadth of understanding of the factors influencing teachers and their self-efficacy beliefs. Each instrument was analysed in its own right, yet the interpretation and analysis of the results combines the methods and instruments — a form of “analytic or interpretive integration” (Moran-Ellis et al., 2006:56) as opposed to triangulation in its truest sense.

4.1.4 The research instruments: Science Teaching Self-Efficacy Beliefs (STEBI)

Numerous instruments have been developed to measure efficacy beliefs in teachers, the majority of which have been developed from Bandura’s work (Henson et al., 2001). Many studies have also used tests developed from Rotter’s (1966) Locus of Control theory; and these have served to inform the knowledge of teacher efficacy as a construct. Typically the most commonly applied instruments developed from Rotter’s work examine a teacher’s perception of whether student success or failure is due to internal (the teacher) or external (the student) factors (Henson et al., 2001). As measuring changes in efficacy was the aim in the current study, instruments derived from Rotter’s work were not used.

Bandura’s (1977; 1997) theories of teaching self-efficacy, and specifically the instruments developed from these theories, were the most appropriate for measuring changes in teacher self-efficacy belief in the current study. Two of the most commonly applied instruments (Henson et al., 2001) are the Teacher Efficacy Scale (TES) developed by Gibson and Dembo (1984), and the Science Teaching Efficacy Belief Instrument (STEBI), designed for both in-service (STEBI A - Riggs & Enochs, 1990) and pre-service (STEBI B - Enochs & Riggs, 1990) teachers. The two versions of the STEBI were selected as the most appropriate for the purposes of this study. They are amongst the most commonly used and validated instruments in this kind of research,
and they are specifically designed for science teaching efficacy beliefs of pre- and in-service teachers, which were central to this project.

The STEBI (A and B) are constructed of two scales: the Personal Science Teaching Efficacy (PSTE) and Science Teaching Outcome Expectancy (STOE) which denote their relationship to Bandura’s two factor theory of efficacy (Bleicher, 2004). The STEBI A has 25 questions requiring the respondent to answer on a five point Likert scale. Each scale yields a score providing an indication of efficacy belief for PSTE or STOE.

The validity of the STEBI A was extensively tested and well established by Riggs and Enochs (1990), and further tested in a variety of contexts (de Laat & Watters, 1995; Ramey-Gassert, 1994). The STEBI B is a slightly modified version (in terms of language and the removal of two questions) of the STEBI A, and was also validated by its developers (Enochs & Riggs, 1990) and in numerous studies of science teaching efficacy of pre-service teachers (Bleicher, 2004). Further validated derivations and descendents of the STEBI A have also been used for the study of efficacy within specific subjects such as chemistry, which used the STEBI-CHEM (Rubeck & Enochs, 1991), and mathematics using the MTEBI (Enochs, Smith, & Huinker, 2000).

The suitability of the STEBI B instrument in particular has led to it being developed and validated for use in a variety of different cultural contexts, including for research on pre-service teachers in Denmark (Andersen, Dragsted, Evans, & Sorenson, 2003), Turkey (Gencer & Cakiroglu, 2007) and Korea (Park, 1996). A study by Ginns et al. found that “...the evidence is sufficiently compelling to support the use of STEBI B as a reliable measure of pre-service teachers’ sense of science teaching efficacy, in an Australian school” (1995:400) and that the effects of any intervention program implemented could be readily measured using the STEBI B.

There have been some criticisms of the validity of the two scales used in the STEBI instruments, in particular the potential for measurement errors in the scores generated (Henson et al., 2001; Tschannen-Moran et al., 1998). Bleicher (2004) conducted a study re-examining the reliability and internal validity of the STEBI B. He modified two items on the STOE scale based on the study results and re-tested the reliability and STOE scale internal validity. The modified version showed improved reliability and internal scale reliability therefore the modified version of the STEBI B was used in this study. Copies of both the STEBI A and STEBI B are provided in Appendix A.
The STEBI instrument has also been shown to provide evidence to support the influence of environmental contexts on teachers’ beliefs (Lumpe et al., 2000), allowing the cross checking of results obtained using the other research methods. The importance of examining other ‘background’ variables such as previous science experiences in conjunction with STEBI results was highlighted by Bleicher (2004). This is supported by Palmer who found that results obtained from the STEBI B “…provided a different picture to that obtained by interview…” (2006a:670). Palmer recommends conducting interviews at the same time as the administration of the STEBI to allow for data comparison and verification. The current research incorporated Palmer’s suggestion in the method design.

4.1.5 The research instruments: Science Curriculum Implementation Questionnaire (SCIQ)

There is growing consensus in the literature that while knowledge of the efficacy beliefs of teachers is valuable, if taken without due considerations of contextual factors, the results are limited in their usefulness (see Bleicher, 2004; Lewthwaite, 2001; Tschannen-Moran et al., 1998). In particular, self-efficacy lends itself to educational research as it is specific enough to be easily measured. However the use of self-efficacy, and of belief inventories like the STEBI, provides limited information from which to make inferences and draw conclusions. The context in which the beliefs are held and formed must also be examined (Pajares, 1992). Understanding the context allows findings to become clearer and more meaningful; ignoring the context of the beliefs would limit the value of the study (ibid).

Lumpe et al. (2000) developed the Context Beliefs about Teaching Science (CBATS) instrument to assess the context beliefs of teachers in relation to science education reform. They used this instrument in conjunction with the STEBI to develop profiles that would enable them to identify the ‘personal belief patterns’ of science teachers. This could then potentially assist in the identification of teachers’ perceptions of strengths and weaknesses in their schools’ science programs (ibid). Teachers’ beliefs about their school environment, including its curriculum, can influence their beliefs about science teaching (Lewthwaite, 2001).

The aim of the current research was to examine the effect of a professional development ‘intervention’ on teacher self-efficacy, with respect to the influence of the school environment context on those teachers’ beliefs. The CBATS was not seen to be as
relevant to the aims of this project as Lewthwaite’s (2001) Science Curriculum Implementation Questionnaire (SCIQ). The SCIQ aims to assist in the identification of factors which teachers perceive as limiting the implementation of science curricula at the school and classroom level — an area of research that is largely underdeveloped (Lewthwaite & Fisher, 2004). The SCIQ was developed and validated through surveys, interviews and focus groups conducted with pre- and in-service teachers in New Zealand. A full description of the development and statistical validation process is contained in Lethwaite (2001).

The SCIQ comprises seven scales, each including seven items. The scales are defined as follows (after Lewthwaite and Fisher, 2004):

- **Resource Adequacy**: the appropriateness of the equipment, resources and facilities required for teaching science within the school
- **Time**: the amount of time teachers perceive they have versus what they need to prepare and deliver science lessons as required by their curriculum
- **School Ethos**: how the school regards science as a subject within the curriculum; its status
- **Professional Support**: the amount of support available to teachers both within and external to the school
- **Professional Adequacy**: the teachers’ perceptions of their own abilities to teach science
- **Professional Science Knowledge**: how well the teachers perceive their colleagues (and their own) knowledge and understanding of science as a curriculum area
- **Professional Attitude and Interest**: perceptions of the attitudes towards, and interest in teaching, science of teachers

High internal consistency for each scale was found through the use of the Cronbach alpha reliability coefficient (alpha values ranged from 0.77 - 0.92) (Lewthwaite, 2001). The response scale ranges over five points, scoring from strongly disagree (1) to strongly agree (5). The scales are divided into two groups of factors — environmental factors and personal attribute factors. The scales included in the environmental factors group are resource adequacy, time, professional support and school ethos. The
remaining scales — professional science knowledge, professional attitude and interest, and professional adequacy — comprise the personal attribute factors group.

For the purposes of the current study, some alterations were made to the SCIQ instrument. Some of the language was changed, attempting to elicit the personal opinion of the respondent more clearly. This was created by the inclusion of more personal statements and phrases such as ‘I think’ and ‘I believe’ rather than asking for a response to a direct statement. Participant responses are then given based on their beliefs, rather than ‘fact’. An example of this is changing the original item ‘Teachers at this school are reluctant to teach science’ to ‘I think that teachers at this school are reluctant to teach science’.

Some items were removed from the SCIQ to improve the context appropriateness of the instrument for Australian teachers. A few of the items were specific to the New Zealand educational system so were either re-worded if the meaning was clear, or omitted if the Australian equivalent was not applicable or accurately identifiable. Other items were repetitious, especially as many of the repetitious items were covered in the STEBI, so these were also omitted. This was particularly the case within the Professional Support and Professional Adequacy scales. The items that were omitted from each scale are shown in Table 4.
Table 4: Scales, item numbers and amendments made to the Science Curriculum Implementation Questionnaire (SCIQ) used in this study

<table>
<thead>
<tr>
<th>Factor</th>
<th>Original Scale Item Number</th>
<th>Scale Item Removed</th>
<th>New Scale Item Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Environmental Factors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resource Adequacy</td>
<td>3, 10, 17, 24, 31, 38, 45</td>
<td>10, 24, 45</td>
<td>3, 14, 24, 31</td>
</tr>
<tr>
<td>Time</td>
<td>6, 13, 20, 27, 34, 41, 48</td>
<td>27</td>
<td>6, 11, 17, 27, 32, 38</td>
</tr>
<tr>
<td>Professional Support</td>
<td>7, 14, 21, 28, 35, 42, 49</td>
<td>7, 14, 49</td>
<td>18, 22, 28, 33</td>
</tr>
<tr>
<td>School Ethos</td>
<td>5, 12, 19, 26, 33, 40, 47</td>
<td>40</td>
<td>5, 10, 16, 21, 26, 37</td>
</tr>
<tr>
<td><strong>Personal Attribute Factors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professional Science Knowledge</td>
<td>1, 8, 15, 22, 29, 36, 43</td>
<td>29</td>
<td>1, 7, 12, 19, 29, 34</td>
</tr>
<tr>
<td>Professional Attitude and Interest</td>
<td>2, 9, 16, 23, 30, 37, 44</td>
<td>None removed</td>
<td>2, 8, 13, 20, 23, 30, 35</td>
</tr>
<tr>
<td>Professional Adequacy</td>
<td>4, 11, 18, 25, 32, 39, 46</td>
<td>25, 39</td>
<td>4, 9, 15, 25, 36</td>
</tr>
</tbody>
</table>

The final version of the SCIQ used in this research contained 38 questions (as opposed to the original 49). This also assisted in minimising the amount of time respondents were required to devote to completing the instruments used in this study. A copy of the original and the modified SCIQ used in this study is available in Appendix A.

The SCIQ has been validated by repeated studies with teachers (Lewthwaite, 2001; Lewthwaite & Fisher, 2004). The use of a validated, standardised instrument allows for information to be collected efficiently and effectively to provide a broad overview (Fullan, 1992). The results from the SCIQ are obtained by calculating the mean and standard deviation of responses for each of the seven scales. The mean indicates the overall level of agreement of the cohort with a factor, as represented by the scale, and the standard deviation indicates the amount of variation among the responses. A high standard deviation indicates that there is a great deal of variation within the cohort, whereas a small standard deviation indicates a greater consensus. The results are then interpreted to obtain a broad general picture of the study cohorts’ perceptions of the environment in which they teach. The SCIQ can differentiate between data obtained for different groups, such as schools (Lewthwaite, 2001), so differences between the sample groups in this study were easily identified.
Lewthwaite (2001) did identify that the SCIQ is limited in that it is unable to differentiate between multidimensional aspects like time. For example time could be considered in terms of time to prepare science lessons and time to actually teach science. In this instance, the SCIQ would not reveal any real detail; the data would show that there is a significant result in the time scale, but we would be unable to discern exactly where the result is coming from. The only way to identify where the variation is coming from is to calculate the individual means and standard deviations for each item comprising the time scale (questions 6, 11, 17, 27, 32, 38). As an example, questions 6 and 32 state:

6. I don’t feel like there is enough time in the school program to fit science in properly.

32. It seems that teachers at this school are adequately prepared to teach to the requirements of the science curriculum.

Question 6 is dealing specifically with the amount of time available teachers physically have in classes in order to teach science. Question 32 is asking more generally about the preparation time available to teachers for getting science lessons ready for delivery to a class. The means and standard deviations for question 6 might show consistent perceptions amongst respondents, but the results for question 32 may show a wide range of perceptions within the study group. Therefore when analysing the results, the conclusion can be made that respondents do feel that there is enough time in class to teach science, but there are too many demands external to teaching in class to enable them to prepare for science lessons adequately. This has been used as one way of obtaining more meaningful results by allowing specific areas within scales to be identified (Lewthwaite & Fisher, 2004). Lewthwaite (2005) further refined the quality of results that could be obtained in the SCIQ by using a longitudinal study, calculating the means and standard deviations of the individual items, and interviewing the participants. Following this approach, analysis of the results obtained in the current study through the SCIQ was complemented by the use of semi-structured interviews.

4.1.6 The research instruments: Semi-structured interviews

Previous research has identified the need for interviews to be used in conjunction with questionnaires in order to verify the results these instruments will yield, as well as gain a more in-depth understanding of the data (Lewthwaite, 2005; Palmer, 2006a; Singh & Shifflette, 1996).
The use of a semi-structured interview design:

…allows for flexibility in the order and wording of the questions so that while all topics are covered with all interviewees, additional topics that arise in the course of the interview can be followed up and the conversation between the interviewer and the teacher can flow naturally… (Finkelstein, 2005:3).

The use of interviews will “provide access to the context of teachers’ action and what they know” (Park & Oliver, 2008:267) and provide a more cohesive framework from within which to analyse and interpret the results.

The interview protocol comprised questions that aimed to identify prior experiences with science (as per Hanuscin et al., 2006; Palmer, 2006b; Stevens & Wenner, 1996) and the factors that influenced the respondents to enter the teaching profession, which some beginning teachers cannot readily answer (Commonwealth of Australia, 2006a). Additionally, each respondent was asked what (or who) were the most positive and most negative personal influences in their teaching. This is an important part of the context of a teacher’s beliefs given the importance of collegial interaction on teacher development (Appleton & Kindt, 2002). These positive or negative influences could include their teachers (at school and at university) as well as their colleagues, external specialists and peers, or even their own family members. The interviews also asked what, if any, science professional development or experiences the participants have been involved in. This was done so as to provide an indication of any other contributing factors and events which may have influenced the context, and thus the results, between one sampling period and the next (Ruspini, 2002).

The questions used provided further detail to the responses given in the SCIQ. Previous work indicating the importance of the social influence of others in the formation of attitudes, particularly those of pre-service teachers, toward science and science teaching (Shrigley, Koballa and Simpson, 1988 in Mulholland & Wallace, 2001) warrants the inclusion of these kinds of questions. So and Watkins (2005) further support this, identifying that the teaching practice of pre-service teachers may be influenced by the context and the level of support they receive from their supervisors, their teacher education institutions, and their school. They assert that this warrants further analysis.

For the pre-service teachers, an additional set of questions was used based on the work of Howitt (2007) who identified the major factors which influence pre-service teachers’ confidence towards science and science teaching. The factors that were used in this
study include their teacher educator, science content knowledge, science pedagogy, science activities, children’s views of science (ascertained during their practicum), the process of investigating scientifically, reflection on practice (their own or that of others) either individually or with their peers, and the influence of their learning environment, be it at their university or their own classrooms when teaching.

The inclusion of these questions in the interview assisted in providing greater insight into the factors that have the greatest influence on pre-service teachers and to the interpretation of the results obtained through the STEBI and the SCIQ. Having the in-service teachers answer questions pertaining to the most negative and positive influences in their teaching careers also provided an insight into how these factors evolved over time. The use of such questions in conjunction with a professional development experience (such as the workshops used in this study) allowed for the identification of clear connections between the experience, background and context of the teacher; an area that must be addressed (Posnanski, 2002).

All respondents were questioned about what they were most and least confident about in teaching. The inclusion of these questions allowed for a comparison between each of the groups to determine if teachers within the same school or experience level shared the same concerns. This assisted in determining the ‘predictability’ of teacher development over time, particularly in the first year as a beginning teacher (Marso & Pigge, 1989).

The identification of these concerns is important as the concerns of teachers “can impede or prevent professional growth” (Peers, Diezmann, & Watters, 2003:103). By identifying these concerns within and between the study groups, this research assisted in the development of the knowledge required to adequately address these issues.

During the final interview the participants were all also asked about whether they perceived there was a role for institutions like science centres and museums with teachers. The purpose of including this question was to determine firstly, how teachers (beginning and experienced) perceive these institutions and secondly, to potentially identify additional ways and means of supporting teachers and achieving science education reform. A copy of the interview protocol used in the current study is provided in Appendix B.

4.1.7 The use of longitudinal studies

Much of the literature discussed has identified the need for longitudinal studies, yet there are very few longitudinal studies in the education sector internationally (Arzi,
Research has continued to identify the factors and influences associated with the development of efficacy, but very few studies have examined these over a period of time (Cantrell et al., 2003). Longer term studies need to be conducted in this area to provide a better understanding and overview of the durability, resilience and generalisability of efficacy (Bleicher, 2004; Palmer, 2006a), and how the beliefs of teachers change over time (Lumpe et al., 2000), particularly during the first year of teaching (Chan, 2008; Luft, 2007). Despite these identified needs, longitudinal studies, which by their very nature would be the most appropriate means to address some of these research issues, are still limited within the education sector.

A longitudinal study can be defined as “data gathered during the observation of subjects on a number of variables over time” (Ruspini, 2002:3). The design considered “most truly longitudinal” (ibid:4) is that of the panel longitudinal study which repeatedly surveys or interviews the same subjects over a period of time. This will allow the identification of baselines of the study groups used and the ongoing contact with the study participants will allow for the monitoring and assessment of change (Research Councils UK, unknown). Given that one of the objectives of this research was to track changes in efficacy beliefs over time, a panel longitudinal study was the most appropriate means by which to do this.

Menard’s (1991) definition of longitudinal studies incorporates both data and the methods of analysis and he defines longitudinal research as research where:

a) data are collected for each item or variable for two or more distinct time periods; b) the subjects or cases analysed are the same or at least comparable from one period to the next; and c) the analysis involves some comparison of data between or among periods (1991:4).

It is Menard’s definition that has been used as the framework for this research design which is discussed in section 4.3.

Longitudinal studies, like all research methods, have inherent strengths and limitations. There are four problems that are specific to longitudinal studies; time, resources, management of data and attrition of participants (White & Arzi, 2005). The length of time over which longitudinal studies are conducted means that the loss of participants, particularly in panel design studies, tends to be cumulative (Ruspini, 2002). This attrition could also lead to a biased sample if the subjects leaving the study are not
typical of those who started it (*ibid*). All research projects have time and resource parameters that make studies less than ideal, and the current research project was no different. The limitations imposed by time and resource availability did assist in clarifying the scope and direction of the current project and aided the development of very specific parameters. The steps taken to attempt to counter attrition of participants are discussed in a later section.

The use of a sole researcher, while a limitation, was also a strength of the current study. It greatly increased the likelihood of standardisation of data collection and analysis (Menard, 1991), thereby minimising confounding of the results. Having the researcher as the constant point of contact throughout the study also facilitated the development of more personal relationships between the researcher and participants (Research Councils UK, unknown) which assisted in the follow up interviews and surveys — especially as they happened some time after the initial workshops.

In any panel design longitudinal study there is also the risk of ‘panel conditioning’ where the use of the same instruments over a period of time may sensitise the participants and influence their response, which may have a positive or negative impact on the data (Menard, 1991; Ruspini, 2002). This was a possibility in the current study; however given the length of time that elapsed between the uses of the repeated instruments (a minimum of five weeks up to 8 months) it was unlikely that the participants would remember enough of the instruments from the previous time for this to be an issue. Irrespective, the repeated instruments are dealing with beliefs, which are more likely to be difficult to change if they have been held for some time (Pajares, 1992) or, especially in the case of the pre-service teachers, are more likely to be influenced by the new context they find themselves operating within (Lumpe *et al.*, 2000). Therefore, panel conditioning was not thought to be a significant influencing factor in the current research.

The volume of data that can be collected in a longitudinal study could mean that the overall results actually raise more questions than they answer and serve to indicate what else the researcher should have looked at, rather than what they actually did (White & Arzi, 2005). This was a possibility in this study, simply due to the wide range of factors and influences that are inherent in educational research. Where any such issues or gaps were identified in this current study, they were recommended as areas for future research.
The amount of data generated over a period of time is also one of the greatest strengths of longitudinal studies as it allows the researcher to gain a more thorough insight into relationships and inferences than they could hope to achieve from a shorter study (White & Arzi, 2005). The use of a range of instruments within a longitudinal study also allows the development of a more comprehensive understanding of the development of change in individuals (Helldén, 2005). The use of a quantitative approach with a longitudinal study allows examination of the growth of teachers, while a qualitative approach in a longitudinal study allows for a richness of data which a quantitative approach alone cannot provide (Reitano, 2004). Both qualitative and quantitative approaches were used in this study and their incorporation into a longitudinal panel design specifically and thoroughly addressed the issues outlined in the research questions.

4.2 Pilot study

In 2006/2007, surveys were conducted with participants in professional development workshops for primary teachers run by the Shell Questacon Science Circus (SQSC), an outreach program of Questacon – The National Science and Technology Centre, which tours rural and regional Australia. The workshops offered by this program are based on topics such as fluids, physics, and sound and music, and comprise simple, hands-on activities using every day materials.

The simple, every day nature of the materials used is one of the greatest strengths in these workshops. As the materials are familiar, teachers feel comfortable using them and experimenting with them, consequently leading teachers to trust the understandings they gain from such experiments (Perera, 2010).

The SQSC workshops are typically conducted in a centrally located school in the area and run for approximately two hours after school, as a one-off event. These are the same workshops that were intended to be used in the main research hence it was necessary to gain an understanding of how the workshops were received by pre-service and in-service teachers, and what kind of information could be collected from studies surrounding their use.

The aims of the workshops are for teachers to engage in the science activities, experiment, become comfortable and familiar with the science behind each activity, have fun, and to leave with ideas and resources to use in their classrooms. These workshops draw upon Bandura’s (1997) four sources of efficacy — in particular that of
mastery and vicarious experiences — by allowing the participants to experience successful completion of the science activities, either themselves or through observing the success of others. Successful completion of the activities and understanding the science content of the activities in the workshops could therefore be expected to assist in the development of positive self-efficacy towards science teaching (Palmer, 2006b).

The workshops are relaxed and informal, facilitated by collegiate groups and the provision of refreshments assists in the reduction of fear or anxiety that teachers may have about not knowing what to expect or what to do in the presented activities. The support from the workshop presenters provides boosts of verbal persuasion through encouragement and positive feedback. The activities use simple materials such as straws and plastic cups to demonstrate basic scientific principles. Teachers are able to work through the activities at their own pace, either individually or with others, and the opportunity is taken part-way through the workshop for the group to share their experiences and ideas on how to include or extend the activities in their class.

The style of these workshops is recommended by Cantrell et al. as providing a “…safe climate for risk-taking and ample opportunities for vicarious experience, positive physiological and emotional arousal, and social persuasion…” (2003:190), which assists in the development of efficacy beliefs. The hands-on nature of the workshop activities actively engages the teachers in the learning process. This provides the advocated emphasis on constructivism and the application of science to the real world, and a model of how such subjects can be incorporated into the classroom (So & Watkins, 2005). The use of everyday materials in the workshops, negating the need for specialised equipment, also helps to make science more accessible and relevant to the participants, both in the workshop and in terms of relevance to the primary school setting (Palmer, 2006b).

Overall, the workshops are designed to engage teachers in science by making it fun and accessible, removing the fear often associated with science activities, and creating a positive science experience. Ginns et al. support the use of this kind of workshop, stating that “…relevant, positive science experiences specifically designed to enhance [teachers’] sense of science teaching efficacy may prove to be an effective strategy” (1995:7).
4.2.1 Testing with in-service teachers

Over the 18 month pilot study survey period, workshops were delivered to 532 teachers in Victoria, Queensland, Tasmania and the Northern Territory by the SQSC presenters. 142 useable surveys were collected — a response rate of 26.7%. The purpose of the pilot study was to gather information to guide the development of this larger doctoral study. Chiefly, the aims of the survey were to find out what teachers’ attitudes were towards science; what motivated them to attend the workshops; if the workshops were useful in any way to them (either attitudinally and/or through the provision of ideas and resources) and to get an indication of the demographics of the teachers that attended the workshops. From the findings of the pilot study (which are described briefly here), the suitability of the workshops for use in the current research could be established, and a clearer understanding of the issues and attitudes of teachers from a broad cross section of the Australian teaching population could be achieved.

The results indicated that the workshops attracted a wide range of teachers, from those who were fairly new to the profession through to those who had been teaching for more than twenty years. The respondents were asked if they had received any formal science training during their teaching qualifications or any qualification prior or afterwards. Of the 142 respondents, 43.7% stated that they had completed some science subjects, 45.1% did not have any science background at all and 11% did not answer or did not provide valid responses. A Spearman’s correlation of the survey results found that irrespective of how long participants had been teaching, there was no statistically significant relationship found between a teacher’s experience and how confident they felt about teaching science ($\rho(140) = 0.027, p \text{ (two tailed)} > 0.05$). The mean confidence level for the respondents was 3.4 - a neutral score tending towards confident, however the confidence level was not strongly positive. Therefore it could be hypothesised that the majority of primary teachers do not feel confident teaching science at any stage of their career. This is supported by the studies of Goodrum et al. (2001) and Appleton (2002; 2003) as discussed in earlier chapters.

Correlations did show a strong positive relationship between respondents’ confidence in, and enjoyment of, teaching science ($\rho(140) = 0.660, p\text{(two tailed)} < 0.01$). Thus it could be further hypothesised that teachers who enjoy science are likely to feel more confident in teaching it, which may in turn lead to them teaching more science, more often. During the delivery of the workshops, several participants remarked on how they wished that they had done something similar to the workshops when they were studying
to be a teacher. This suggested that the participants felt their approach to science teaching could have been positively influenced during their training. These comments triggered the research question pertaining to the usefulness of these workshops (or informal education providers such as science centres) in pre-service teacher training.

Participants were asked what factors motivated their decision to attend the workshops. Attendance was generally driven by a desire to improve their science teaching skills and an interest in science. For many respondents, word of mouth about the nature of the workshop content and the reputation of Questacon as a provider was incentive. For other participants, the incentive to attend was a directive from a head teacher or principal. Despite being ‘forced’ to attend, these participants still ranked their experience as very positive and useful, but this does raise the question of how a school environment can influence the teaching of science, which was also considered in the current study. This has been examined previously by Lewthwaite and Fisher (2004) and in a more recent study by Nir and Bogler (2008), which found that the level of support of the principal and the environment in which workshops are delivered all influence the effectiveness of professional development interventions.

All respondents indicated that the workshops were very useful to them, with 65.0% of respondents saying that the workshop met their expectations, and 34.0% saying that they exceeded their expectations. Participants were asked to indicate what they took away from the workshops. They could select multiple responses from a list, and results showed that the workshops were considered particularly valuable in providing ideas (64.1%) and resources (51.4%) they could use in the classroom. Just over a quarter of the participants (27.5%) indicated that the workshops had given them more confidence in their ability to teach science, and 19.0% felt that they left with a better understanding of science. A typical comment given by participants as to the most valuable aspect of the workshops was “Noticing enthusiasm and confidence increase in all as we proceeded around activities” (emphasis respondent’s own). Even during this short time frame, the teachers were able to self-assess and recognise a change in their own feelings towards science activities.

Respondents were also asked to indicate if they ‘found out’ (as opposed to ‘learnt’, given the difficulties associated with accurately quantifying learning) the science behind the activities in the workshops. This question was asked to ascertain how the participants used the workshops, and what factors could be identified as potentially having the most influence. The majority of respondents (71.3%) stated that they had
found out all of the science behind the workshop activities, while 26.9% said that they had found some but not all. When asked how they found out the science, the vast majority (91.6%) read the instructional sheets with each activity, 55.5% tried the activities themselves and 53.5% discussed the activities with the other teachers present. Almost half of the participants (48.0%) stated that they also discussed the activities with the workshop facilitators. This supports the literature which argues the importance of collaborative learning (for example Desimone et al., 2002; Penlington, 2008) and to an extent the importance of a supportive school environment (Lewthwaite, 2001).

Due to the nature of the pilot study it was not possible to track teachers to determine if they did indeed actually use the resources and ideas they gained from the workshop in their classrooms. This, among the other findings generated by this pilot study, identified the need for a longer term study to be conducted and provided evidence as to the suitability of the workshops for use with in-service teachers. Additionally, these preliminary findings also support further research into the influence of the school environment and of using groups of teachers from the same school as a study population.

4.2.2 Testing with pre-service teachers

Preliminary work was conducted, by the author of this study, with a group of second year Bachelor of Education (Primary) students at an Australian university. The purpose of this preliminary test was to examine the suitability of these workshops for pre-service teachers, and to identify if the short term influences were of a similar nature to those seen in the in-service pilot study. The students participated in two hands-on workshops, one near the beginning of their second semester and the second near the end of second semester. The workshops used were the same ones used in the original pilot study (sound and music, physics, fluids), with the addition of a slightly different style of workshop (which contained a short lecture element instead of just hands-on activities and informal discussion) on climate change. An excerpt of the activities from the workshop resource booklets is provided in Appendix C as an example of the workshop content.

Participants were asked to complete short questionnaires after each workshop to measure their confidence in and enjoyment of science; to identify what was the most positive and negative aspect of the workshops; and to see if there was anything that made them feel more confident in their ability to teach science.
After the first workshop the average scores respondents gave to their confidence and enjoyment were 2.7 and 2.9 respectively, using a scale where 1 was not at all confident/do not enjoy at all and 5 was really confident/really enjoy. After the second session these scores had increased to 3.2 and 3.1 respectively. One participant responded that they were somewhere between a 3 and a 4 “after today”. This overall slight increase in self assessed confidence and enjoyment of the pre-service teachers might be attributed to the progression of their semester’s work. This is consistent with Hudson (2006) who found that second year pre-service teachers were more likely to show significant increases in confidence at the end of coursework. However many of the comments made by the participants indicated that the workshops had contributed in some way, for example:

\[
\text{I felt that having understood why things were happening allowed me to have a greater knowledge of the experiment conducted. Therefore when teaching the subject I would be more confident answering queries and explaining why things happen.}
\]

\[
\text{The fact that everyday items were used to conduct simple experiments [made me feel more confident]. It puts science within my reach so to speak.}
\]

Based on the preliminary findings from both pre-service and in-service pilot study groups, the use of the SQSC workshops was deemed suitable for the purpose of this research for both target groups.

4.2.3 Workshop format used in the current research

The workshops used by the SQSC are typically delivered as a one-off PD, with four science topic ‘stations’ containing several experiments set up in a room. Teachers can rotate from experiment to experiment and topic to topic as they like. The workshops are usually held after school hours, typically starting around 4pm and lasting for up to two hours. For the purposes of the current study, the workshops were to be divided into four sessions (one for each topic covered - sound and music, fluids, physics and climate change) to provide a continuing PD experience. The rationale for this was that teachers could do all of the experiments in the one topic during the session, as well as discuss the activities with their colleagues, providing a more in-depth experience. The participants then had the opportunity to use some of the activities in class in the intervening week/s. At the next workshop they discussed, with the researcher and their own colleagues, how the activities were received by their class and their own personal experience in teaching
them. The resulting continuing PD structure of the workshops employed in the current study provided the opportunity for in-depth exploration and reflection by the participants, facets identified as key to the provision of effective PD (Ingvarson et al., 2005).

4.3 Study design

4.3.1 The Evolution of the Study Design: Recruitment - pre-service teachers

Initially two Australian universities that offered four year Bachelor of Education (Primary) programs within the same city in the Australian Capital Territory (ACT) were approached to participate. One declined stating that they felt their method of instruction was too similar to the style of workshop ‘intervention’ this research would use, hence using their students would not yield any useful results. The other university agreed to participate and assisted in the recruitment of participants.

The course structure of the participating university is that of a four year full-time (or equivalent part time) undergraduate degree. For successful completion students must complete 320 credit points of units, 100 of which are curriculum foundations units. These comprise 20 credit points each in English, mathematics and science plus other core theology or philosophy subjects and/or an elective, depending on whether or not accreditation to teach in religious schools is being sought by the student. The remaining credit points are accredited through the completion of curriculum and pedagogical units and electives. In addition, over the four years the students are expected to complete 80 days of supervised teaching and 20 days of ‘school and community based learning’ which is typically completed in environments external to the school classroom such as informal education institutions or education centres within specialist organisations.

The initial research design was quasi-experimental in nature (Campbell & Stanley, 1963 in White & Arzi, 2005). One group of final (fourth) year students (Group 1) was to be surveyed at the end of the year to find out their attitudes towards teaching in general; science teaching and to measure their science teaching self-efficacy. The surveys would then be repeated 6 and 12 months later and the participants interviewed at these times. Group 1 would not have completed any workshops, effectively providing a ‘control’ group. The second group to be included was to be sourced from the next cohort of final year students in the following year (Group 2) with the first surveys (as those described previously) being administered in the first half of their final year. This cohort would have then participated in the series of workshops and completed another series of the
same surveys immediately following the completion of the fourth and final workshop. The group would then have been surveyed and interviewed at the completion of their degree (approximately 6 months later) and again the following year after they had been teaching in schools for approximately 6 months. Any participants who were not teaching in a school environment would be precluded from participating in this final aspect of the study.

A third cohort (Group 3) was initially going to be included. This group would have been selected at the same time as Group 2 and would complete the same timeline and process of workshops, surveys and interviews. This group was also to undertake a work placement at an informal science education institution, such as a science centre.

In September 2007 an invitation to participate in the study was sent to the potential Group 1 cohort via an email from their year coordinator. From a pool of approximately 40 participants, not one response was received. Due to the proximity of the invitation being sent to the completion of the classes for the semester, there was not any opportunity for a face to face presentation to provide more information and try to attract participants that way. A reissue of the invitation by email failed to receive a response. This necessitated a rethink of the structure of the research program, which then expanded to incorporate two groups of in-service teachers.

In February of 2008 at the beginning of the first semester for the year, the invitation was sent to the commencing fourth year students. This invitation used slightly different language than that of the previous, taking a more informal, ‘marketing’ approach focussing on attracting those students who wanted more confidence, ideas and resources to teach science and some free professional development. A copy of the invitation is in Appendix D. From a cohort size of approximately 40 students, 14 responded stating that they would like to participate.

### 4.3.2 Recruitment - in-service teachers

The initial study design was going to compare the pre-service study groups (2 and 3) with two groups of in-service teachers who would follow the same fieldwork process and timeline — including the in-service group undertaking a work placement at an informal science education institution.

An ACT primary school was invited to participate, based on the earlier approach by their deputy principal to Questacon (their local science centre) for a professional development session as a part of their school planning day. The deputy principal issued
an invitation to their staff to participate and from a potential cohort of 15 teachers, 7 elected to participate.

To test the notion of the influence of a teacher’s attitude to science as much as possible, the teachers who were (local) members of Questacon — and thus arguably more positive about science or at least positively oriented towards teaching it — were invited via email to participate in the study. Only those teachers who were teaching in primary schools were selected, leaving a potential cohort of about 60 teachers. Emails were followed up either via further email or phone call and any interested participants were sent information sheets (see Appendix D) about the study. Some members had recently changed to non-teaching roles (such as principal) and offered to recruit someone else from their school instead. After three weeks of an intensive recruitment campaign, five participants had volunteered. As each respondent indicated their willingness to be involved they were given a time line of when they would be contacted next to arrange dates and locations for the workshops, but were invited to get in touch should they have any queries or concerns prior to then.

When attempting to arrange the logistical aspects of the workshops with the group, an email was sent outlining the different options for location and participants were told that a time and location that suited the group as a whole would be selected. Within two weeks of this email being sent out, two participants had withdrawn due to “over commitment of their time” and a further two participants did not ever respond to repeated efforts to contact them. The one remaining participant who had responded with their availability was notified that it was unlikely that this particular group would go ahead in the research project, but they were more than welcome to still attend the workshops, either with other groups or individually at a time of their choosing, without the need to complete any surveys or interviews. This offer was not taken up.

At a teacher information night held at Questacon, information leaflets about the research project were made available to those teachers in attendance. Of 19 attendees, one teacher was interested in the study and asked if they could distribute it around the staff in their primary school in a neighbouring New South Wales (NSW) area. Follow-up with this teacher resulted in 10 teachers electing to be involved in the workshop.

Given the difficulties of recruiting participants in the first place, it was determined that the inclusion of the work placement option of the study (Group 3) would not provide a sufficient number of participants, from either pre-service or in-service groups, for the
results to be very accurate or interpretable. Therefore this aspect was removed from the study. A flowchart of the evolution of the research design is provided in Figure 3.

**Figure 3: Flow chart showing evolution of study design in response to recruitment difficulties**

Initial ethics submission. Approved

Approached two Universities

One Uni declines

One Uni accepts. Pilot studies conducted. Attempt to recruit 4th years (“control” Group 1). Unsuccessful

Study design redeveloped. New ethics submission made and approved.

ACT Primary school approached. Participants recruited.

Next final year cohort at participating Uni approached. Participants recruited.

Science centre teacher members approached. Limited uptake and near immediate loss of all participants.

Information distributed at science centre teacher information night. Interested teacher from NSW recruits colleagues.

Ethics resubmission for amendment to study cohorts. Approved.

Fieldwork commences
4.3.3 Retention of participants

One of the biggest challenges in the first few weeks of the fieldwork was the retention of the already small number of participants. The key determining factor for a participant to remain included in the study was the completion of the four workshops. These were held at the time and location negotiated to suit the best interests of each of the different study groups. Aside from the completion of the four workshops, the participants must also have completed the research instruments at the prescribed times so as to ensure comparability within and between groups.

To assist in the retention of the participants, each participant was offered a certificate for their curriculum vitae (an example provided Appendix D) upon completion of the four workshops, and a $50 gift voucher for them to use as they saw fit at a local bookshop (which stocks many educational texts and resources) if they completed all of the workshops and all the necessary surveys and interviews for the study. This assisted in attracting and retaining participants, with many expressing pleasure at receiving something for being involved. It also provided a suitable answer to the occasional teacher who asked at the first workshop “so are you paying us for this?” The question may have been intended as tongue in cheek, however the information that they were receiving a book voucher if they completed the entire study did come as a pleasant surprise to them.

The inclusion of refreshments at each workshop also contributed to making the workshops a pleasant experience and contributed to the informal, social feel. As the workshops progressed, many teachers began bringing in their own contributions, creating an almost festive atmosphere as the participants shared food, along with ideas and experiences arising from the completion of the workshop activities.

From the pre-service group of 14 students, preferred times and locations for the workshops were negotiated, with their class timetables necessitating two sessions to accommodate all participants. Within the first two weeks of the workshops beginning, three participants did not show up and subsequently withdrew and a further two withdrew after the first workshop citing a lack of time and too many other competing demands. A total of 9 students from the pre-service group completed all of the workshops. All except for one were teaching in school the following year. This participant’s data was excluded from the study, leaving a final pre-service study cohort of 8.
From the ACT primary school, 7 teachers elected to participate and all completed the set of workshops, and all surveys and interviews. From the NSW primary school, 10 teachers elected to participate and all completed the first workshop. Three teachers did not return to do the remaining workshops citing other demands on their time preventing their involvement, and one final teacher did not attend the last workshop due to illness, and thus did not complete the necessary set of research instruments at that time. Numerous approaches to arrange an alternative time to complete the workshop and the research instruments did not yield a timely response, which was exacerbated by the end of term holidays. Given the length of time that had elapsed between the remainder of the group completing their workshops and surveys, even if this participant had rescheduled their final workshop and submitted their instruments, their results would not be comparable with the rest of the group so this participant was withdrawn from the study. A total of 6 teachers from the NSW primary school completed all of the workshops, surveys and interviews.

**4.3.4 A challenging research population**

From a potential overall study cohort of approximately 73 people (combining the in-service and pre-service groups), there were 31 participants at the commencement of the study. Twenty one participants completed the whole study, a retention rate of 67.7%. This retention is better than other published studies in the same field. For example, Watters and Ginns (2000) reported a retention rate of 14.3%, Woolfolk Hoy and Burke Spero (2005) retained 54.7% of their participants and Palmer (2006a) kept 36.7% of his initial study population. Thus in comparison to other research in the same field, the retention of participants in the current study can be considered to be very good.

The recruitment and retention difficulties described in the same geographic region are not unique to this study. In her unpublished Honours thesis, Pollari (2008) outlines similar difficulties attracting pre-service and in-service teachers to her ACT based study, including a refusal to participate from the same University which declined to assist in this research project. The difficulties Pollari experienced in attracting primary teachers also necessitated several amendments to her research design and ultimately greatly limited the number of participants in her study.

These recruitment issues were not entirely unexpected due to the context in which this study was conducted. The ACT is a small geographic region therefore the population size from which a sample can be drawn is limited. Secondly, the time available for the
recruitment of participants to this study (within the overall research timeline available for a doctoral degree) necessitated the use of the most time efficient and easily accessible population as possible. The recruitment phase of this research (including pilot testing and the necessary resubmissions for ethics clearance due to the number of study design changes) took approximately eight months. This was because of the availability of the identified potential participant cohorts due to school and university term breaks, and the availability of the staff contacts within the identified institutions that were necessary to facilitate the recruitment process.

In order to ensure the completion of this study within the available time, the decision was taken to use the participants that had been recruited and begin the research, as it was unlikely that any further expenditure of time and energy would yield significantly greater numbers of participants from other schools. Posnanski (2002) supports this decision. In his study of the effect of a professional development model on in-service teachers efficacy beliefs, he was unable to attract a ‘critical mass’ of teachers; no more than two to four from each school were willing to participate. As discussed in Chapter 2, several other researchers experienced similar difficulties leading to small sample sizes in their studies (see Judson & Lawson, 2007; Roehrig & Luft, 2006; Watters & Ginns, 1995; Woolfolk Hoy & Burke Spero, 2005). Therefore the retention of 13 teachers from two primary schools in this context was good. This is supported by White and Arzi who state “usually, researchers have to work with whomever they can get. This is particularly the case with longitudinal studies, which require commitment from the subjects of the research for a long period” (2005:141).

Even from these few examples it can be seen that studies involving teachers (be they pre-service or in-service) and longitudinal designs are highly susceptible to attrition, necessitating preventative and compensating measures.

4.3.5 Small sample sizes in education research

As discussed in sections 2.3.5 and 4.3.3, there are many inherent challenges in attracting and retaining teachers for use in research. Beginning teachers feel overwhelmed by the demands of their first teaching year, let alone any extra requirements of their time to participate in research (Luft, 2007). Even pre-service teachers tend to be overwhelmed by the perceived demands of participating in research, as shown through the early withdrawal of five students from this study due to logistical or personal problems.
The studies with small sample sizes (see Watters & Ginnns, 2000; Woolfolk Hoy & Burke Spero, 2005) used qualitative research methods, which minimised the need for large numbers of study participants (Patton, 1990 in McLoughlin & Dana, 1999). The desired outcome of the research is also important in determining how many participants are required for the results to be useful. If the research aims to contribute to creating new knowledge connections and understanding of a particular topic, as it is in this study, then even the use of only one participant is acceptable if the depth of the study is sufficient to allow the knowledge connections to be made (Donmoyer, 1990).

Cantrell et al. (2003) advocates the use of entire cohorts as a means of strengthening results that could be affected by participant attrition. However, a longitudinal study with a cohort is highly susceptible to unrepresentative results as numbers can be greatly affected by students missing testing sessions, providing incomplete responses or not providing consistent identifiers to allow for the accurate pairing of response sheets (Palmer, 2006a). Irrespective, Palmer still recommended the use of a single large cohort from within a highly structured program (to minimise students missing sessions) for such studies, however this would not address the problem of incomplete answers or identifiers. Palmer incorporated multiple research methods (formal and informal surveys and individual interviews) to compensate and to provide cross checks of the data. This multiple method approach was used in the current study to ensure that the results were as sound as possible.

The use of a single large cohort was not necessary or possible for the current research, so three smaller cohorts were used. Judson and Lawson (2007) employed a similar approach in their research, using two small cohorts (of nine and 16 teachers) from two different schools. They maintain that the use of the two groups from within two different contexts increases the ability to generalise the results of the study as “…the use of two groups …each within a different content domain, makes it less likely that study results will be due to local circumstances…or will be linked to content-specific factors” (p493).

The nature of this study was not intended to be prescriptive, so much as descriptive and indicative in order to provide the reader with “…sufficient information and analytic detail that he or she may understand the particular in enough depth to utilise the information in other applicable contexts” (McLoughlin & Dana, 1999:73).
4.3.6 Study design for all cohorts

The final groups of participants were pre-service teachers, one ACT primary school cohort, and one NSW primary school cohort. At the initial session, each participant completed a generic ‘About You’ survey which asked about their teaching experience, science background and strengths and fears about science teaching and teaching in general. Two questions also asked participants to rate their confidence in, and enjoyment of, science teaching. Participants in each cohort provided responses to the appropriate efficacy survey (STEBI A for in-service teachers, STEBI B for pre-service) throughout the study period. Immediately after the completion of the final workshop, participants completed the STEBI surveys and a general feedback survey which asked again about their confidence in, and enjoyment of, science teaching. They were also asked whether they had used, or intended to use, any of the activities covered by the workshops in their class. This general feedback survey was included to provide a basic indication of what immediate influence the workshops may have had on the teachers’ perceptions of science and their intent.

In-service teachers provided responses to the SCIQ survey at the same time as the STEBI. The pre-service teachers were only given the SCIQ in the last sample period as prior to this time they were not working full time within a school environment, therefore could not provide valid responses to this context based survey. The influence of the pre-service teachers’ context was captured during two semi-structured interviews. Conducted with all participants (including in-service), these interviews provided background about participants’ previous experiences with science and the greatest influences on their confidences and fears pertaining to teaching. This combination of quantitative and qualitative research instruments, conducted over a 12 month period, provided a richness of data which complemented the numbers.

Each cohort received four (4) workshops on a particular science topic, as tested previously with in-service and pre-service teachers. Workshops were delivered approximately on a fortnightly basis, although scheduling conflicts once caused approximately four weeks to elapse between workshop sessions for the NSW participants. Participants were able to select their preferred location and time for the workshops to be held, which was determined by the group and honoured by the researcher. The topics covered were climate change, physics, fluids and music. Each workshop ran for up to one hour and was facilitated by the researcher to engender an informal, collaborative environment for the participants. At the completion of each
workshop, each participant received an electronic copy of the supporting resource booklet. Participants were also invited to contact the researcher for any other ideas or resources they required or were interested in throughout the study period. An indicative guide to the timing of each aspect of the fieldwork is provided in Table 5.

Table 5: An overview of the indicative timings for each component of the study fieldwork, and the instruments used for each cohort. (STEBI = Science Teaching Efficacy Belief Instrument: STEBI A = for in-service teachers; STEBI B = for pre-service teachers; SCIQ = Science Curriculum Implementation Questionnaire)

<table>
<thead>
<tr>
<th>Timing</th>
<th>Instrument</th>
<th>Cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre-service (n = 8)</td>
</tr>
<tr>
<td>February/March 08</td>
<td>Demographic survey</td>
<td>✓</td>
</tr>
<tr>
<td>(Period 1)</td>
<td>STEBI A</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>STEBI B</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>SCIQ</td>
<td></td>
</tr>
<tr>
<td>March - June 08</td>
<td>Workshops</td>
<td>✓</td>
</tr>
<tr>
<td>June 08</td>
<td>STEBI A</td>
<td>✓</td>
</tr>
<tr>
<td>(Period 2)</td>
<td>STEBI B</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>SCIQ</td>
<td></td>
</tr>
<tr>
<td></td>
<td>General workshop feedback</td>
<td>✓</td>
</tr>
<tr>
<td>October 08</td>
<td>STEBI A</td>
<td>✓</td>
</tr>
<tr>
<td>(Period 3)</td>
<td>STEBI B</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>SCIQ</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interview</td>
<td>✓</td>
</tr>
<tr>
<td>May 09</td>
<td>STEBI A</td>
<td>✓</td>
</tr>
<tr>
<td>(Period 4)</td>
<td>SCIQ</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Interview</td>
<td>✓</td>
</tr>
</tbody>
</table>

4.4 Data analysis

For each survey instrument, participants were asked to include an identification code (their initials and date of birth) to allow for a comparison of each individual’s responses
over the different survey periods. As the aim of this research was to determine if self-efficacy beliefs have been affected, comparisons of beliefs before, immediately after and two delayed post-intervention measures were taken and compared.

### 4.4.1 STEBI A and B analysis

Both versions of the STEBI used in this study asked respondents to indicate their level of agreement with the item based on a five point Likert scale where 5 is strongly agree, 4 agree, 3 is uncertain, 2 is disagree and 1 is strongly disagree. Each instrument has two scales, the efficacy belief (PSTE) scale and the outcome expectancy (STOE) scale, the items for which are scattered randomly throughout the STEBI instrument. For both instruments, some items are reverse scored so as to “produce high scores for those high and low scores for those low in efficacy and outcome expectancy beliefs” (Enochs & Riggs, 1990:706). The STEBI A consists of 25 items, while the STEBI B uses 23 items. For each instrument the PSTE and STOE scales are added using the scores described to generate a score for each scale. The composition of the scales, reverse score items and score ranges for each scale for each STEBI instrument are shown in Table 6.

**Table 6: Overview of items included in efficacy belief and outcome expectancy scales, and reversed score items in the STEBI A and B instruments**

<table>
<thead>
<tr>
<th>Composition</th>
<th>STEBI A</th>
<th>STEBI B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reversed score items</td>
<td>1, 2, 4, 5, 7, 9, 11, 12, 14, 15, 16, 18, 23</td>
<td>3, 6, 8, 10, 13, 17, 19, 20, 21, 23</td>
</tr>
<tr>
<td>Efficacy belief scale (PSTE)</td>
<td>2, 3, 5, 6, 8, 12, 17, 18, 19, 21, 22, 23, 24</td>
<td>2, 3, 5, 6, 8, 12, 17, 18, 19, 21, 22, 23</td>
</tr>
<tr>
<td>Range of scores for PSTE Scale</td>
<td>13 - 65</td>
<td>13 - 65</td>
</tr>
<tr>
<td>Outcome expectancy scale (STOE)</td>
<td>1, 4, 7, 9, 10, 11, 13, 14, 15, 16, 20, 25</td>
<td>1, 4, 7, 9, 10, 11, 13, 14, 15, 16</td>
</tr>
<tr>
<td>Range of scores for STOE Scale</td>
<td>12 - 60 (10 - 50)</td>
<td>10 - 50</td>
</tr>
</tbody>
</table>

Typically, analysis of these instruments involves factor analysis. Due to the small sample size used in the current study, this was not possible. The alternative steps taken to maximise the internal reliability and construct validity of both PSTE and STOE scales are as follows.
1. Prior to analysis, the results obtained at the final administration of the STEBI A (Time 4) and STEBI B (Time 3) were analysed for internal reliability using Cronbach’s alpha. The STEBI A returned alphas of 0.91 for the PSTE scale, and 0.78 for the STOE scale. These are almost identical values to those obtained by Riggs and Enochs (1990) who achieved alpha values of 0.92 for the PSTE and 0.77 for the STOE. Robinson, Shaver and Wrightsman (1991) set a generally applied minimum threshold for an item to be included in the STEBI analysis which is a corrected item-total correlation value of 0.3. Examination of the PSTE scale found all items with corrected item-total correlations above 0.3. In the STOE scale, items 9 and 20 were below the 0.3 threshold and were excluded from all analyses of the STEBI A. The next iteration also found item 14 to fall just under the 0.3 threshold but the removal of this item had a minimal (<0.005) impact on the alpha so item 14 was retained. The final Cronbach alpha for the STOE scale was 0.81. Thus the range for the STOE scale for the STEBI A for this study is now 10 - 50 as shown in brackets in Table 6.

2. The STEBI B alphas at Time 3 were 0.90 (PSTE) and 0.86 (STOE) with no item showing a corrected item-total correlation value below 0.3, so no items were removed. The alpha values obtained were equivalent to those given by STEBI B developers (Enochs & Riggs, 1990), who achieved 0.90 for the PSTE scale and 0.76 for the STOE. As an additional check, each time the STEBI B was administered, the alphas for the PSTE and STOE scales were calculated. The STOE scale showed a gradual increase in alpha value each time. This signified the increasing confidence the pre-service students felt in their ability to achieve outcomes, despite not truly understanding the role of teacher as they were not working in a school full time yet.

The scores for the PSTE and STOE scale for each individual were calculated and monitored after each administration of the STEBI surveys to assess if any changes in beliefs were occurring over time. The calculation of individual scores for each scale assisted in the identification of any participant who had negative efficacy beliefs, and allowed the tracking of any changes in self-efficacy beliefs through the study (Palmer, 2006a). These scores were also compared with the demographics of the participants to see if factors such as teaching experience or science background had any association with the beliefs of participants in this study (Bleicher, 2004).
Additional analyses were conducted on cohort level data. Research period and cohort effects on scores were tested using a linear mixed effects model using an AR(1) correlation structure. Research period and cohort were the fixed effects in the model, and individual was the random effect. Research period and cohort interactions were also tested. P-values less than 0.05 were considered statistically significant. The IBM Statistical Package for Social Science (SPSS - version 16 and version 19) was used for all analyses.

4.4.2 SCIQ analysis

The means of each of the scales included in the SCIQ were calculated to identify any general trends of perceptions as per Lewthwaite (2001; 2005). If it was required to gain extra depth in understanding of the data, the means of individual items were also calculated, as described in section 4.1.5. The degree of consistency amongst respondents for each scale was calculated through the use of standard deviations. Again, these were calculated for individual items if required. The same linear mixed effects model analyses were also conducted on the SCIQ data.

4.4.3 Semi-structured interviews

For each of the interviews conducted, participant responses were transcribed in full. An example of one of the interview transcriptions is provided in Appendix B. From each interview, quotes that expressed a need, challenge or positive aspect of science, science teaching and teaching in general were identified (as per Finkelstein, 2005). These responses were then examined for common words and themes from which a coding system was developed which allowed for the data collected to be compiled into categories. For example, any response that referred to books, equipment or a specialist teacher was coded as resources. The use of a coding system assists in the identification and definition of ideas which “...at first were nebulous so that they can be refined and expanded” (Singh & Shifflette, 1996:149).

The coded interviews were then examined at an individual and group level. Individual responses were compared for the two interview periods, looking for any attitudinal changes of the participant towards science or teaching. Similarities and differences between pre-service and in-service participant groups were also identified. Participant responses in the interviews were then examined in conjunction with the data collected through the two survey instruments throughout the research period.
4.5 Ethical considerations

4.5.1 Protection of participant confidentiality

The information being collected in the current study was not likely to be considered sensitive or confidential; however participant anonymity was protected. All documents containing the names and contact details of participants were stored securely, in password protected computer files, and (in the case of hard-copy material and audio tapes) in a locked filing cabinet. These details were not disclosed to any person outside the research team. Documents containing personal information were destroyed securely by deleting computer files and shredding any paper copies printed. De-identified material was stored in archives to assist future research. All names reported in this thesis are pseudonyms.

Participants were informed that it may be possible to identify a participant from the substance of their comments, even though comments were not attributed to their name. Participants were also informed that their comments may be used in reports or other publications (unless they withdraw consent). This understanding allowed the participants to make appropriate decisions about disclosure of critical or identifying information. It is worthwhile to note however that the subject matter of this research is not one that particularly invites controversial disclosures.

4.6 Summary

Based on the gaps in knowledge and research needs identified in the literature reviewed in the preceding chapters, five research questions were identified for examination in this thesis. The current research was longitudinal, drawing on qualitative and quantitative research methods to ensure a comprehensive range of results that encompassed the beliefs, backgrounds and external influencing factors under which the in-service and pre-service teachers operated.

In order to gain the maximum amount of information, a combination of qualitative and quantitative instruments was required due to the small sample size used in this study. However, using small sample sizes is common within educational research (Cantrell et al., 2003; Palmer, 2006a) as teachers are notoriously time poor (Rennie et al., 2001), which limits their ability, and enthusiasm, for further commitment of their time. Pre-service and beginning teachers are focused on surviving their early years of teaching, and any additional requests for their time are often beyond the capacity of many to contemplate, let alone commit to (Luft, 2007).
The results obtained in this research will contribute to the understanding of how the beliefs of teachers are formed and influenced at various stages of their careers, and if the informal science education sector can be better exploited as a mechanism for positive change. The next chapter outlines the key findings of this research, providing the basis upon which implications and conclusions can be drawn and recommendations for future research made.
Chapter 5: Results

5.0 Presentation of findings from the current study

This chapter presents the results obtained from the use of the multiple instruments described in Chapter 4. The research questions identified in the preceding chapters will be used as the framework for the presentation of the results, with each research question being answered using data obtained from surveys and interviews.

The chapter first describes the participants and their career influences and teaching beliefs. The next section outlines the changes in their self-efficacy over the course of the study and how the workshops may have influenced this. The differences between the effects on the pre-service and in-service participants are presented in section 5.3. Section 5.4 examines how teaching experience may have influenced any changes in science teaching self-efficacy. Section 5.5 presents the data used to examine the influence of the school environment on teachers’ science teaching self-efficacy and perceptions of science. Finally, the participants’ perspectives of the potential role for science centres and museums with and for teachers are presented.

The aim of this chapter is to provide an overview of the main trends and impacts identified in the current study, allowing conclusions to be drawn in the next chapter and providing the basis for recommendations for future work.

5.1 The study population — demographics, career choice influences and fears

5.1.1 Description of research periods used in results

Each sample period of the study will be described as follows:

- Period 1: is the initial administration of the surveys prior to the workshops
- Period 2: is the administration of the surveys immediately after the completion of the workshops
- Period 3: is the completion of the surveys and first interview four months after the completion of the workshops
- Period 4: is the final administration of the surveys and the second interview which was conducted 11 months after the completion of the workshops
5.1.2 Study participants — demographics

The study population comprised 21 individuals: seven in-service teachers working within an ACT school; six in-service teachers working within a NSW school; and eight pre-service teachers who were beginning teachers in schools around Australia and the UK in the final data gathering phase. Table 7 provides an overview of the basic demographics of the study population, showing the age, teaching experience and science background of each of the participants. Pseudonyms will be used as identifiers throughout the results and discussion.

The cohorts vary in terms of age and teaching experience. The participants from the ACT school are typically older, late career teachers without any science backgrounds. One ACT participant (Susan) entered the teaching profession marginally later than her colleagues and via postgraduate entry, having previously worked as a librarian. The NSW participants were much more diverse with three highly experienced teachers, and three early career teachers, including one who was still a beginning teacher (Paul).
Table 7: Demographics of study population

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Participant</th>
<th>Age Range</th>
<th>Number of years teaching</th>
<th>Science Background</th>
<th>Additional contextualising information (where relevant to results)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT In-service</td>
<td>Paula</td>
<td>45 - 50</td>
<td>20+</td>
<td>None</td>
<td>Most fearful of science</td>
</tr>
<tr>
<td></td>
<td>Valerie</td>
<td>51 - 56</td>
<td>20+</td>
<td>None</td>
<td>Team teaches with Brian</td>
</tr>
<tr>
<td></td>
<td>Kerrie</td>
<td>51 - 56</td>
<td>20+</td>
<td>None</td>
<td>Limited teaching between sample periods 3 and 4 due to illness</td>
</tr>
<tr>
<td></td>
<td>Elizabeth</td>
<td>51 - 56</td>
<td>20+</td>
<td>None</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Lorraine</td>
<td>51 - 56</td>
<td>20+</td>
<td>None</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Brian</td>
<td>63+</td>
<td>20+</td>
<td>None</td>
<td>Acting deputy principal</td>
</tr>
<tr>
<td></td>
<td>Susan</td>
<td>-</td>
<td>15 - 20</td>
<td>Some units in postgraduate course</td>
<td>Most science positive participant</td>
</tr>
<tr>
<td>NSW In-service</td>
<td>Hayley</td>
<td>57 - 62</td>
<td>20+</td>
<td>None</td>
<td>Support teacher</td>
</tr>
<tr>
<td></td>
<td>Simone</td>
<td>39 - 44</td>
<td>15 - 20</td>
<td>Basic science/biology unit in Dip Ed</td>
<td>Changed schools between sample periods 3 and 4</td>
</tr>
<tr>
<td></td>
<td>Tanya</td>
<td>27 - 32</td>
<td>4 - 6</td>
<td>None</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Lisa</td>
<td>27 - 32</td>
<td>4 - 6</td>
<td>None</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Paul</td>
<td>51 - 56</td>
<td>1 - 3</td>
<td>B. Ed with Environmental Studies and Science II</td>
<td>Changed schools after sample period 2; works in special needs school.</td>
</tr>
<tr>
<td></td>
<td>Anita</td>
<td>45 - 50</td>
<td>20+</td>
<td>One subject on Birds of Australia</td>
<td>Changed schools between sample periods 3 and 4</td>
</tr>
<tr>
<td>Pre-service</td>
<td>Anthea</td>
<td>27 - 32</td>
<td>&lt; 1</td>
<td>Two science &amp; technology units as part of Bachelor of Primary Teaching</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Kendra</td>
<td>21 - 26</td>
<td>&lt; 1</td>
<td>As above</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Jaeda</td>
<td>21 - 26</td>
<td>&lt; 1</td>
<td>As above</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Kate</td>
<td>21 - 26</td>
<td>&lt; 1</td>
<td>As above</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Peter</td>
<td>51 - 56</td>
<td>&lt; 1</td>
<td>As above</td>
<td>Teaching in Torres Strait in sample period 4</td>
</tr>
<tr>
<td></td>
<td>Vanessa</td>
<td>21 - 26</td>
<td>&lt; 1</td>
<td>As above</td>
<td>Informal education experience</td>
</tr>
<tr>
<td></td>
<td>Lauren</td>
<td>21 - 26</td>
<td>&lt; 1</td>
<td>As above</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Sam</td>
<td>21 - 26</td>
<td>&lt; 1</td>
<td>As above</td>
<td>Teaching in UK in sample period 4</td>
</tr>
</tbody>
</table>
5.1.3 What influenced the participants to become teachers?

During the first interview after the workshops had been completed (Period 3), further insight into the backgrounds and motivations of the participants was elicited by asking what factors influenced the participants’ decision to become a teacher. When the interview transcripts were sorted and coded according to key words, the influences could be broken down into five different groups:

- other teachers during their own education;
- opinions of family/friends and other teachers;
- a love of children;
- personal enjoyment of school/learning; and,
- a desire to make a difference.

The influence of teachers during the participants’ own education was evident through five respondents identifying them as a key influence in their decision to pursue a teaching career. In particular, high school teachers appeared to have greatest influence as shown by comments such as:

*I guess the teachers I had during high school would influence [my decision to become a teacher]...Later on in high school I liked my teachers so they had an impact (Lisa, interview Oct 08).*

*Other teachers in primary and high school — I had some really good teachers (Vanessa, interview Oct 08).*

The influence of teachers was also indicated in the responses related to the participant’s own enjoyment of school:

*A love of learning. A high school teacher encouraged me to learn and I really enjoyed learning and from that I wanted to become a teacher (Lauren, interview Oct 08).*

Having the support of a family member was also a strong influence, with seven participants indicating that this was one of the main factors influencing their decision to enter the profession themselves. In some cases, other members of the family were teachers; in others the family provided the impetus for the participant to pursue that career path as shown by the following response:
I really have no idea [what factors influenced my decision to become a teacher]. I think it was because my parents said once you become a teacher you can always fall back on it (Anita, interview Oct 08).

Of all 21 participants, four indicated that they wanted to make a difference and felt that they could best do this via teaching. Interestingly, each of these responses was provided by a pre-service teacher. In-service participants tended to refer more to their own love of children and learning, and of the influence of family and colleagues. Other participants provided some honest explanations of factors that began, in each of the following responses, teaching careers that have since spanned over 20 years:

I guess because that was the thing to do in my day. You became a teacher or went into the public service or a nurse, so I can’t claim any burning ambition to save the world (Kerrie, interview Oct 08).

My best friend signed up to be a teacher (Elizabeth, interview Oct 08).

It was a second choice. I went for an interview to be an occupational therapist and there were very limited places. There weren’t any, so I went into teaching (Hayley, interview Oct 08).

5.1.4 In-service participants’ science background and education

Of the in-service teachers, the majority recall doing science up to a certain level in secondary school and then not encountering it again unless they actively sought it out. Some typical responses indicate that science in high school was mandatory, thus the only reason it was chosen:

I was really off science when I was in Year 10 because we had to do all of them...biology, chemistry and physics...and then we had to choose one in year 11 and 12 and I chose biology because I just couldn’t get a handle on physics and chem. At all...I just struggled with it. I just didn’t enjoy it. It wasn’t my cup of tea (Paula, interview Oct 08).

I did physics and chemistry. I went through the old system to the intermediate and then I did biology to the Leaving Certificate. Whatever science we did at college and nothing else extra curricular (Hayley, interview Oct 08).

Other respondents indicated that they did some science during their teacher training, although it was minimal:
I didn’t really do much real science and didn’t do any at uni other than we had one subject that was five weeks of science and that was it…that’s really all I had (Tanya, interview Oct 08).

One of the in-service teachers did not ever attend a high school and became a teacher through vocational courses focussing on history, philosophy and education:

I have no background in science whatsoever, except for forestry, and no, I didn’t do a forestry degree. I didn’t go to forestry school, it was just I was doing photo assessment surveys in New South Wales in the late sixties/seventies...I don’t know about science, simply because I couldn’t do it by correspondence out in the bush; there was no facility (Brian, interview Oct 08).

One teacher tried to incorporate as many science subjects as they could during their teacher training (Paul) due to their own personal interest in science, while another simply had a passion for science and brought this to their teaching any way they could:

I have always been particularly keen on teaching science. I generally run my themes around science and it’s developed to where I am now the computer teacher however half of my curriculum is based on science...Science experiments are my life...No formal training, self taught (Susan, interview Oct 08).

5.1.5 Teacher training received by pre-service participants: did they perceive it as effective?

Each of the pre-service participants had completed a minimum of two units of science and technology as part of their degree. The majority of pre-service participants were female in their early twenties, one was late twenties to early thirties and the one male participant was significantly older, undertaking a career change. Many of the pre-service participants expressed that they felt their science exposure was minimal, with some admitting that science had not been a focus in their high school education or teacher training:

Whatever I’ve got at uni, only one subject was very practical...I don’t feel that one subject was enough to equip me to teach science in school...I remember doing a couple of science experiments in primary school. I attempted one semester of biology in college, but I got asked to leave...yeah it didn’t work out!...Growing up with science for me was
very much a “once every fortnight on a Friday afternoon” thing, it wasn’t a very important thing (Kate, interview Oct 08).

Others admitted that science had not been the greatest focus in their educational backgrounds, but also stated that they did not feel that the science that they were exposed to during their teacher training was enough:

Primary school was great...we did everything. Then years 7 - 10, it just didn’t captivate me for some reason...It wasn’t any particular teacher or anything, it just didn’t jump at me so I did the bare minimum. Years 11 and 12, I did no science at all, just avoided the whole thing. At uni we’ve done three courses which have been a total waste of time. I didn’t get anything out of it that I would think I could use in a classroom...(Sam, interview Oct 08).

My uni science wasn’t enough. It was only two units of science, I think they now do maybe one more, but I wouldn’t say that it was the best science education courses that I could have been exposed to (Vanessa, interview Oct 08).

I didn’t really walk away from our science lessons feeling like I learnt science (Kendra, interview Oct 08).

The pre-service participants were asked in the final interview, once they had been out teaching in schools for a term, if they felt that their university training had prepared them adequately for teaching in general. None of them responded with a wholehearted yes, the closest being from Anthea saying “yes, to a degree”. For the majority (7 out of 8) the responses were categorised as yes/no; typically in the affirmative for the theory that was provided, but acknowledging that more on the job experience was required in order to truly prepare them for the realities of teaching:

In many ways it has, but I think in many ways it never could have...there are some things, like I’ve never been shown how to write a report, but I don’t think the Uni could have taught me that because it is so different for each school (Jaeda, interview May 09).

This sentiment was echoed by Kendra who felt that:

It gives you so much theory but they miss out massive chunks like how to write good reports and how to deal with parental conflict. They totally
bypass all of that area. What they give you is good but they seem to have big chunks that are missing (Kendra, interview May 09).

This was supported by Sam who felt that the theory they were taught was not as useful as it could have been, and the time in class could have been better spent learning actual strategies:

*I feel that we did too much psychology based things...and that’s not what I needed. The thing that I find would have helped would have been behaviour management strategies which I didn’t learn at uni, that’s something I learnt from other teachers on prac* (Sam, interview May 09).

One respondent (Kate) felt that her university training did not prepare her at all for teaching, but rather it was the practical component of the course that provided the knowledge she felt she needed:

*I don’t want to say bad things about my University but I learnt the most I’ve ever learnt on my fourth year prac. I learnt about things like staff room politics, I learnt about pushing yourself to the absolute limit...although my [supervising prac] teacher last year did have very high expectations, I learnt so much that Uni certainly did not prepare me for. You know the little ins and outs of teaching that you don’t know until you are standing in front of seventeen kids and oh my gosh, they’re yours. There’s a lot of things they don’t prepare you for I must admit* (Kate, interview May 09).

One of the pre-service participants, who began teaching in a remote school in the Torres Strait in their first year out, found that their teaching environment influenced how relevant they felt their University training was:

*Probably if I was in the mainstream environment then 70 - 80% but up here probably only 20 - 30% worth of value over the four years...But I suppose there’s no university really that can teach you this unless you did two month prac every year in the four years or something like that* (Peter, interview May 09).

Overall it appears that the students felt prepared in terms of theory, but practical experience was the aspect that provided them with the best preparation.
5.1.6 Summary: participants’ background and influences

The majority of in-service participants do not have any scientific formal training. The pre-service participants have each done two subjects through the course of their teaching degree. Participant motivations for becoming a teacher can be categorised into five different groups: other teachers during their own education; opinions of family/friends and other teachers; a love of children; personal enjoyment of school/learning and a desire to make a difference. The desire to make a difference was most often cited by the pre-service group, with many in-service participants nominating the opinions or actions of friends and family as being a key factor in their career choice. The in-service participants did not have a formal science background, and admit that the manner in which science was taught when they were school students contributed to their lack of interest in the subject. The pre-service participants had each completed two units of science during their teacher training, however many do not feel that these subjects actually taught them, or made them feel comfortable teaching, science.

5.2 Research question 1: Did the workshops influence science teaching self-efficacy?

5.2.1 Validity of STEBI survey results

As described in section 4.4.1, the reliability of the Personal Science Teaching Efficacy (PSTE) and Science Teaching Outcome Expectancy (STOE) scales was maximised by the exclusion of items 9 and 20 from the STEBI A scale. The STEBI B was deemed internally consistent based on the Cronbach alpha values and no items were excluded. The changes in self-efficacy of the in-service participants observed in the current study are comparable to larger studies in the field. The mean values obtained for the STEBI A were 46.58 for the PSTE and 33.51 for the STOE. Other studies of self-efficacy changes in primary teachers, such as Riggs and Enochs (1990) used a much larger study population of 288 teachers and obtained higher average scores of 56.54 (PSTE) and 48.09 (STOE). Smaller studies such as those by de Laat and Watters (1995), obtained mean PSTE values of 49.6, and a mean STOE value of 33.9 from a population of 37 teachers. The means obtained in this study are comparable to the de Laat and Watters study, although the means are slightly lower.

The pre-test PSTE and STOE means from the pre-service participants (STEBI B) in this study were 46.38 and 36.06 respectively. A study by Watters and Ginns (2000) with Australian pre-service teachers yielded pre-test PSTE and STOE mean scores of 44.8
and 35 respectively. The study by Palmer (2006a) returned a pre-test PSTE mean of 43 and pre-test STOE mean of 34. The results of the current study show comparable pre PSTE and STOE means, indicating that the participants in this study are similar to other pre-service teachers in Australia.

The STEBI A and B surveys were administered four times throughout the study period. The pre-service cohort completed the pre-service teacher specific STEBI B survey on the first three times, and then completed the in-service specific STEBI A in the final sample period. The difference in scale size does not affect PSTE range. The difference in scale size would normally increase the STOE range at period 4 however the interpretation is the same. With two items excluded from analysis of the STEBI A STOE scores the range becomes 10 - 50 instead of 12 - 65.

The results for each individual are displayed by cohort (Figures 4 - 10) divided into the two scales (PSTE and STOE). The individual PSTE and STOE scores for each participant at each sample period are provided in Appendix E.

5.2.2 ACT in-service cohort: Changes in self-efficacy over the study period

Before interpreting the ACT teacher results it should be noted that for the three months preceding the administration of the final surveys (period 4), Kerrie had not been teaching due to illness. Between periods 2 and 3, Brian had changed positions to an administrative role, limiting his teaching time to a few hours a week.

Four of the seven ACT in-service participants showed quite low PSTE scores at the initial survey point, returning scores around the 30 mark out of a possible 65 (Figure 4). With the exception of Paula and Brian, all show an increase in their PSTE score immediately after the workshops (period 2 — see Figure 4). Although Brian did not show an increase in his score between period 1 and period 2, his initial PSTE score was just below 50, giving him a much higher efficacy belief than many of his colleagues to start with.
Figure 4: Comparison of PSTE scores (range 13 - 65) of ACT in-service participants across the study period.

All of the ACT in-service teachers show an increase in their PSTE score from the initial administering of the survey before the workshops (period 1) in comparison to the final administration of the survey some 11 months after the workshops (period 4 - see Figure 4). Susan consistently returns the highest PSTE scores of the cohort, even returning the maximum score of 65 on the PSTE scale at the sample period immediately after the completion of the workshops (period 2). Kerrie and Lorraine show quite large increases in their PSTE scores over the study period with Kerrie’s PSTE score increasing from 30 to 52, while Lorraine’s increased from 32 to 46.

The STOE scores for the ACT in-service participants gave inconsistent, and slightly confusing, results (Figure 5).
Figure 5: Comparison of STOE scores (range 10 - 50) of ACT in-service participants across the study period.

Of the seven participants only Paula, Elizabeth and Brian show an increase in their STOE scores over the study period. The remainder had fluctuating STOE scores, with the majority showing a decrease over the course of the study. In particular, Kerrie’s scores are most confusing. Her scores are illustrated in Figure 6. Her PSTE scores showed two increases and one small decrease throughout the study, however it appears that the greater her PSTE score, the lower her corresponding STOE score. Likewise, Paula showed minimal, non-sustained increases in her PSTE scores, however her STOE score increased at the final survey point, when her PSTE score returned to its original low level.

Susan, whose PSTE scores were consistently high (also see Figure 6), returned STOE scores that seemed to decrease over the study period, dropping to the second lowest STOE score of the ACT in-service cohort at period 4. Interestingly, her STOE and PSTE scores follow the same trends throughout — showing corresponding increases and decreases.
Elizabeth’s results (see Figures 4 and 5) showed consistent increases in her STOE scores; but the lowest STOE score corresponded with the greatest increase in her PSTE. Both sets of Elizabeth’s scores stabilised over the remaining two survey periods showing consistent increases or maintenance of the higher level.

The same is observable in Lorraine’s results (Figures 4 and 5). Whenever she returned a high PSTE result, the corresponding STOE score was decreased or lower. Whenever her PSTE score decreased, her STOE score increased, ultimately producing what appears to be a converse effect of the two scales, similar to that observed in Kerrie’s results. Possible reasons for these results will be presented in Chapter 6.

5.2.3 NSW in-service cohort: Changes in self-efficacy over the study period

Figure 7 shows the PSTE scores for the NSW cohort over the study period. It should be noted that Simone and Anita were teaching at different schools at the time of the final survey (period 4). In addition, Paul had been teaching at a different school for both periods 3 and 4, catering for students with special needs.
Of the NSW in-service teachers, all show an increase in their PSTE scores immediately after the workshops (period 2) in comparison to their initial score (period 1), with the exception of Tanya who maintained the same level. All NSW in-service participants showed higher PSTE scores at the final survey period (period 4) than they did at the initial (period 1). The increases in the NSW cohort were smaller than those seen in the ACT cohort, with Lisa showing the biggest increase from an initial score of 40 to 52 (at period 3) before settling at 50 (period 4). Simone also showed a large increase between periods 1 and 2, with her PSTE score increasing from 46 to 57. However this increase was not maintained and her final PSTE score was 48, marginally higher than her initial. Many of the participants did show a slight decrease in their PSTE score between periods 3 and 4, with the exception of Anita who showed an increase in her PSTE score, yielding her highest score out of the study period. Sample period 4 also coincided with Anita beginning to teach at a different school.
Figure 8: Comparison of STOE scores (range 10 - 50) of NSW in-service participants across the study period.

Four out of six of the NSW in-service participants (Hayley, Simone, Lisa and Paul) exhibited a lower STOE score at the final sample period than they did at the first (Figure 8). This is despite the fact that all of them exhibited higher PSTE scores at period 4 in comparison to period 1. For some participants, such as Hayley, Lisa and Anita, the initial increase in their PSTE scores was accompanied by a decrease in their STOE scores between periods 1 and 2, similar to the results seen in the ACT cohort. This decrease is also seen in the results for Tanya, despite the fact that her PSTE score did not change between periods 1 and 2.

5.2.4 Pre-service cohort: Changes in self-efficacy over the study period

The results of the pre-service participants span their final seven months of teacher training (periods 1 - 3) and the first four months of teaching in schools (period 4). All were working in ‘mainstream’ schools in Australia with the exception of Peter who was working in a remote school in the Torres Strait, and Sam who was teaching in an independent boarding school in the United Kingdom.

The initial PSTE scores show a wide range of beliefs about their abilities held by the pre-service participants (Figure 9).
Immediately after the workshops (period 2), all of the pre-service participants — with the exception of Peter — showed an increase in their PSTE scores. This was particularly marked in Kendra (increase of 11 points), Kate (increase of 15 points) and Lauren (increase of 12 points). Kate and Lauren both maintained similarly high PSTE scores for the remainder of the study, whereas Kendra showed decreasing PSTE scores. Her score at the final survey period was equal to her initial score.

Of the pre-service participants, all showed increased PSTE scores at the final sample period with the exception of Kendra, Peter and Sam. Kendra describes having many resources, such as Primary Connections (Australian Academy of Science, 2010) and books of simple experiments, but still does not feel that she has the content knowledge she believes she requires to teach science:

(Activity books) are helpful, but not as important as knowing the reasons why things work, like having the science content knowledge... (Science pedagogy) is very important, but not as important as actually knowing the facts... I don’t learn by reading, I have to do it myself so I learn the science content by actually doing it... I didn’t really walk away from our science lessons feeling like I learnt science. (Kendra, interview Oct 08).
For Peter, these results could be interpreted based on his teaching context, as described in the results presented in section 5.5. Sam showed a marked increase in her PSTE scores immediately after the workshops, saying that:

*The stuff we did with you was the first actual, interactive, useful experiments that I have had as a teacher* (Sam, interview Oct 08).

However once teaching full time, Sam acknowledged that she was not actually personally teaching science as she had a specialist science teacher in her school who took her students for science once a week.

*I don’t actually have to do science with my kids but she’s like the next door teacher so we do a lot of work together...I take them for geography and history and that kind of thing and she takes them for science but...we talk about everything that we’re doing and try and inter-relate everything...so no personal science teaching but I’m very aware of what they’re doing* (Sam, interview May 09).

All pre-service participants except for Kendra and Peter showed an increase in their STOE score immediately after the workshop (period 2 — see Figure 10). These same two participants, plus Lauren all showed a decrease in their STOE scores at period 4 (STEBI A Score) in comparison to period 1. Anthea and Sam returned the same STOE
scores between the third and final periods (period 3 and STEBI A Score), whereas Kate showed an increase over the same interval. All other participants showed a decrease in their STOE between the third and final periods.

5.2.5 Summary: STEBI results

The use of the STEBI instruments over time allowed any longer term impacts of the workshops to be tracked for each participant. Overall it appears that the workshops positively influenced the confidence of the participants in science teaching, especially shown in the PSTE scale, and this positive influence was maintained for at least 11 months. However the results did show some interesting variations. For the ACT cohort in particular, the STOE scores tended to increase as their PSTE scores decreased — especially those participants who were science averse. In addition, one participant who showed steady increase in her PSTE scores showed the same steady decrease in her STOE score. The results for the pre-service participants showed an increase in both the PSTE and STOE scales, although the increase in the STOE was not maintained once they were out teaching in schools.

5.2.6 First interview: Did changes in efficacy translate to changes in the amount of science taught?

Each of the teachers was asked at the first interview conducted around four months after the completion of the workshops how much science they had taught, on average, each week in class. For the pre-service participants, this estimate would be based on any teaching practicum time they had completed during this four month period. At the first interview, 16 respondents (all pre-service, five from the ACT and three from NSW) stated that they taught less than one hour a week. Three in-service participants from NSW taught one hour per week of science, and two in-service participants in the ACT taught more than one hour per week. The structure of the curriculum was a determining factor for many of those teaching less than one hour per week, particularly the pre-service teachers. The grade they were teaching was also an influence:

*With the way the curriculum is structured [Connected Outcomes Groups (COGs) in NSW where she was undertaking her practicum] during the last nine week prac I’ve done two science lessons. There wasn’t a lot of explaining of why things work or how to do a good test in these lessons because I’m really not sure that the level is appropriate for kindergarten. Like, do kindergarten kids need to be specifically told “right, this is*
science and this is what it all means”? Can they really grasp that at this age? I don’t know… (Anthea, interview Oct 08).

For the pre-service teachers, this often means that early science teaching experiences are limited as the curriculum dictates what they are teaching during their practicum:

We haven’t really explored any [science] last term. They were doing media studies so not much science, it was more SOSE (Studies of Society and Environment). There’s no scope at all to teach what you want to in practice…usually they integrate science into their other integrated subjects but there wasn’t any at all, as far as I could see (Lauren, interview Oct 08).

This is sometimes the case for in-service participants, particularly those who act as support teachers and have to follow lesson plans developed by someone else. This limits the flexibility of the support teacher and the scope of what they can teach, which is a source of frustration as exemplified by the following responses from an in-service participant at both interviews:

I have taught diddly squat [science] because I’ve gone from one class to another and I was off class for three weeks in the middle of term so I’ve been running like mad to catch up with everything that was missed while I was sick. I hope to [teach science]. The children that I have are very animated and interested (Hayley, interview Oct 08).

I was teaching year one, and all of their stuff was in place so there was [no science] last year and for the first term of this year I was support teacher for a class for a teacher who was coming back from stress leave. So I was a wall flower (Hayley, interview May 09).

Other in-service participants found that the requirements of their jobs often meant that they were limited in what they were able to teach and in what quantity, as described by Brian who moved to act as deputy principal; a largely non-teaching position:

...Had I been on class I’d have done more science. I’d have leaned fairly heavily on [the workshops] (Brian, interview Oct 08).

For many of the in-service teachers, the curriculum structure also dictates whether or not they teach science:
...When I first started teaching there were test tubes and you did actual science experiments but now they seem to be moving away from that. That’s where I was least confident, but it’s not there any more so you don’t have to [do it] (Anita, interview Oct 08).

[I haven’t taught any science], not this year, but certainly this term as it is the science unit (Paula, interview Oct 08).

Anita and Paula were two of the more science averse participants in this study, and this example shows how easy it is to remove science from day to day teaching based on curriculum requirements. This interview was conducted in the final term of the year, and Paula will only teach science now it is specifically required, whereas Anita “isn’t very science oriented” this term as it is not in the curriculum. Paula acknowledges that this is the case, stating during the same interview that science is “just one of those things that gets missed”.

Despite the limited opportunities available to many of the pre-service participants to teach science while on their practicum, some of them identified that they had already used the workshop activities in their future lesson plans:

...We’re doing a whole unit next semester on the changing environment so we’ll be using the activities from the climate change workshop (Sam, interview Oct 08).

I’ve written the next [science] unit. It’s looking at simple inventions and forces. I used the activities from your physics workshop…(Kendra, interview Oct 08).

One of the pre-service teachers, Jaeda, continued to find the workshops useful beyond her practicum, where she used some of the activities in a science week held by the school (interview Oct 08) but has also employed them in her new school:

...this term we are doing weather...All the activities you gave me on the climate change workshop I’ve shared that with the other teachers as well, so that was really good (Jaeda, interview May 09).

5.2.7 Second interview: Did changes in efficacy translate to changes in the amount of science taught?

At the second interview, participants were again asked how much science they had taught. Ten participants (four from ACT, three from each remaining participant cohort),
still taught less than one hour per week, seven (two pre-service, two ACT in-service and three NSW in-service) taught an equivalent of one hour per week and five participants (two ACT in-service and three pre-service) taught more than one hour of science in class per week. Of the participants who taught less than one hour per week, two (Peter and Paul) were limited due to the nature of the schools in which they taught. Peter faced language constraints and additional demands in his school in the Torres Strait, while Paul was teaching in a special needs school where he describes retaining student attention for more than 20 minutes at a time as a challenge. Paula conceded that she had done “a little bit, not much” but would do more in the next coming semesters depending on her “unit of work and when we’re going to be doing it” (interview, May 09).

Of the participants who taught science for more than an hour a week, two emerged from the ACT in-service participant group; one was Susan who is very ‘pro’ science, and the other was Elizabeth who had been doing one hour or less per week at the time of the first interview. Elizabeth had previously also identified science as being her area of least confidence in teaching.

One of the other ACT in-service teachers acknowledged that, although the amount of science she was teaching hadn’t changed that much (still about an hour per week), the workshop activities had become a part of her science program and had helped to increase the amount within her program:

I’ve certainly used some of [the workshop activities] in my science program and I’ve put more in my program too. Just the ones you gave us…(Lorraine, interview Oct 08).

Of the pre-service participants, three are teaching more than one hour per week of science and two are teaching an hour per week. None of the pre-service participants identify science as their area of least confidence, as discussed in an earlier section, but are actually identifying science as an enjoyable thing to teach with positive effects on the students too:

Most of the time it is science that they [the students] really look forward to because that is one of the really interactive lessons we have. Science is not hard to motivate the students into which is really good (Kate, interview May 09).

One of the in-service teachers, Simone, uses science as an effective tool for motivating her students and as a means of behaviour management:
I think a lot of teachers don’t know what they’re missing out on in terms of motivating students actually, and if you asked any of the kids in my room what their favourite thing is to do, aside from sport with the boys, it would be science. And I use it as a discipline tool, that’s how effective it is...you get a lot of difficult students, difficult schools — you do science. I did it last year. That in itself proves that it works in motivating students who are low achievers (Simone, interview May 09).

This is supported by comments from Elizabeth:

I think kids love science and it’s a good way to get kids that are behaviour problems into it because they enjoy it so much (Elizabeth, interview Oct 08).

Behaviour management, focus of the curriculum and the perceptions of science of other teachers are often identified as limiting factors to teaching science, typified in the extreme by Anita:

...less behaviour problems in the room. No more mental health kids who if we did use [science] equipment would break it and try to kill you. What would help me [to teach science] is no more behaviour problems (Anita, interview Oct 08).

5.2.8 The influence of the curriculum and participants’ perceptions of time

Some of the in-service participants felt that the curriculum simply did not allow for science to be taught, as seen through comments made at both interviews:

...Because our...curriculum is so prescriptive we have these specific set units of work, and that’s why I’m not doing science this term, because it’s not in our set units for this term (Tanya, interview Oct 08).

...Unless there’s a prominent place for it in the curriculum and it’s accessible...One of the teachers today alluded to the fact that we could have a science day at school and realise a whole lot of outcomes in the curriculum. Because the outcomes are there to be realised through teaching science but there’s just not the time, it seems to get crowded out...(Hayley, interview May 09).
This was contested by some of the other participants, who acknowledge that although time is a factor, it is possible to teach science and there needs to be a change in the teaching mentality:

\[I \text{ think because we are so curriculum heavy, we’re absolutely chockers, it’s really hard and that’s why I do [science] days instead of once a week because there’s always interruptions, and I don’t think people are confident to teach it at all...they don’t see the value in it...they don’t see the science as a big priority which is something that we have to change. We have to change that in the teaching culture, particularly in primary school...every school I have taught at in the past twenty years is exactly the same...you have to change that whole teacher mentality on it actually (Simone, interview May 09).\]

\[...it would be good to be able to do more science for fun rather than just everything that is dictated by the curriculum...I believe that there is enough time to teach science, I don’t believe that a lack of time is an excuse for not teaching science. But when you have a prescribed curriculum which you have to teach to, then you teach that first. You have to. That’s where the conflict is for me. I teach what I have to teach, and I make sure that I do all that and I do it well. There is enough time but getting through what you have to teach before you can do any other fun staff is difficult (Tanya, interview May 09).\]

From many of the comments made during the interviews, it appeared that there were opportunities to include science in some of the subjects that were being covered that term, but they were not being identified or used. Similarly, many of the participants’ definitions of science were limiting. Valerie for example, team teaches a class with Brian. Valerie takes the students for health for 45 minutes a fortnight, and Brian teaches them science for 45 minutes per fortnight. Valerie did not consider health to be science, despite the fact that she was teaching her students about the circulatory system. When prompted she acknowledged that it was actually a science based topic, but because it wasn’t ‘packaged’ as part of the science curriculum she did not consider that she was teaching science. Similarly, Vanessa spoke of a health and physical development unit being taught while she was on practicum, and cited this unit as the reason why science was not being taught this term. It appears that, for many teachers, science is a totally separate subject from health, which is a totally separate subject from mathematics and
so on. Each subject is ‘boxed’ and dealt with separately. Susan was the only participant who did not appear to follow this line of thought, stating that she “likes to have science go right through [her] entire curriculum” (interview May 09).

5.2.9 Summary: Changes in participants’ practice

When asked how much science they taught in school at the first interview (four months after the workshops were completed), the majority of participants responded less than one hour per week. Key reasons were identified as follows:

- The structure of the curriculum at the time of the pre-service participants’ practicum minimised the opportunities to teach science.
- In-service participants were more likely to cite lack of time due to the curriculum structure as their reason for not teaching more science.
- For the science averse participants in this study, this was also used as a reason for not teaching science at all during the year.
- Three in-service participants disagreed with the time argument, stating that the mentality of teachers needs to change. Evidence of this was seen by teachers viewing each subject in its own separate ‘box’, and not identifying opportunities to integrate science into other areas of the curriculum, even when the synergies were obvious.

At the end of the research period, about 11 months after the completion of the workshops, the participants were again asked how much science they were teaching. Results can be summarised as follows:

- While the amount taught stayed the same for many participants, they did report using the workshop activities in their science teaching, and adding more into their existing programs.
- One formerly science ‘fearing’ ACT in-service participant in particular increased their science teaching time.
- Three of the eight pre-service participants were teaching more than one hour of science per week at the end of the research period.
- Science was still considered a difficult subject to teach by some of the participants due to the amount of time and resources required.
• Many other participants acknowledged how much students enjoy science and argued that science teaching can actually be used as a behavioural management tool.

5.3 Research question 2: Differences between pre-service and in-service teachers

5.3.1 Differences in science teaching self-efficacy

When compared at a cohort level (Table 8), the NSW in-service participants consistently had the highest mean PSTE scores, but they also showed the smallest overall increase (approximately four points). The pre-service cohort showed an increase of just less than six points in their PSTE scores, while the ACT in-service cohort yielded a nine point increase.

Table 8: Comparison of mean PSTE and STOE scores for each cohort at each sample period and as a mean for the entire study.

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Period 1</th>
<th>Period 2</th>
<th>Period 3</th>
<th>Period 4</th>
<th>Average over study periods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PSTE</td>
<td>STOE</td>
<td>PSTE</td>
<td>STOE</td>
<td>PSTE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PSTE</td>
<td>STOE</td>
<td>STOE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PSTE</td>
<td>STOE</td>
<td>PSTE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>STOE</td>
<td></td>
<td>STOE</td>
</tr>
<tr>
<td>ACT</td>
<td>39.29</td>
<td>34.14</td>
<td>46.29</td>
<td>32.57</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>33.43</td>
<td>44.79</td>
<td>33.57</td>
<td>44.79</td>
<td>33.43</td>
</tr>
<tr>
<td>NSW</td>
<td>45.17</td>
<td>34.00</td>
<td>49.17</td>
<td>33.50</td>
<td>49.83</td>
</tr>
<tr>
<td></td>
<td>33.33</td>
<td>48.38</td>
<td>33.58</td>
<td>48.38</td>
<td>33.58</td>
</tr>
<tr>
<td>PRE</td>
<td>41.88</td>
<td>34.38</td>
<td>49</td>
<td>37.50</td>
<td>47.25</td>
</tr>
<tr>
<td></td>
<td>34.38</td>
<td>46.38</td>
<td>34.38</td>
<td>46.38</td>
<td>36.06</td>
</tr>
</tbody>
</table>

For each of the cohorts, the greatest increase in their PSTE scores was seen at sample period two, collected immediately after the completion of the series of four workshops. For both the ACT and pre-service cohorts there was a minor decrease in their PSTE scores at the third sample period, but this was balanced by a further small increase in their scores at the fourth and final sample period. The mean PSTE scores of the NSW cohort showed little variation between period 2 and period 4.

For each of the in-service cohorts, their PSTE scores were higher at period 4 than they were at period 1, and maintained at the same increased levels seen at period 2. The pre-service cohort also showed an increased PSTE score at period 4 in comparison to period 1, although there was a small decrease from the period 2 level. The overall average PSTE scores for the cohorts are in the final column of Table 8. ACT had the lowest PSTE overall, followed by the pre-service cohort and finally the NSW in-service cohort,
although it should be noted that there were less than four points difference between the lowest and highest cohorts, and about two points difference between the cohorts.

Linear mixed effects model analysis of the differences in the PSTE scores showed a statistically significant period effect (p <0.001). The PSTE scores in periods 2, 3 and 4 were all statistically significantly higher than the scores in period 1 for each of the cohorts.

The STOE scores show that both the in-service cohorts had similar STOE scores throughout the entire study, with very little variation throughout. For both of the in-service cohorts, their STOE scores decreased and were marginally lower at the final sample period than at the initial. In comparison, the pre-service cohort showed a mean STOE score similar to that of the in-service cohorts at period 1. The pre-service STOE score increased at periods 2 and 3, before returning to its initial level at period 4. On average, the pre-service cohort had the highest STOE score, with the in-service cohorts showing nearly identical means throughout the study. Linear mixed effects model analysis of the STOE scores also showed that there was an increasing trend over the four periods for the STOE scores for the pre-service cohort but not for either of the in-service cohorts.

The mean, range and standard deviation of the PSTE and STOE scores were calculated using the data from the whole study. The results were calculated first using only the in-service cohort STEBI A data, and then re-calculated including the STEBI A data of the pre-service cohort collected during the final sample period. By doing the two separate calculations, the effect of the pre-service population on the variation within the study sample could be identified. As shown in the results in Table 9, the pre-service cohort contributed very little variation overall.

Table 9: Comparison of PSTE and STOE ranges, means and standard deviations from the STEBI A surveys using the in-service study cohort only, and then including the STEBI A data collected from the pre-service cohort at the final sample period (Period 4).

<table>
<thead>
<tr>
<th></th>
<th>ACT &amp; NSW only (P1 - P4)</th>
<th>With pre-service cohort at P4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td>PSTE</td>
<td>30 - 65</td>
<td>46.44</td>
</tr>
<tr>
<td>STOE</td>
<td>21 - 43</td>
<td>33.50</td>
</tr>
</tbody>
</table>
The greatest source of variance (shown by standard deviation) is in the PSTE scores, irrespective of whether the pre-service teacher data is included or not. The standard deviations in the present study are representative of the large amount of variance that is to be expected with a small sample size.

5.3.2 Fears in science teaching

At the first session prior to commencing the workshops, participants were asked to identify their greatest fear/concern or challenge in science teaching, and in teaching in general. From the responses of all participants, fears/concerns and challenges about science teaching can be broken down into two major groups — 1) Perceived lack of scientific knowledge and understanding; 2) Resources

1) Lack of knowledge

Typical responses indicated a fear of not being able to answer children’s questions or to provide quality information. For the in-service teachers, many of the responses detailed their own lack of science knowledge and of “not getting it right” (Kerrie, initial ‘About You’ survey). Not knowing the answers to students’ questions was one of the factors impeding in-service teachers’ science teaching, as they felt less comfortable with potentially being ‘put on the spot’:

> If I’ve got a lot of knowledge about it [the subject] then I’m fine and can teach it rather than some other things. Like I’ve got a pretty good knowledge of maths so if I’m teaching that and get asked a question off centre and out of the blue I’m pretty confident I can answer all that. But I’m not with science so I have to make sure that I think I’ve covered all bases because I don’t think my knowledge is marvellous (Lorraine, interview Oct 08).

This same concern is one identified by many of the pre-service teachers during their first interviews, for example:

> Science is something that I don’t have a lot of the knowledge. If children ask me questions, I’ll freak out, I’ll totally freak out…most things, once I’ve got the idea I’ll just go off the cuff and just do it. But if I was teaching science I’d want to know exactly how to explain…the process (Sam, interview Oct 08).
If you know what you’re talking about then you don’t have to worry about questions and how to explain things clearly (Vanessa, interview Oct 08).

For each of the pre-service teachers, their fears, while based on their own perceived lack of knowledge, were more pedagogical in nature, typified by the following:

_We haven’t done anything much at uni on how to teach science to children, the units we did were on content so I am not sure how to approach science concepts when teaching children (Kate, interview Oct 08)._  

2) Resources

The same pedagogical fears did not appear in any of the in-service teachers’ responses, who appeared to hold more fears/challenges or concerns in relation to resources. Specifically the time and perceived difficulties associated with accumulating and organising the necessary equipment to teach science was considered a key challenge, and possibly an impediment, to science teaching. One of the in-service teachers (Anita) expressed a concern about the behaviour management of children during a science lesson as they can tend to be overexcited, especially when lots of ‘stuff” is being used.

5.3.3 General teaching fears

Behaviour management was identified by eight out of 13 in-service teachers as their biggest challenge related to teaching in general, in comparison to only one pre-service teacher. The majority of responses given by pre-service teachers were focussed more on the workload associated with being a teacher, and the processes of teaching itself such as assessment and successfully motivating and engaging students. This lack of student motivation in class was also identified by one of the early career in-service teachers (Tanya), and also by a highly experienced teacher (Brian), as a key challenge. One in-service teacher expressed concern that she couldn’t cover all the topics in the curriculum competently with all of the other subjects she is expected to cover (Simone).

5.3.4 Participants’ confidence in science teaching

Immediately prior to commencing the workshops, and immediately after completing all four workshops, the participants were asked to complete surveys indicating their level of enjoyment of science teaching, and their confidence in science teaching. Respondents were asked to rate their level of confidence and enjoyment on a five point scale, where 1
was not at all confident or do not enjoy at all, through to 5 being extremely confident or really enjoy. The graphs for each respondent in each group are shown in Figures 11 - 13.

Figure 11: Comparison of confidence levels pre- and post-workshop of individuals in ACT in-service cohort

Figure 12: Comparison of confidence levels pre- and post-workshop of individuals in NSW in-service cohort

For all of the in-service teachers, confidence remained at the same level (7 of 13 respondents) or increased (6 of 13) after completion of the workshops. The greatest change in in-service teacher confidence levels was in Paula who scored ‘1 - not at all
confident’ on the initial survey but after completing the workshop returned a score of ‘3 - neutral’.

![Graph showing confidence levels pre- and post-workshop for pre-service teachers.]

**Figure 13: Comparison of confidence levels pre- and post-workshop of individuals in the pre-service cohort**

All of the pre-service teachers except for Peter showed an increase in confidence after the completion of the workshops (Figure 13). Peter maintained the same confidence level. In the last interview conducted about 11 months after the post workshop survey, Peter said that he found that his school operated within a completely different environment and context to that which he had been preparing for at University, and he felt that this influenced his confidence levels, yet his self assessment score remained the same:

*I have to actually say at the moment there’s not a lot of confidence there and I’m not sure if this is because I’m in the first year out or if it’s because of the scenario I’m in [remote school in Torres Strait]...*(Peter, interview Oct 08).

In-service teachers, on average, had higher confidence levels than the pre-service participants before the workshops, whereas the pre-service teachers showed the greatest increase in confidence levels after the workshops.

For the pre-service cohort, seeing how to run science activities as they had been displayed in the workshops was identified as being a contributing factor to their overall confidence:
After the workshops I feel a bit more confident in how to run [science activities]. I liked how it was an already prepared environment. The instructions were there and also the explanations relating to real life and I found that really useful (Kate, interview May 09).

In-service teachers, who noted an increase in confidence levels, also indicated that their old values and beliefs were still an influence:

I suppose I think I’m a lot better than I was confidence wise, but I think I still feel I still have that old teacher sort of style where I think I have to know everything before I can get started. I don’t like if children ask me a question and I don’t know the answer. Something I think you have to get over a bit…(Elizabeth, interview May 09).

Well I’d say probably the science area again because I’m not confident with getting the things that I need to…putting my hand on things easily to be able to teach experiments or do stuff in class. And quite honestly a lot of it is just time, it is a time thing... (Paula, interview May 09).

5.3.5 Participants’ enjoyment of science teaching

Across all participant groups, respondents tended to indicate higher scores for enjoyment of science teaching in comparison to confidence in science teaching (see Figures 14 - 16)

![ACT In-service teachers - participants' enjoyment of science teaching pre- and immediately post workshops](image)

Figure 14: Comparison of enjoyment levels pre- and post-workshop of individuals in the ACT in-service cohort
When examined individually, the enjoyment of the in-service groups stayed at the same level (7/13) or increased (6/13). One participant (Hayley) in NSW showed the largest increase, with her initial self ranking of enjoyment given as ‘2 - I don’t really enjoy’ before the workshops, in comparison to a level of ‘4 - quite enjoy’ immediately after the workshops. Only one participant (Tanya) indicated a decrease in enjoyment, however her scores were still in the positive, decreasing from five to four.

Figure 15: Comparison of enjoyment levels pre- and post-workshop of individuals in the NSW in-service cohort

Figure 16: Comparison of enjoyment levels pre- and post-workshop of individuals in the pre-service cohort
Pre-service participants all showed either an increase in enjoyment (4/8) or maintenance of the same level (4/8). Two pre-service participants showed a marked increase in enjoyment with one (Jaeda) moving from ‘neutral’ (3) to ‘really enjoy’ (4.5), while the other (Anthea) moved from a score of ‘2’ indicating ‘I don’t really enjoy’ up to a score of ‘4’, ‘quite enjoy’ (see Figure 16).

The average score for each group’s confidence and enjoyment pre and post workshop are compared in Figure 17.

![Comparison of mean self reported scores given for confidence and enjoyment of science teaching pre and immediately post workshops](image)

**Figure 17:** Comparison of mean scores of confidence and enjoyment immediately pre and post workshops for each participant group. 1 = not at all and 5 = extremely/ really.

Each cohort showed increased confidence and enjoyment. The NSW in-service group had the highest confidence levels both pre and post workshop. The pre-service cohort showed the lowest confidence levels pre-workshop, which increased post-workshop to higher levels than those of the ACT in-service group. Overall, the pre-service cohort showed the greatest gain in confidence, followed by ACT in-service and then NSW. Likewise, all cohorts showed an increase in their enjoyment of science teaching. Once again, the pre-service cohort showed the greatest increase in enjoyment of science teaching, followed by the ACT and then the NSW cohorts. Linear mixed effects model analyses found that the scores in period 2 were statistically significantly higher than in period 1 for both enjoyment (p = 0.007) and for confidence (p < 0.001). There was no statistically significant difference found in enjoyment or confidence levels between the cohorts.
5.3.6 Areas of most and least confidence in teaching generally

Participants were asked to identify the areas of teaching where they felt the most and the least confident during interviews conducted approximately four and ten months after the completion of the workshops. An overview of these results is provided in Table 10. The category ‘other’ incorporates responses such as life experience or a year level (most confident), or dealing with children with learning difficulties (least confident). Participants could nominate more than one factor.

Despite the majority of in-service teachers nominating behaviour management and student motivation as their biggest challenge when it came to teaching during the initial surveys (as reported in the previous section), seven of the in-service teachers also identified these as the areas that they felt most confident about, with one participant (Lorraine) nominating both.

Table 10: Overview of participants’ responses at the first interview (4 months after workshop completion) and final interview (11 months after workshop) of what aspects of teaching they felt most and least confident (conf) about. Numbers indicate total of participants choosing each factor.

<table>
<thead>
<tr>
<th>Factor</th>
<th>First Interview</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In-service</td>
<td>Preservice</td>
<td>In-service</td>
<td>Preservice</td>
<td>In-service</td>
<td>Preservice</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Most conf</td>
<td>Least conf</td>
<td>Most conf</td>
<td>Least conf</td>
<td>Most conf</td>
<td>Least conf</td>
<td></td>
</tr>
<tr>
<td>Behaviour management</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Student motivation/engagement</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Science</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Sports/PE</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Mathematics</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Music</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Other specific subject</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Reporting/administration/lesson</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>planning/parent interviews</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Time management</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

For the majority of all the in-service participants (7 out of 12), the areas where they felt least confident teaching tended to be the specialty subjects such as music in particular (4/7), sport/PE, and mathematics. At the first interview, five of the in-service
participants nominated science as their area of least confidence. One of these respondents was from NSW, the rest were from the ACT school. During the final interviews only one of the ACT in-service teachers (Paula) nominated science as their area of least confidence in teaching. Many of the others who had said science in the initial interview still nominated the same speciality subject areas such as music, but science was no longer mentioned as an area of least confidence.

Pre-service participants tended to feel most confident with particular areas or niches in teaching, such as mathematics, religion and teaching in the infants school. Two of the pre-service teachers specifically mentioned their increased confidence in being able to pull together a good lesson plan, as well as being able to teach a class without having to lean on that plan too heavily. The pre-service respondents tended to feel least confident about the administration side of teaching, dealing with parents, behaviour management and other subjects such as mathematics, art and creative writing. Two of the pre-service participants specifically identified science as their area of least confidence.

At no time did any of the participants identify science as the area where they felt the most confident about teaching — even the self professed ‘science positive’ teachers who incorporated a lot of science teaching into their lessons. Interestingly the most science positive teacher (Susan) and the least science positive teacher (Paula) both reported at the final interview that they were most confident about “everything” to do with teaching. Paula quantified this by saying that she more felt “under-resourced” (interview, May 09).

At the final interview, three of the eight pre-service participants still nominated other subjects (mathematics and English) and the rest were least confident in the administrative and pedagogical aspects of teaching such as time management, reporting and student engagement.

5.3.7 Summary: the differences between the pre-service and in-service cohorts

Both pre-service and in-service participants showed positive gains in their science teaching self-efficacy, particularly in the PSTE scale. The ACT in-service cohort yielded the greatest gain in PSTE overall, followed by the pre-service cohort then the NSW in-service cohort. The differences in PSTE scores between the cohorts was not statistically significant, however the difference in scores between period 1 and period 2 was found to be statistically significant (p < 0.001).
The greatest difference was seen in the mean STOE scores. The mean STOE scale scores of the in-service cohorts showed very little variation throughout the study period. In comparison, the mean STOE score of the pre-service cohort showed incremental increases until the final sample period, when they were out teaching in schools; their mean STOE score then returned to its original level. There was an increasing trend in STOE scores for the pre-service cohort identified in the linear mixed effects model analysis but there was no statistically significant difference between the pre- and in-service cohorts.

All participants either maintained or increased their score for their level of confidence in teaching science after the workshops, remaining at least neutral in their confidence in their ability to teach science or moving into feeling confident or very confident. The greatest gains were seen in those participants who initially returned scores indicating they were not confident in, or did not enjoy, science teaching. The pre-service cohort showed the greatest gains overall. The in-service cohort was more likely to return the same scores for both confidence and enjoyment in both pre and post workshop questionnaires.

The pre-service and in-service cohorts differed in their fears and uncertainties in teaching science. The key differences can be summarised as follows:

**In-service teachers**

- The more experienced in-service teachers in particular felt they needed to know all of the answers in a science subject before teaching it to the children.

- The collection of the necessary resources and time to teach science was consistently identified by the in-service participants as being a major impediment to science teaching.

- In-service teachers were most likely to nominate science or some other ‘specialty’, resource-intensive subject such as music or art as their area of least confidence in teaching.

- However after the workshops, only one participant still nominated science as their greatest concern in comparison to five in the pre-workshop questionnaire. Other specialty subjects such as art and music were still nominated by the same teachers.
• Behaviour management of students is the predominant general teaching fear of in-service teachers

Pre-service teachers

• Pre-service teachers were more fearful of the process of teaching science itself, founded on pedagogy rather than their own science knowledge.

• Their general fears in teaching are based on the basic mechanisms and processes of being a teacher.

• Pre-service teachers also nominated some specific subjects such as mathematics, but were more likely to name processes of teaching and administrative concerns as their areas of least confidence.

5.4 Research question 3: Do the number of years of teaching experience cause differing effects and impacts?

5.4.1 Limiting repetition in the presentation of results

The PSTE and STOE scores were examined at each sample period and compared based on the teaching experience of the participants to observe any change in the score over time. The scores of each participant have been discussed earlier in this chapter, and will not be repeated here. The purpose of this comparison is to show trends based on the teaching experience of the participants.

Only one participant (Paul) had between one and three years experience. As his results have been covered within the NSW in-service cohort in section 5.3, they will not be repeated here. Additionally, the PSTE and STOE scores of those with <1 year of teaching experience have already been discussed in the preceding section (see Figures 9 - 10) so will also not be included in this section. The comparison of the mean score, on both scales, for each participant based on their teaching experience is provided in Appendix E.

5.4.2 The changes in self-efficacy: A cohort-by-cohort overview

Given the large amount of variation in the range of scores, it is more useful to first consider the overall mean of each cohort (Figure 18).
Comparison of overall mean PSTE and STOE scores for each teaching experience cohort

Figure 18: Comparison of overall mean PSTE and STOE scores for each ‘experience cohort’ for the entire study period. PSTE scale range 13 - 65; STOE scale range 10 - 50.

Highly experienced teachers (20+ years- seven participants) yielded the lowest mean PSTE scores of all study participants, and teachers with between 15 and 20 years of experience (two participants) returned the highest. The 15 - 20 year and 20+ year cohorts returned almost equal STOE means. The early career (1 - 3 and 4 - 6 years - one and two participants respectively) teachers showed very similar PSTE and STOE means. The pre-service/beginning teachers (< 1 year) had the highest mean STOE score over the duration of the study. Linear mixed effects model analysis suggests that experience is a statistically significant predictor of the scores (p < 0.05) however there is not a trend with more experience equating to a higher score. These results could have been influenced by the very small number of participants in the 15 - 20 (two participants), 4 - 6 (two participants) and 1 - 3 year (one participant) cohorts and may not be representative. A larger sample would be required to confirm the pattern.

Figure 19 shows that even highly experienced teachers showed increases in their PSTE over the duration of the study, with the exception of Paula as discussed previously.
Figure 19: Comparison of PSTE scores of participants with 20+ years teaching experience across all sample periods. Score range 13 - 65.

As noted earlier, the STOE scores were less straightforward (Figure 20), often showing increases where PSTE scores had decreased and vice versa.

Figure 20: Comparison of STOE scores of participants with 20+ years teaching experience across all sample periods. Score range 10 - 50.

Table 11 compares the scores of participants with 15 - 20 and 4 - 6 years of experience. Given the small number of participants in both cohorts, it was more useful and economical to tabulate these results rather than produce many graphs.

For both participants in the 15 - 20 years experience cohort, their PSTE increased at period 2, and although it declined at the next two sample periods, it was maintained at a
higher level at period 4 than was shown at period 1. Both participants showed a decrease in their STOE score over the duration of the study (Table 11).

Table 11 Comparison of PSTE and STOE scores of participants with 15 - 20 and 4 - 6 years teaching experience across all sample periods.

<table>
<thead>
<tr>
<th>Experience cohort</th>
<th>Participant</th>
<th>PSTE (Score range 13 - 65)</th>
<th>STOE (Score range 12 - 60)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Period 1</td>
<td>Period 2</td>
</tr>
<tr>
<td>15 - 20 years</td>
<td>Susan</td>
<td>58</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>Simone</td>
<td>46</td>
<td>57</td>
</tr>
<tr>
<td>4 - 6 years</td>
<td>Tanya</td>
<td>53</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Lisa</td>
<td>40</td>
<td>47</td>
</tr>
</tbody>
</table>

Changes were less discernible in the teachers with 4 - 6 years of teaching experience. Both exhibited an increase in their PSTE (Table 11) while one exhibited an increase in their STOE score (Tanya), the other (Lisa) returned to their original STOE score at the final sample period (see Table 11, period 4). It is worth noting that the changes in the STOE scores were minimal, resulting in between a one and four point difference, whereas the PSTE scores showed between three and 12 points difference at each sample period.

Given the small sample size, the results for the 15 - 20 and 4 - 6 year cohorts are at best indicative of a pattern that could only be confirmed with a larger study.

5.4.3 Comparison of overall change in science teaching self-efficacy of each experience cohort

The differences in the overall change in self-efficacy between the first sample period (period 1) and the final sample period (period 4) between the different cohorts was calculated by subtracting the mean period 4 PSTE score from the mean period 1 PSTE score to get the overall change in PSTE. The same calculation was conducted using the mean STOE scores from the same periods. The change in PSTE and STOE scores for each experience cohort is shown in Table 12.
Table 12: Comparison of overall change in mean PSTE and STOE scores for each teaching experience cohort.

<table>
<thead>
<tr>
<th>Teaching Experience Cohort</th>
<th>Mean PSTE Score Period 1</th>
<th>Mean PSTE Score Period 4</th>
<th>Difference in mean PSTE score (P4 - P1)</th>
<th>Mean STOE Score Period 1</th>
<th>Mean STOE Score Period 4</th>
<th>Difference in mean STOE score (P4 - P1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20+ years</td>
<td>37.65</td>
<td>46.38</td>
<td>8.75</td>
<td>34.75</td>
<td>35.13</td>
<td>0.38</td>
</tr>
<tr>
<td>15 - 20 years</td>
<td>52</td>
<td>54.5</td>
<td>2.5</td>
<td>36</td>
<td>30</td>
<td>-6</td>
</tr>
<tr>
<td>4 - 6 years</td>
<td>46.5</td>
<td>53</td>
<td>6.5</td>
<td>31</td>
<td>32.5</td>
<td>1.5</td>
</tr>
<tr>
<td>1 - 3 years</td>
<td>48</td>
<td>50</td>
<td>2</td>
<td>31</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>&lt; 1 year</td>
<td>41.88</td>
<td>47.38</td>
<td>5.5</td>
<td>34.75</td>
<td>34.75</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 12 shows that all of the teacher experience cohorts experienced an increase in their overall PSTE, with the teachers with more than 20 years of experience showing the greatest increase overall. The 20+, 4 - 6 year and pre-service experience cohorts’ STOE scores remained largely unchanged. Teachers in the 15 - 20 and 1 - 3 year experience cohorts all returned a decrease in their overall STOE scores. As mentioned earlier, analysis suggests that experience is a statistically significant predictor of score, but a larger study is needed to confirm a trend.

5.4.4 Summary: Differences in self-efficacy changes based on teaching experience

As discussed in section 5.3, all participants showed an increase in their science teaching self-efficacy scores. When these scores were examined based on the number of years of participants’ teaching experience in this section, the participants with more than 20 years of experience showed the greatest overall increase in PSTE. The larger experience cohorts (20+ years and pre-service) did not show any large changes on the STOE scale. The cohorts with similar levels of experience (1 - 3 with 4 - 6 years experience and 15 - 20 years experience with 20+ years experience), returned very similar mean scores on both scales. These results should be considered indicative rather than representative based on the small number of individuals in the study. A larger study would be needed to confirm these results.
5.5 Research question 4: The influence of previous science experiences

5.5.1 The influence of participants’ experiences as science learners on their perceptions of science

As identified in section 5.1, the majority of the respondents have very little experience in science within their own educational backgrounds. While for many this is a self-confessed lack of interest in science, for others it was due to circumstance such as undertaking schooling by correspondence. For some teachers, their impressions of science were influenced by other, external factors. Just as their own teachers were big influences in their career choices, for some participants their teachers during their own schooling and teacher training were also important influences in their perceptions of, and attitudes towards, science:

*I did biology in high school, and chemistry and physics but I didn’t get on very well. I was taught very poorly, very badly ... My one memory is in high school with Mr Smith (name changed) dropping his contact lens into the hydrochloric acid. It was a hard lens. That is my one great thing ever being taught science. The rest of it I was bored out of my brain* (Susan, interview Oct 08).

This example shows how a teacher could potentially turn a student away from science if they did not already have an interest in the subject, which Susan did. This is supported by the comments of one of the in-service participants from the other school, who criticised the effectiveness of science education in teacher training and reiterated the need for personal interest and passion:

*I don’t think really we can be jack of all trades and be into all subjects. It needs to be something you are passionate about. You are far more effective as a teacher when you are passionate about it and if you are not trained say in biology since you did it at 18 and [if you only study] the one [science] component at university, so what we are doing is only working blindly...University is just a joke. Half of them [lecturers] haven’t taught at all and so I think they don’t teach it effectively at all. It leaves us in the dark* (Simone, interview Oct 08).

However a negative experience with a science teacher or educator can also have a positive influence:
I didn’t have much of an interest in science in high school. I think that was because of a bad experience with a teacher...Some of the lecturers at uni weren’t that great...some were really good, but others it’s sort of like they don’t even have someone to teach the teachers sort of thing...They sort of didn’t make me feel comfortable so it’s more like “stuff you, I’m going to be really good at science just to show you!” (Vanessa, interview Oct 08).

Spite may not be the most obvious motivator for student success, however in this instance it provided the impetus for Vanessa to seek out other science experiences, which she did at an informal science education centre attached to a government science research body. This experience in science education, outside of the school environment, gave her insight into another side of science education:

Working [there] was really good, because it was...not in a school, but it was working in education and I got to work with children of all age groups. I even got to do some year 11 physics and that sort of thing and that gave me real confidence. And it was a lot of fun, it made science fun...(Vanessa, interview Oct 08).

The role and influence of informal science education centres is discussed further in section 5.7.

5.5.2 The influence of professional development and science outside the school setting

Participants were asked what, if any, science based professional development (PD), excursions or experiences they had completed or had prior to the workshops, and then for the duration of the time between the completion of the workshops and the final survey period.

Of the in-service participants, only one (Anita) had completed any PD after the workshops.

[I attended a] professional development day where we looked at science experiments, much the same as the ones you showed us, and how to utilise those in the classroom. I thought what you did with us was more useful. She only did two and you showed us many, many more and the way you presented them — I liked having the cards and seeing what I had to do...(Anita, interview May 09).
One of the in-service participants acknowledged that while he could probably search out, and find, science based PD programs privately he did not see that the relevant Department of Education was offering much in this area:

> Usually in the plethora of emails I’ve had there have been very few, if any I’d actually say in the last twelve months, anything to do with ‘do you want to upgrade your science knowledge’ type courses. This is just from the department itself...There are courses on heaps of things [from the department] on literacy and numeracy, but very few, if any, on science (Brian, interview May 09).

Of the pre-service participants, one had received a literacy based PD, but nothing science based. Only one pre-service participant felt that her science skills were being ‘developed’ in some way:

> We have a specialist science teacher... so it’s not so much professional development, but because she’s been trained in it she’s been teaching me things that I don’t know (Sam, interview May 09).

Many of the participants noted that they had been, or were going, on excursions or receiving incursions from science related organisations and programs. Four of the NSW in-service participants and one pre-service participant mentioned an incursion from, or excursion to, a science centre; another one from NSW and two from the ACT mentioned excursions to an environmental education centre and a space observatory while two of the pre-service participants mentioned visiting the Amazing World of Science at National Science Week in Canberra. All of these other excursions and science experiences were to informal science education settings. Eleven of the total cohort of participants had, or were going to have, some kind of interaction with an informal science education setting, in comparison to the one participant who had received formal PD in science.

5.5.3 Summary: the influence of previous science experiences on participants’ perceptions of science

As reported in section 5.1, none of the in-service teachers had a formal background in science. The pre-service participants did receive two units in science but did not feel adequately prepared for science teaching. For a few participants, their most positive experiences in science were found outside the formal education setting.
Any science excursions or experiences the participants had during the course of this current study, beyond the workshops, were either to, or via, informal science education institutions. Only one participant had received any science based professional development, and she described it as very limited. The formal education sector does not appear to offer much by way of ongoing professional development in science to teachers — at least within the regions included in this research project.

5.6 Research question 5: The influence of the school environment

5.6.1 Positive and negative influences in teaching generally

All study participants were asked what has had the greatest positive and negative influence on them during their teaching career or training, and were told that this could be anything or anyone from within or external to their school and/or university. The most positive and negative influences identified are set out in Table 13. Over half of the participants (12) stated that other teachers had the greatest positive influence; nine of these responses came from in-service participants, three of the pre-service participants mentioned their teachers from their practicum.

Table 13: Factors identified by participants as most and least positive influences on their teaching career/training

<table>
<thead>
<tr>
<th>Factor</th>
<th>Most Positive</th>
<th>Least Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In-service</td>
<td>Pre-service</td>
</tr>
<tr>
<td>Other teachers</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>School Environment</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Informal education</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Students</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Curriculum/Time Pressures</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Department of Education</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Administrative requirements</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

All made comments about being supported, mentored or inspired by other teachers who they have worked with, one in particular as it relates to science teaching:

...When you come across another inspirational teacher who has science as their big gig and...teaching science that way is a really positive role that works...Lots of fun and inspiration (Anita, interview Oct 08).
Six of the eight pre-service participants identified other teachers as their most negative influence on their teaching career and training so far, including their university lecturers:

*I do remember there was one session we had which was done by outside presenters...and they were fantastic. They energized the whole class. But that didn’t last...Some of the uni lecturers... were quite uninspiring and they’re out of touch with what happens in the classroom* (Anthea, interview Oct 08).

*To be honest, science at uni. We felt like we learnt nothing. I came out more confused about science than when I went in there. The teacher was hopeless* (Lauren, interview Oct 08).

For others, their supervising teachers while on their practicum were identified as negative influences:

*Having a prac teacher that doesn’t really let you develop your own style of teaching. You get in there and they encourage you to try new things, but it means not stepping outside the square...so that’s kind of a shame sometimes. Also those teachers who go ‘oh well, you think it’s hard now, wait until ten years time when you’re thirty and wondering what happened to your twenties’ — yeah thanks for that! So I guess teacher’s comments [are the most negative things for me] (Kate, interview Oct 08).

The one in-service teacher who found other teachers to be their greatest negative influence was Paul, who is a beginning teacher, who stated that his most negative influence was:

*...seeing other teachers who sort of look at the children as all the same. That their behaviour is the same because the teacher sort of thinks that. I see that as a negative thing and they quite often sort of teach over the top of the children and [the children] don’t seem to learn* (Paul, interview Oct 08).

The only other negative influence identified by pre-service participants was that of the administrative aspect of teaching. Jaeda was overwhelmed by the amount of paperwork required:
...There are hours and hours of paperwork that goes with being a teacher! All the lesson plans and formalities! Why can’t we just show the kids something really engaging and exciting? (Jaeda, interview Oct 08).

Time, or lack thereof, for teaching in the curriculum was identified by four in-service participants. This was also related to the Department of Education as typified by Valerie’s response:

Greater number of demands from the Department. The more things you have to do in the same amount of time; things being added on top of things rather than something else being taken away (Valerie, interview Oct 08).

Students, not surprisingly, were also identified as both positive and negative aspects of teaching. For Brian, seeing the ‘oh, I get it!’ dawn of comprehension on a student’s face is the most positive influence for his teaching, while other respondents indicated that behaviour management and student attitudes are the most negative aspects of their teaching:

I don’t really feel negative about my teaching, but problems in the classroom make it more negative because you spend more time disciplining than you do being a teacher (Lisa, interview Oct 08).

Four participants (one in-service, three pre-service) identified experiences in informal education as the most positive influence in their teaching career and training. For one pre-service participant, seeing the interest and enthusiasm generated at a science festival was particularly positive:

...Looking at the volumes of children who attend [science festivals]. The different activities they can do and it’s great to see them exploring and getting dirty, not sitting glued to the TV (Peter, interview Oct 08).

Three respondents (one in-service and two pre-service) specifically mentioned the workshops that they had completed for this study, and conducted by the author of this dissertation, as being their most positive teaching influence so far, particularly pertaining to science teaching:

It was you, most definitely...in terms of actually being a teacher and using science experiments, it was those things [the workshops] we did with you (Sam, interview Oct 08).
The other remaining respondent, Vanessa, identified her time working at an informal science education centre as being the most positive influence as it was a lot of fun and gave her “real confidence” (interview, Oct 08).

The school environment was evenly split into the most positive and most negative influence for the in-service teachers. The most positive comments related to having a supportive executive and to the school in general, while the negatives referred to school politics and “too many chiefs” (Simone, interview Oct 08). The influence of the school environment was examined more closely using the Science Curriculum Implementation Questionnaire (SCIQ) (Section 5.6.3).

5.6.2 Summary: Greatest influences on teaching

Participants identified other teachers as being the greatest influences on their own teaching careers. In-service participants usually credited other teachers as the most positive influence, whereas the pre-service participants were more likely to identify other teachers as their most negative influence. Four participants identified informal science education experiences as their most positive influence so far, three of whom named the workshops used in the current research project.

5.6.3 ACT in-service cohort: Influences on science teaching as identified using the SCIQ

The SCIQ was administered four times throughout the study; once immediately prior to the workshops, once immediately after the workshops, then four months and 11 months after the workshops were completed. Each scale within the SCIQ was scored on a five point Likert scale, where 1 is strongly disagree and 5 is strongly agree. The descriptions of each scale are provided in the preceding chapter (section 4.1.5). The means and standard deviations were calculated for each scale at each sample period and compared. Given the size of the means, a standard deviation was considered high if it approached a value of one (1), which often represented about a third of the mean being discussed. The results from the ACT in-service cohort are shown in Table 14.
Table 14: Comparison of means and standard deviations for each scale in the SCIQ from ACT in-service cohort across whole study period.

<table>
<thead>
<tr>
<th>Scales</th>
<th>Mean P1</th>
<th>SD1</th>
<th>Mean P2</th>
<th>SD2</th>
<th>Mean P3</th>
<th>SD3</th>
<th>Mean P4</th>
<th>SD4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resource Adequacy (RA)</td>
<td>2.79</td>
<td>0.55</td>
<td>2.79</td>
<td>0.47</td>
<td>2.75</td>
<td>0.43</td>
<td>2.75</td>
<td>0.58</td>
</tr>
<tr>
<td>Time (T)</td>
<td>3.48</td>
<td>0.78</td>
<td>3.48</td>
<td>0.66</td>
<td>3.5</td>
<td>0.71</td>
<td>3.26</td>
<td>0.53</td>
</tr>
<tr>
<td>Professional Support (PS)</td>
<td>3.21</td>
<td>0.68</td>
<td>3.3</td>
<td>0.61</td>
<td>3.5</td>
<td>0.71</td>
<td>3.36</td>
<td>0.56</td>
</tr>
<tr>
<td>School Ethos (SE)</td>
<td>2.81</td>
<td>0.8</td>
<td>2.76</td>
<td>0.73</td>
<td>3.19</td>
<td>0.89</td>
<td>2.84</td>
<td>0.7</td>
</tr>
<tr>
<td>Personal Attribute Factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professional Science Knowledge (PSK)</td>
<td>3.07</td>
<td>0.62</td>
<td>3.17</td>
<td>0.37</td>
<td>3.21</td>
<td>0.47</td>
<td>3.21</td>
<td>0.61</td>
</tr>
<tr>
<td>Professional Attitude &amp; Interest (PAI)</td>
<td>3.04</td>
<td>0.6</td>
<td>3.2</td>
<td>0.33</td>
<td>3.29</td>
<td>0.51</td>
<td>3.27</td>
<td>0.49</td>
</tr>
<tr>
<td>Professional Adequacy (PA)</td>
<td>2.99</td>
<td>0.37</td>
<td>3.05</td>
<td>0.26</td>
<td>3</td>
<td>0.45</td>
<td>3.09</td>
<td>0.23</td>
</tr>
</tbody>
</table>

The ACT in-service cohort had a generally positive perception of the attitudes and interest of teachers in the school towards science and science teaching (PAI), the level of professional support (PS) and of the science knowledge and understanding of the teachers within the school (PSK). This is exemplified by Elizabeth, who exhibited an increase in the amount of science that she taught, and attributed it to “being inspired by my colleagues I think!” (interview, May 09).

The participants had a neutral perception of their colleagues’ competence and ability in science teaching (PA) with the mean showing neither a strong nor weak result. The ACT in-service cohort showed consensus regarding PA in particular, as indicated by the small standard deviation. All of the personal attribute factors (PA, PSK and PAI) show an increase when comparing the mean at period 1 (P1) to that obtained at period 4 (P4). Linear mixed effects model analysis did not find this increase to be statistically significant.

The key issue for the ACT cohort is the resource adequacy (RA) of the school, with means consistently indicating disagreement with the notion that the school is adequately resourced for science teaching. There is some variation within the responses, as indicated by the comparably higher standard deviation, but generally the respondents perceive the school to be poorly resourced. This is supported from the interviews where
the availability of the resources required to teach science is seen as a barrier to science teaching:

*I find with science...the thing which makes it the least attractive to teach is collecting all the bits and pieces, particularly if you’re doing experimental type stuff. Getting all that gear together, and then finding that something you thought was at the school is not, or is lost, or someone else has got it...it’s more a logistical thing than a dislike of actually teaching science...I’d like to teach more science because I know the kids enjoy it, but...when you have 34 kids and a small space and finding all the gear, I think you tend to put it in the too hard basket, which is probably not the right thing to do but it happens (Valerie, interview Oct 08).

...It’s just that we never seem to have anything when you want to do something. Like we wouldn’t want Bunsen burners and beakers but we would like little telescopes and we were doing space and...make like a space vehicle and there’s nothing sort of you know in stores — you have to dig around and get things for yourself (Elizabeth, interview May 09).

Greater variation of responses was found within the scales for school ethos (SE) and time (T). The school ethos appears to be neither positively nor negatively geared towards science as a subject area, although the mean at P4 shows a slight decrease towards the negative. Time is considered a factor that impedes science teaching, as identified through the interview data as discussed in the previous section. This is not a view held by all respondents, as indicated by the high standard deviation.

5.6.4 NSW in-service cohort: Influences on science teaching as identified using the SCIQ

Table 15 shows the responses of the NSW in-service cohort. The resource adequacy (RA), professional attitude and interest (PAI) and professional adequacy (PA) scales showed the least variation in responses throughout the study, although the amount of variation in responses for PAI and PA increased over the duration of the project. PA was also initially on the negative side of neutral at P1 however, immediately after the workshops (period 2 - P2) this increased to a more neutral score tending towards the positive. This was maintained for the remainder of the study. Professional Science Knowledge (PSK) also increased between P1 and P2 and was maintained for the
remainder of the project, however this was also accompanied by an increase in variation of responses. Professional Support (PS) oscillates around neutral to adequate throughout the study but also shows the greatest variation of all scales. None of these changes in scores were found to be statistically significant.

Table 15: Comparison of means and standard deviations for each scale in the SCIQ from NSW in-service cohort across whole study period.

<table>
<thead>
<tr>
<th>Scales</th>
<th>Mean P1</th>
<th>SD1</th>
<th>Mean P2</th>
<th>SD2</th>
<th>Mean P3</th>
<th>SD3</th>
<th>Mean P4</th>
<th>SD4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resource Adequacy (RA)</td>
<td>2.63</td>
<td>0.56</td>
<td>3.08</td>
<td>1.16</td>
<td>3.04</td>
<td>0.43</td>
<td>3.04</td>
<td>0.37</td>
</tr>
<tr>
<td>Time (T)</td>
<td>3.44</td>
<td>0.42</td>
<td>3.42</td>
<td>0.42</td>
<td>3.67</td>
<td>0.43</td>
<td>3.83</td>
<td>0.63</td>
</tr>
<tr>
<td>Professional Support (PS)</td>
<td>2.96</td>
<td>0.53</td>
<td>3.21</td>
<td>0.56</td>
<td>3.17</td>
<td>0.61</td>
<td>3.13</td>
<td>0.8</td>
</tr>
<tr>
<td>School Ethos (SE)</td>
<td>2.5</td>
<td>0.64</td>
<td>2.46</td>
<td>0.37</td>
<td>2.72</td>
<td>0.63</td>
<td>2.69</td>
<td>0.74</td>
</tr>
<tr>
<td>Personal Attribute Factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professional Science Knowledge (PSK)</td>
<td>2.89</td>
<td>0.39</td>
<td>3.17</td>
<td>0.46</td>
<td>3.39</td>
<td>0.69</td>
<td>3.14</td>
<td>0.64</td>
</tr>
<tr>
<td>Professional Attitude &amp; Interest (PAI)</td>
<td>2.74</td>
<td>0.21</td>
<td>2.86</td>
<td>0.27</td>
<td>3.02</td>
<td>0.39</td>
<td>2.98</td>
<td>0.46</td>
</tr>
<tr>
<td>Professional Adequacy (PA)</td>
<td>2.87</td>
<td>0.16</td>
<td>3.26</td>
<td>0.3</td>
<td>3.17</td>
<td>0.48</td>
<td>3.17</td>
<td>0.43</td>
</tr>
</tbody>
</table>

School ethos (SE) consistently returned the lowest mean scores of all scales across all sample periods, indicating that science has a low status within the school. Paul had changed to teaching in a special needs school after P2, but examination of his period 3 (P3) and P4 results did not highlight any real differences in his perceptions of the two schools. Many of his scores were around the neutral (3) mark, perhaps indicating his lack of familiarity with the school environments to answer with any real certainty. This was supported by his interview responses, and is an identified limitation of the SCIQ as discussed in the following section.

Two of the NSW in-service participants, Simone and Anita, changed schools about four months before the final survey period. During the interviews, the difference between their old school environment and their new school environment was apparent through their comments and the scores they returned on the SCIQ. Anita for example, returned her highest scores on all scales at P4 in comparison to all other sample periods. This
was particularly noticeable in the scales comprising the personal attribute factors (PA, PSK, PAI) but especially so in the school ethos (SE) scale. During the first three sample periods Anita returned average scores on the SE scale ranging between 2.17 - 2.83. At the final survey period, once she had started at her new school, her average on the SE scale was ‘4’, indicating that her new school environment gave much more status to science than the previous one. Anita also returned her highest score on the time scale, indicating that she felt more keenly that time was a factor limiting the delivery of science in the classroom at her new school. This is despite perceiving that she was also in a better resourced and more science positive school:

I’m not at [the old school] anymore, it’s all good now (Anita, interview May 09).

The change of school can alter the professional environment of a teacher, including the resources available to them and the level of support. Simone returned her highest mean on the resource adequacy scale at P4; once she had begun at her new school. Her interview comments indicated the reason for this increase:

...we’ve got a thousand science books and a thousand resources and I’ve got a parent body that’s willing to spend, whatever I want I can have, that’s the kind of school I am at…(Simone, interview May 09).

The socioeconomic status of the school appears to also have an influence on the nature of the students they are teaching:

The kids are highly motivated here...you have a completely different clientele. The kids are far more interested, much more...this sounds terrible, middle class. You have very professional parents and you have a much higher interest level and I think this rubs off on to the students, more so than where I was teaching before. Understandings are far more advanced and life experience I suppose as well (Simone, interview May 09).

What is interesting to note is that despite the resources and the motivated student body, Simone did not show any change on mean school ethos scale, returning the same scores as she did at her previous school. Again, her interview comments provide further detail:

I get bombarded with ‘I can buy this stuff and I can buy books’....and I think well I might want it but nobody else is going to use it. It just sits in the strongroom and doesn’t get used at all…that’s how I see this new
school, it's no different to the motivation [to teach science] at [the old school]. It's exactly the same (Simone, interview May 09).

Similar to the ACT cohort, the NSW in-service cohort agreed that time was an impediment to science teaching, although P4 showed that there was more variation in the participant responses, as seen by the increased standard deviation. This increase could be attributed to the changes in schools by some of the participants, and the subsequent influence on their perceptions. However in the interviews, the NSW participants were far more likely to identify time as an impediment, as discussed in section 5.2.8, while at the same time maintaining that it should not be an excuse for not teaching science:

...I believe that there is enough time to teach science, I don’t believe that a lack of time is an excuse for not teaching science. But when you have a prescribed curriculum which you have to teach to, then you teach that first (Tanya, interview May 09).

This is supported by one of the other NSW participants who found she faced similar issues, irrespective of the school she was at, and blames the curriculum priorities of the NSW Department of Education:

...It feels like the Department is pushing us away from science...It’s all about literacy and numeracy (Anita, interview Oct 08).

5.6.5 Pre-service cohort: Influences on science teaching as identified using the SCIQ

The pre-service cohort was only given the SCIQ at P4, as this was the only time that they were within the same school environment for a prolonged period. The means and standard deviations are shown in Table 16.
Table 16: Means and standard deviations for each scale in the SCIQ from the pre-service cohort at the final sample period of the study.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Environmental Factors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resource Adequacy (RA)</td>
<td>3.09</td>
<td>0.55</td>
</tr>
<tr>
<td>Time (T)</td>
<td>3.4</td>
<td>0.96</td>
</tr>
<tr>
<td>Professional Support (PS)</td>
<td>3.5</td>
<td>0.38</td>
</tr>
<tr>
<td><strong>Personal Attribute Factors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School Ethos (SE)</td>
<td>3.15</td>
<td>0.59</td>
</tr>
<tr>
<td>Professional Science Knowledge (PSK)</td>
<td>3.44</td>
<td>0.32</td>
</tr>
<tr>
<td>Professional Attitude and Interest (PAI)</td>
<td>3.57</td>
<td>0.29</td>
</tr>
<tr>
<td>Professional Adequacy (PA)</td>
<td>3.33</td>
<td>0.3</td>
</tr>
</tbody>
</table>

For each of the scales, the pre-service cohort returned averages that were at least neutral, tending towards the positive/affirmative. The least variation was seen in the PS, PSK, PAI and PA scales, indicating that the pre-service cohort felt that their colleagues in their respective schools were supportive of science as a curriculum area, but also supportive of them, as evidenced by the following comments:

...I think I have gained the most knowledge from actually teaching in the classroom and being supported by other great teachers... (Vanessa, interview May 09).

...I've got a lot of support from the other people in my band development, so the other year 4 and year 3 teachers are really supportive... (Kate, interview May 09).

There was more variation of response seen in SE, which yielded a close to neutral mean indicating that science was neither supported nor suppressed in the schools. RA was also neutral indicating that the available resources were considered adequate but not excellent, or even good. The mean score of the time scale indicated that time was considered an impediment to science teaching. The mean returned by the pre-service cohort was similar to that of the ACT teachers, which was lower than that of the NSW teachers. As in all cohorts, this scale showed the greatest variation in responses indicating that not all teachers perceive time to be a limiting factor.
5.6.6 Limitations of the SCIQ

Irrespective of the means returned for each scale of the SCIQ, there was generally a high level of variation amongst the cohorts. This is to be expected due to the small sample size, but additional difficulties were experienced when interpreting the SCIQ results. Examining the responses over time at an individual level shows that the variation was occurring not only across the cohort but also for individuals at the different sample periods. As an example, the individual results from the NSW in-service cohort for the professional support scale are shown in Figure 21 below. Every participant in this cohort showed some variation in their response during the study period, with only Simone and Lisa appearing largely consistent.

![Figure 21: Comparison of mean scores returned for professional support scale of the SCIQ by NSW in-service participants throughout study period, demonstrating high levels of variation in responses at an individual level.](image)

This amount of individual variation was not always observed among the rest of the sample, as shown in the results for the resource adequacy scale for the ACT in-service participants (Figure 22). While some variation between responses was seen at the individual level, greater consistency was observed throughout the study period, particularly in the case of Elizabeth and Brian who returned the same scores for the RA scale throughout the study.
Many of the respondents indicated that they felt the SCIQ as an instrument was very repetitive. This was after many of the repetitive questions had already been removed. Of greater issue however was the perceived difficulty of answering some of the questions ‘on behalf of’ all teachers at the same school. For many of the participants, particularly when the pre-service teachers first went into schools, they felt that they did not yet know the school or the other teaching body well enough to comment. This was not confined only to the pre-service participants, with some of the in-service teachers, who had taught at the same school with the same colleagues for many years, finding similar problems:

*I feel a little awkward talking for everyone else in the school in the surveys. I really don’t know everyone’s background and it’s hard for me to say what everyone else is like* (Lorraine, interview May 09).

The uncertainty of the participants about the backgrounds or perceptions of their colleagues resulted in many ‘neutral’ responses, which limited the usefulness of the data collected by the SCIQ:

*You may have noticed from what I answered on the questionnaire there are a lot of ‘Ns’ because there are a lot of things I can’t find at school, and science doesn’t seem… it’s not sort of a… first… in a subject. I don’t even think it rates for some of the teachers but I’m not too sure so that’s why I had to write N for everything* (Paul, interview May 09).
The SCIQ data could be more accurately interpreted and critiqued when it was examined in conjunction with the interview data, which provided further depth and context to the SCIQ results.

5.6.7 Summary: Environmental influences identified using the SCIQ

The SCIQ, although not without limitations, identified other influencing factors within the school environments of the participants. The biggest issue faced by the ACT in-service cohort was the perceived availability of resources to teach science. Over the duration of the research, they showed an increase across all personal attribute scales. Many of the ACT participants also mentioned the positive influence of their colleagues and the power of the shared experience in helping motivate and inspire each other in their science teaching.

The NSW cohort showed increased scores in each of the factors of the environmental and personal attribute scales; however the areas of greatest increase (professional attitude and professional science knowledge) also had some of the greatest variation. The biggest issue identified by the NSW cohort was school ethos. Interestingly this applied to all participants, even those who were no longer teaching at the same school.

The pre-service participants all indicated neutral tending to positive scores for all factors, indicating that they perceived that time was an impediment to science teaching. As with all cohorts, the time factor also exhibited the greatest variation, suggesting that this was not a view held by all participants. Overall, the curriculum, resource availability and teacher attitude were identified by all participants as the biggest issues and factors influencing science teaching. None of the changes in scores over the research periods were found to be statistically significant.

5.6.8 One thing to help teach science

All participants were asked at both interviews if they could have one thing to teach science, what would it be? The majority of responses at both interviews (15 and 16 out of 21 respondents respectively) were related to resources. This was described as money to buy resources, the resources themselves or a specific room set up with the necessary equipment and resources to run science.

A purpose built science room like you’ve got a purpose built music room or art room. Where you can take the kids and all the gear you need is there...and [you] know that the stuff was in the cupboards...(Valerie, interview May 09).
Some of the participants mentioned using their own money to buy the necessary equipment to teach science in class:

*More equipment. You often find ideas that you would like to do but need the money to spend. Sometimes you spend your own and that’s fine, but all the time? More equipment and money to spend (Tanya, interview Oct 08).*

*More resources, the school’s pretty lacking in resources in terms of science so you sort of have to make do and bring what you need. So I suppose you can always teach science without expensive resources. They don’t have any specific science equipment like beakers, and they hardly have any maths equipment so if you want to do any sort of things with measurement to do with science then you are pretty limited. They don’t have many science related curriculum resources in the library, you have to go looking or buy them yourself. Stuff like that...It’s just stuff for me to do. Like we have to supply our own plastic cups and our own potting mix. It either comes out of the class budget, which is pretty small, or your own pocket. There’s no place to even really collect resources. There’s no science storeroom. There’s one for maths, English and art, but no science place (Vanessa, interview May 09).*

The latter portion of Vanessa’s comment could also be indicative of the status of science as a subject within her school. Examining her individual SCIQ scores, the school ethos scale returned a neutral score of three, indicating that she did not perceive science as being supported or downplayed in her school, but the score of 2.5 for the resource scale did indicate that resources were an issue for her, as indicated in her interview.

Ready made resources like the Primary Connections kits (Australian Academy of Science, 2010), or a sample lesson plan or a book of experiments would be ideal for four of the respondents, particularly ones that minimise the work effort for the teacher in terms of research:

*A prescriptive kit with all of the resources in it (Anita, interview May 09).*

*A book of really awesome experiments that are easy to do and actually explained. Like to have the actual explanation with the experiments that says this is why this happens (Kendra, interview May 09).*
A similar number of respondents (five at first interview, three at the second) would choose to have a human resource in the form of a specialist science teacher.

*I think there is a place for science specialists as well…that kind of thing would be really good. Sometimes you need someone to kind of inspire you to do these things too…*(Kerrie, interview May 09).

This inspirational aspect was also identified by those respondents (four at both interviews) who identified that some other form of professional development would be the one thing they would like to help them teach science:

...You can go and get resources yourself but you need someone…to come in … just to recharge the batteries, so you need the resources there but you also need the other human resources, other people who know so much (Brian, interview May 09).

This was not confined to the in-service teachers, with a pre-service teacher also identifying that they too needed the human resource to help them teach science:

*I guess it would be some sort of course that covers all these basic concepts that kids are going to be expected to learn in school, and all the basic do’s and don’ts — how you should and shouldn’t approach it. The teachers should be learning these concepts as well as how they would be taught to the kids - killing two birds with one stone. Run more workshops, please! Seriously, the unis are failing to provide proper science units and we’re just going to have this generation of teachers that are...just not going to teach science. I’m still hesitant and I had the workshop that you [ran]. If I was a student and I hadn’t done the workshops that you did I doubt that I’d be teaching science (Kate, interview Oct 08).

One of the in-service teachers also identified these workshops as being the one thing she would like to help her to teach science:

*I really thought that those experiments and the things you sent [resource booklets for the experiments conducted in the workshops] were very helpful, and they were easy, the equipment was easy and I liked how it was explained. I haven’t got particularly a science brain and unless I read about why things happen and I like to be organised before teaching it to the kids, so that sort of thing I think is good. I certainly found the
experiments we did at school [the workshops] worthwhile with the other teachers, so that sort of thing I like (Lorraine, interview May 09).

Similar sentiments were expressed by a pre-service participant who identified that the resource booklets which the workshops were based on were very useful, beneficial to her science teaching and her chosen ‘one thing’:

*Resources like what you gave us that show us what to do and how to explain it* (Jaeda, interview Oct 08).

The workshops that were run for this study were specifically designed by a science centre and offered as professional development sessions to teachers Australia wide. Their appropriateness for this had already been ascertained in previous evaluations, as well as a precursor to this study as discussed in Chapter 4. The next section will look at how the workshops were perceived by the study participants in terms of a potential role for informal science education centres.

5.6.9 Summary: What do teachers want to help them teach science?

When asked to nominate one thing to assist in their science teaching, all participants irrespective of experience or cohort wanted resources in terms of ideas, knowledge and physical ‘things’. A specialist to teach science was also a popular option, with many participants also stipulating that the specialist even need not teach, but simply provide support, training and motivation to other teachers; this would be considered a valuable resource.

5.7 Research question 6: Is there a role for informal science education?

5.7.1 Influences of the workshops and informal science education on teachers and identified needs arising from these experiences

Previous sections in this chapter have introduced some of the experiences of the participants with informal science education institutions, such as Vanessa who found that her work experience with an informal science education centre provided her with more confidence to teach science. Another pre-service participant identified that visiting a science centre with her own children helped provide her with ideas which she could translate into her own teaching:

*I’ve been to Science Time at [the local science centre] a few times and taken activities from that and used them in holiday programs I’ve run with special needs students… I’ll also use [the science centre] activities*
in class in the future. I’ve just found them really useful and a great source of ideas (Anthea, interview Oct 08).

Other participants noted that they have been on excursions to science centres and museums which were useful in consolidating students’ ideas about topics covered in class:

[The local science centre] last year when I was on prac, they had the natural phenomena [exhibition] there and our kids absolutely loved it and for them it actually consolidated a lot of the ideas that we’d been talking about in class. And they played on the displays; they had a lot to talk about on the bus on the way back to school. And then we had our own science festival at school where the parents came though and every child had a science display…to show the parents and the other children in the school…so in terms of science museums and things being a good resource I think they really are. It’s just about timing, whether or not it ties in with the program (Kate, interview May 09).

An experience with an informal science education program may not have immediate relevance to the students, but may come to the fore later, as two participants found after a program visited their schools:

...Although that [the visit] was months ago, last term, it linked in with what we’re doing now, talking about travelling to the moon, being in space...all that sort of stuff...They’re dragging out bits of information that they thought they didn’t have which is coming to the fore and they’re able to answer questions so that’s really good (Paul, interview May 09).

When I was up on my prac I mentioned [the science centre] and a lot of the children, their eyes popped up, and they remembered that a road show had been up there the year before...They certainly remembered, not everything, but they could certainly recount a lot of the experiments and that sort of thing...(Peter, interview May 09).

Beyond providing the students with information about, and enjoyment of, science, informal science education organisations also play a role in assisting teachers with their own science knowledge, enjoyment and confidence. Two of the pre-service participants (Kendra and Sam) identified these workshops as being the most positive influence on their teaching careers in terms of learning how to teach science. For some of the other
pre-service teachers, the workshops completed in this study were identified as one of the key positive experiences they had actually had with science in their training:

*I don’t feel that one subject [at uni] was enough to equip me to teach science so I was very grateful for the workshops...I’ve applied to teach in rural New South Wales and I wondered about resources in terms of equipment to do science in class...After the workshops I started thinking about the kinds of things you used in the different experiments and it was all really simple...and it made me realise that even in rural schools we could get simple stuff like that pretty easily and if that was all we needed to do science then that was doable (Kate, interview Oct 08).

*The science activities we did in these workshops were fantastic. We actually feel like we can do some science now! (Lauren, interview Oct 08).

The impacts of the workshops, in terms of providing a sense of confidence and capability, were not relegated purely to the pre-service teachers. Some of the in-service teachers, particularly in the ACT in-service cohort, reported similar findings, as summarised by comments in both interviews from Brian:

*[The workshops] were good, well packaged, exciting and interesting...Had I been on class, I’d have done more science. I’d have leaned fairly heavily on what you were teaching. The danger being when you run out of these ideas do you come to a full stop? I probably would tend to say in some areas I probably would but not in the area of science...and it was the workshops that did it (Brian, interview Oct 08).

*I really enjoyed those sessions. There was a lot of talk and maybe we should have done a bit more experimenting than we did, but it kind of gave an impetus to the seven of us who did it without which we would be more, well, I speak for myself, would be more backing off from science than turned out to be the case, given the fact that you did this [workshop] with us (Brian, interview May 09).

Both pre-service and in-service cohorts expressed a desire for more activities, resources and courses. This was reinforced when all participants were asked about what kind of role they saw for informal science education institutions.
5.7.2 Do teachers perceive that informal science education institutions have a role to play to help them?

At the final interview, all participants were asked if there was a role for science centres and museums with teachers. Each participant stated unequivocally that there was, with responses easily categorised into three groups; first, an information source, second a motivator for teachers, and finally as a source for further courses and training.

An information source was the most commonly cited role for science centres and museums, with 15 of the 21 participants identifying this particular aspect. These responses can be broken down further into more specific categories. Science centres and museums were often identified as a source of specialist knowledge, a place that teachers could go to in order to find more information out about a topic or to provide an extension activity to complement what was being done in the classroom.

...If they could intertwine with the units that we teach, we could use their kind of knowledge, their expert knowledge — which we don’t have — for the areas that we need to teach...and help our children (Lisa, interview May 09).

One of the pre-service teachers echoed this common sentiment, but also provided an insight into how she perceived the preparation and general practice of teachers:

I think definitely [they have a role to play] because they know so much more about the topic. Teachers really only learn what they need to teach... (Kendra, interview May 09).

Even if teachers only ‘learn what they need to teach’, providing them with ideas and resources to do so easily was still highly valued, and was one of the key benefits of the workshops identified by participants:

I enjoyed the things we did last year and I made up a couple of little folders with all the activities in them, printed them off, and they’re a great little resource. If you want to do something you can have a flick through there and think ‘oh yeah, I’ll do that’. They were great (Valerie, interview May 09).

The things like you were giving us...those practical things that will give a short, swift idea to the teacher but lots of fun to the children. Doing the experiments so that they will learn by doing it (Paul, interview Oct 08).
For many of the participants, despite being very positive about the benefits of the workshops and the activities as a useful resource, their comments indicated that the perceived time constraints in the curriculum were still major stumbling blocks for teaching science:

*I really enjoyed doing the activities you brought in and I’ve got myself a nice folder of resources together now…and because our curriculum is quite prescriptive…I’m just going to have to work out where [the activities] fit it and where I can use them (Tanya, interview Oct 08).

For other participants, the activities provided an impetus and they incorporated them into their teaching almost immediately, and shared them with others, as described in section 5.2.6. This supports the identified role of science centres and museums as a motivator:

*You need someone…to come in and do what you did last year to give the rest of us the ‘eureka’ feeling - “oh! I get it!” or “Oh! I’ve never thought of this!”…we really did enjoy the time and there wasn’t any of that “oh, do we have to come again?”…[Science centres] can provide…resources, background, scientific justification for things and happening or not happening. You get the “aha!” factor with the kids…those sort of experiences to give variety beyond the classroom. [Science centres and museums] are very much a help (Brian, interview May 09).

Motivation for the students was echoed by another in-service participant who also identified young teachers as being important motivators:

*Things like [science centres and museums] or having young teachers who are ready to be out there, that’s great and those sort of things can get the children’s minds going…Having teachers and science museums and places like that where we can either go or they come here, that’s really positive (Paul, interview May 09).

The idea of motivating teachers is further supported by Simone who nominated this as the role for science centres and museums above all else:

*They need to motivate teachers. Nobody’s going to do anything unless they’re motivated to do it, and show them how easy it is to fit science into the curriculum. Absolutely [there is a role] (interview May 09).
Motivating teachers, and particularly young teachers, could also be related to the third potential role identified by the study participants; that of providing courses and training to teachers. For some of the pre-service participants, this was suggested as the key role that science centres and science museums could play in supporting universities in teacher training:

*I think that the workshops were fantastic and I really hope that that could become a greater focus in university. You explained how it all made sense and the university hadn’t done that* (Jaeda, interview May 09).

For other pre-service participants, having a science centre involved in their teacher training was perceived as one way of getting some of the knowledge required to teach science, and as a way of tapping in to the expert knowledge held by such institutions:

*Most definitely, because [science centres and museums] have got the knowledge that we don’t get. The science unit we did at university was an absolute waste of time. I didn’t learn anything that I would use in a primary school classroom and we did two or three units which just went kind of round and round in circles and we talked about odd bits and pieces. So if like museums and places like [science centres] and stuff can get involved then that would be fantastic. Even if just to give the teacher more of an idea of ways to make it interesting and ways to develop things so it’s not just that surface teaching...I’d much prefer to know about the topics [so] that I’d feel comfortable answering questions and that kind of thing which an experienced person would be able to tell me, to explain it* (Sam, interview May 09).

In-service participants supported the idea of science centres and museums providing training to pre- and in-service teachers. Paula also felt that informal education institutions could have an integral role in the more formal side of education:

*Yes I do think so [there is a role], like the sort of PD that is supplied and the stuff that you did at school (the workshops) where it’s hands-on resources and then supplying us with activities, I think in that way it would be awesome. But even just in terms of developing curriculum and activities and getting those out to us, those sorts of things in so many areas have been let go by every education department. They don’t value*
people who are experts being able to put together resources for teachers basically (interview May 09).

It appears that all of the identified roles for science centres and museums are intertwined — and that the expert knowledge, ideas and resources could ostensibly be applied to teacher training, professional and curriculum development.

5.7.3 Summary: participant perceptions of the role for informal science education institutions

The long term impact of informal science education experiences on students has been observed by many of the participants. The results presented here suggest that the style of professional development provided by informal education organisations can positively influence beginning and experienced teachers alike. The ACT cohort, comprising highly experienced teachers, showed increased confidence and self-efficacy in their science teaching, which led to improved, more positive perceptions of their own attitudes and abilities to teach science. The pre-service cohort gained extra confidence in their ability to teach science from the workshops, with many crediting the workshops with providing them with skills and information they felt was lacking in their formal teacher education.

All participants agreed that there was a role for informal science education organisations within the formal education sphere. From all participant responses, three main functions were identified. Informal science education organisations can function:

1) as a source of information/resources and ideas;

2) as a motivator, again providing resources, ideas and a ‘recharge’ for teachers; and

3) as a source of training and ongoing professional development.

Each of these three roles draws on the expert knowledge, ideas and resources of these informal science education organisations, and each of these roles can directly assist teachers to teach science, potentially via such means as teacher training, professional development and curriculum development.

5.8 Summary of main findings

This chapter presented the results of the current study, examining the changes in teaching efficacy and the influences of beliefs and the school environment. The main findings are listed under the appropriate research questions as follows:
Research Question 1: Do science centre produced, short professional development workshops have any effect on teachers’ science teaching self-efficacy?

- The workshops used in this research increased the confidence and enjoyment of science teaching for all participants, but particularly for the pre-service participants.

- The workshops positively influenced the self-efficacy of all of the participants, with the exception of two pre-service participants (Peter and Sam) and one in-service participant (Paula). This positive influence was maintained in all of the other participants for at least 11 months after the workshops had been completed.

- By period 4, Peter and Sam were both in very different teaching environments in comparison to their cohort colleagues, and the in-service cohort participants, and this could have influenced their efficacy beliefs.

- The results did raise questions about the relationship between the two scales used in the STEBI instrument as there appeared to be a converse relationship between the Personal Science Teaching Efficacy and the Science Teaching Outcome Expectancy scales. Only in the pre-service teachers did the two scales appear to increase or decrease consistently in tandem — with the exception of the one pre-service teacher who was not personally teaching science.

- The ACT in-service participants showed the greatest gains in science teaching self-efficacy of all participant cohorts, followed by the pre-service and then the NSW in-service cohorts. The differences between the cohorts were not found to be statistically significant but the differences in PSTE and STOE scores between period 1 and periods 2, 3 and 4 were statistically significant.

Research Question 2: Do science centre produced, short professional development workshops affect pre-service teachers differently from in-service teachers?

- The fears and science teaching impediments of the pre- and in-service cohorts were examined first to gain an understanding of how the two cohorts differed. Pre-service teachers tended to have pedagogical fears related to their teaching practice, generally and in science. In-service teachers were more likely to nominate the availability of time and resources as impediments to science teaching, along with student behaviour management.
• Specialty, resource intensive subjects such as science, music and art tend to be
the subjects that the participants nominated as their areas of least confidence.
However after the completion of the workshops, while music and art were still
nominated, science was not.

Research Question 3: Do science centre produced, short professional development
workshops have differing effects and impacts depending on a teachers’ teaching
experience?

• All participants showed an increase in their science teaching self-efficacy scores,
with the exception of Peter and Sam (both pre-service teachers) and Paula (ACT
in-service) whose PSTE score was the same at period 4 as it was at period 1, but
her STOE score had increased.

• The most experienced (20+ years of teaching) cohort showed the greatest overall
increase in PSTE. The changes in the mean STOE scores for all cohorts were
minimal.

• The pre-service participants did show a small increase in their mean STOE scale
score but this was not maintained. Their mean STOE score returned to its
original level at period 4, when they were out teaching in schools.

• The cohorts with similar levels of experience (1 - 3 with 4 - 6 years experience
and 15 - 20 years experience with 20+ years experience), returned very similar
mean scores on both scales.

Research Question 4: Does an individual’s previous experience with science
influence how they feel about science teaching?

• Previous experiences in science influenced how the teachers perceived science,
and in some instances provided the impetus to do better and find better ways of
approaching it.

• Many of the respondents indicated that their science experiences outside of any
formal training were with informal science education organisations — for four
participants these were also some of the most positive influences in their
teaching careers.

• Three of these participants identified the workshops used in this study as the
most positive influences on their own science teaching
Research Question 5: Does the environment of the school influence the self-efficacy of the teacher or how likely they are to teach science?

- The changes in efficacy and seeing the kinds of materials used in the workshops appeared to influence the perceptions of the teachers in terms of the professional science knowledge, attitudes and interest of themselves and their colleagues.

- Resources continued to be identified by the ACT cohort as a major impediment to science teaching.

- The NSW cohort found time to be the greatest barrier to science teaching; however the ethos of the school was also much lower than that of the ACT cohort.

- There was a lot of variation in the SCIQ results, with many participants arguing that time should not be an excuse for not teaching science, and rather the attitude and motivation of teachers themselves needed attention.

Research Question 6: Do teachers perceive a role for informal science education institutions with teachers?

- All teachers identified a potential role for science centres and museums in the provision of resources in terms of ideas and expert knowledge.

- These resources, ideas and knowledge, the participants argue, could then be applied to teacher training, professional development and also incorporated into the formal side of education in curriculum development.

The next chapter will synthesise these results, and ground them within existing research and theory, to provide clear outcomes and directions for future research.
Chapter 6: Discussion and Conclusions

6.0 Putting the results in context

Science education in Australia has suffered due to the lack of confidence and feeling of under preparedness held by many beginning and experienced primary school teachers. The general status of science within Australian curricula is low, with little time devoted to the teaching of science in the classroom. Chapter 2 outlined the importance of science education and the attempts that have been made in previous studies to identify the factors which influence teachers’ beliefs and perceptions of science. While numerous studies have been conducted on teachers’ self-efficacy, there is a dearth of information regarding the influence of the school environment on these beliefs, and the subsequent practice of teachers. Chapter 3 examined the potential role for informal science education institutions, particularly in the provision of teacher training and professional development. This is a largely uncharted area due to the challenges associated with measuring the impact of an informal education experience, and the paucity of information that exists in the literature.

This thesis addressed research questions pertaining to the impact of science centre style, short professional development workshops on both pre-service and in-service teachers. In addressing these research questions, qualitative and quantitative techniques were used, focussing on changes in science teaching self-efficacy and the influence of external and environmental factors.

This chapter is structured around the research questions examined in the current study. Section 6.1 outlines how science centre developed, short professional development workshops positively affected teachers’ science teaching self-efficacy and how this was shown in the teachers’ practice. The influence of the curriculum structure is also discussed. Section 6.2 examines how these changes in self-efficacy differed between the pre-service and in-service cohorts. Comparison of the effects of the number of years of teaching experience on the changes in self-efficacy of the participants is provided in section 6.3. The relationship of the results of this project to those in the literature is discussed in all three sections.

The influence of the participants’ previous experiences in science is discussed in section 6.4, along with that of informal education experiences and the importance of effective teacher training. Section 6.5 examines the influence of the school environment on self-efficacy and teaching practice. Section 6.6 outlines the role for informal education
providers as identified by the study participants and how this can be used to best effect in science education reform. For each of these three sections, the findings of this project are contextualised within the wider body of literature, addressing identified knowledge gaps. Section 6.7 presents the conclusions of the current study, in the context of the aim and the scope detailed in Chapter 1. Limitations within the current study are discussed and recommendations for future research made.

6.1 Do science centre produced, short professional development workshops have any effect on teachers’ science teaching self-efficacy?

6.1.1 The effects of the professional development workshops on participants’ science teaching self-efficacy

The results showed that the self-efficacy of all but two pre-service participants was increased after the completion of the series of workshops. This increase was maintained in all but three of the participants for at least 11 months after the workshops ended. This indicates that the workshops were influential in increasing the participants’ PSTE beliefs, which was corroborated by the comments made during interviews and their subsequent self-reported changes in practice. Linear mixed effects model analysis showed that the increase in PSTE scores between period 1 and period 4 was statistically significant ($p < 0.001$). The sample size used in the current study was small, so the results may not be representative. However, the data collected through the interviews and the lack of any other science based professional development activities undertaken by the participants intimates that a cause-effect relationship could exist.

Overall, the results on the STOE scale were less conclusive than those for the PSTE scale. Linear mixed effects model analysis did not identify any statistically significant results. Although it was hoped that an increase in STOE scores would be observed, it was not expected based on the existing criticisms of the STOE scale in the literature, as discussed in section 2.3.2. Pre-service teachers were more likely to show an increase in STOE over the duration of the study, until the final sample period where many of the STOE scores dropped once they began teaching full time. This drop is attributed to the pre-service teachers’ unrealistic expectations of achievable outcomes, due to their limited experience and understanding of the nature of teaching (Swarz & McMunn Dooley, 2010). This pattern has been observed in other longitudinal studies of pre-service teachers (Hoy & Woolfolk, 1990 in Swars & McMunn Dooley, 2010). The in-service participants’ STOE scores were largely unchanged throughout the study;
however if any change was observed it was a minimal decrease in STOE. This could imply that more experienced teachers could have greater confidence in their ability to teach science, but be less confident in achieving the desired outcomes with their students. They are perhaps more realistic about their ability to overcome difficulties. This explanation is similar to the findings of De Souza et al. who state, “…teachers with a greater number of years of teaching experience were less confident of their students’ achievement (outcome expectancy) than teachers with less experience” (2004:851) and suggest that other external factors should be considered.

A problem with De Souza et al.’s conclusion is illustrated by Elizabeth’s results. Elizabeth showed the greatest increase in PSTE of all the ACT participants, yet her highest PSTE score coincided with her returning her lowest STOE score. The data collected in her interviews did not cite student or classroom problems or issues of underachievement. Nor did she believe that the school environment was preventing her from achieving outcomes — in fact she was one of the most vocal proponents of the value of the support of her colleagues in helping her to change her practice. Despite rigorous consideration of external factors, a clear explanation for these results was not found. This is an example of problems encountered in the use of the STEBI instrument, which are discussed further in section 6.7.

The workshops used in the present research, although occurring over four different sessions, were short. The total amount of time spent working with the teacher participants was under five hours. Kahle and Boone (2000) argue that a professional development intervention of this length would not achieve any tangible, long lasting result. This is supported by Supovitz and Turner (2000) who maintained that for professional development to be effective it should have duration of at least 80 hours. Yet the results obtained in the present study indicate that self-efficacy was maintained or enhanced in all but three participants. Their teaching practice was influenced and they reported an improved sense of confidence and enjoyment in science teaching as a result of this short intervention. Each of these results was still measurable at least 11 months after the workshops were completed. The results presented here are comparable to those reported in a study on the impacts on confidence and science teaching self-efficacy of a 13 week science methods course at a university (Palmer, 2006a).

For four, one-hour workshops to achieve the same as that of a 13 week course in a formal education setting indicates that the efficiency of short term professional development should not be dismissed. This is supported by Desimone et al. (2002), who
did not find any significant relationship between the duration of professional development undertaken by teachers and the subsequent student outcomes in their classes. Science teaching professional development in general has been found to be less successful than professional development in other areas (Hilliard, 1997). It would be beneficial for the status of science education internationally if any program capable of achieving positive results on teacher attitudes and beliefs about science was considered as a useful tool, irrespective of duration.

The results of this research show that short, science centre produced workshops can have positive and enduring impacts on both pre-service and in-service teachers. This is a valuable finding for an area of research that has little documented evidence of impact in teacher professional development (Astor-Jack et al., 2007; Garnett, 2002) and particularly how this impact changes over time (ecsite UK, 2008a).

6.1.2 The influence of the workshop structure and format

The structure of the workshop activities and the opportunities to have fun with science while engaging with it successfully are typical of the constructivist nature of informal science education offerings (Melber & Cox-Peterson, 2005; Posnanski, 2002; So & Watkins, 2005) and are in line with Bandura’s widely accepted sources of self-efficacy (Khourey-Bowers & Simonis, 2004; Woolfolk Hoy & Burke Spero, 2005).

All of the participants found the workshops enjoyable and useful, with three of the participants nominating the workshops used in the current study specifically as their most positive influence on their teaching practice. The positive influence of the workshops was particularly noticeable in the ACT in-service cohort which had the majority of respondents feeling least confident in teaching science. By the end of this study, these participants had not only stopped feeling as uncertain about teaching science, but they had increased the amount of science that they taught and/or included more activities into their programs, based on what they had seen in the workshop.

Possible reasons for the ACT cohorts’ change in attitude towards science teaching could be attributed to several different factors, including the nature of the workshops themselves.

The workshop sessions with the ACT cohort always featured a lot of talk between the participants and frequent sharing of ideas of how activities could be used in class, or how activities had been received by their class the previous week. The participants nominated the support from their colleagues as one of the greatest influences in
changing their science teaching practice. This supports the notion of the effectiveness of
collegial interaction and collective professional development to influence classroom
practice (Hewson et al., 1999a; Penlington, 2008). A recent doctoral study by Perera
(2010) found that the collegial interactions between workshop participants helped to
build feelings of trust and support. The findings of this current research certainly agree
with Perera’s results. The support felt by the teachers and their change in practice could
then arguably have flow on, positive, effects on the outcomes of students (Garet et al.,
2001; Price Waterhouse, 1995), however this was not examined in the current study.
Future studies could benefit from incorporating measures of student outcomes, such as
evidence of increased understanding of concepts or engagement in science lessons.

Classroom students also act as an influence on the success of any professional
development activity, as illustrated through the comments of Anita. Despite noting the
workshops as being highly influential on her science teaching practice she was reluctant
to engage in hands-on activities with her students as she feared the consequences and
the intensive requirement for behaviour management. Behaviour management of
disruptive pupils has been identified as one of the main reasons why teachers leave the
profession (Kyriacou & Kunc, 2007), so it is not surprising that it was mentioned as a
barrier to science teaching by one of the participant teachers. It is more surprising that it
was mentioned by only one participant. The success of the workshops was strongly
influenced by the participants’ work context, discussed in greater detail in section 6.5.

It is important to note that simply including hands-on activities in lessons does not mean
that teachers will become effective teachers of science. While constructivism is the
“guiding philosophy routinely taught to those aspiring to become teachers in many of
our faculties of education” (Carter & Wheldall, 2008:17), the appropriate understanding
of the principles of constructivism can occasionally be missed. There is a danger that
beginning teachers, and perhaps experienced teachers too, may believe that the use of
hands-on activities, without any development of conceptual understanding or scientific
inquiry skills, is enough for “meaningful learning” (Talanquer et al., 2009:15). This
“naïve” (ibid:15) definition of constructivism is counterproductive to any reforms made
professional development however notes that, in his study, the use of science
communication practices in framing and delivering these constructivist principles were
what truly facilitated the workshops’ learning experiences and their subsequent success.
Arguably then, informal science education providers such as science centres, who
employ science communication strategies in their content delivery, are well placed to effectively promote constructivist pedagogy to teachers through training and professional development. This is further discussed in section 6.6. The manner in which the participants were employing the workshop activities in their own classrooms was not examined in the current study as a teacher’s understanding of constructivism was not being examined here. It could, however, be beneficial to include in future research.

6.1.3 The importance of including resources with professional development activities

Each of the workshops came with a resource booklet, which many of the participants kept as a resource for future use. Nearly half of the pre-service participants indicated that they had used the workshop activities, as well as shared them with their teaching colleagues. This shows the relevance of the workshop materials to the needs of the pre-service teachers, and also indicates the potential for the longevity of the impacts of the workshop. This is supported by the findings of Ginns and Watters who identified that “...unless preservice teachers have deliberately kept resources, and have the opportunity to revisit their course material when beginning to teach, much of the significance and value [of a course or workshop]…is lost” (1999:314). Coupled with the maintained increase in science teaching self-efficacy, it can be concluded that the workshops and the resource booklets were instrumental in creating, and sustaining, enhanced attitudes towards science teaching of all participants in the present study.

6.1.4 Changes in practice as an indicator of a change in science teaching self-efficacy, and the influence of the curriculum

For the purposes of this project, a change in practice was typically identified as an increase in the amount of time spent actually teaching science and in the kinds of activities included in the participants’ science programs. The majority of the participating teachers in the current study maintained or increased the amount of time they spent teaching science, or they increased the hands-on content in their science programs. This was also reflected in the statistically significant (p< 0.001) increases in self-efficacy (PSTE) in all of the participant cohorts and, in the case of the in-service teachers (who completed the Science Curriculum Implementation Questionnaire (SCIQ) four times), an increase in the mean score for Professional Science Knowledge (PSK). The converse (low self-efficacy and low PSK) association has been found in previous
studies (Baker, 1994 in Lewthwaite, 2001) therefore it is reasonable to assume that the
two factors also associate positively.

The amount of science taught was measured by the interview data from each of the
participants, self-reporting on how much science they had taught in class. Techniques
such as recording classes on video or the use of journals were not employed in this
study as the influence on practice was not an essential component of the research
questions. However future studies on the influence of informal science education
professional development on teacher practice would benefit from this additional
analysis in conjunction with the methods used in the present study.

At the first interview, the majority of participants reported spending less than one hour
per week on science teaching. The reasons for this were largely attributed to the
structure of the curriculum — a science subject was not being covered that term, but
would be next term. The participants in the current study acknowledged that science is
often not perceived as a curriculum priority, a sentiment echoed in the literature
Therefore it is easy to relinquish in favour of other, more high profile subjects. What
was concerning was not just that science was not included in the curriculum for an
entire term, but that the teachers did not see that the subjects that were to be taught had
relationships to science. This could also be a shortcoming in the curricula in the ACT
and in NSW.

Despite some apparently obvious links to science, all but one of the study participants
did not consider subjects such as sport, health and studies of society and environment as
potential avenues for the teaching of science. Science is a particularly effective tool to
use in the teaching of mathematics and literacy (Association for Science Education,
2008), with opportunities to introduce new vocabulary and practice mathematical skills
such as measurement and graphing change. This did not appear to be recognised by the
participants in the current study, some of whom attributed the highly specific nature of
the curriculum as a reason for not integrating the different subjects in their lessons.

It is possible that the curriculum is responsible for this perception. In trying to clarify
exactly what outcomes the teachers are expected to get from their students, the
curriculum documents may have become far too prescriptive. The end result is that
teachers feel like they have to achieve all that is set out in the curriculum document for
each subject and by the time that is done then there is no time left in the day. This could
be one of the main reasons why time is so often reported as a reason why science is not
being taught, as was shown in the interview comments collected in the present study. This conclusion is supported by the larger body of research where science curricula worldwide have been criticised for being content heavy (Fensham, 2002; Rennie et al., 2001) and overly prescribed with limited opportunity for student involvement (Suarez et al., 1998) with the crowded school days often precluding the incorporation of hands-on activities (Carnemolla, 2007; Hewson et al., 1999b). Future studies may benefit from curriculum analyses, particularly once the new nationwide curriculum is implemented in Australia.

There is still a need for the teachers themselves to understand the purpose of science education, as well as the content, and then how to convey this in an engaging manner. As seen in the results obtained in the present study, along with those cited in the literature, teacher education is falling short, often on all counts. Hands-on science, as employed by informal science education institutions, is one means of creating the engagement and understanding in students and teachers alike. But like any reform, it will be like throwing seeds on stony ground if the school context is not taken into account as well, as will be discussed in section 6.5.

6.2 Do science centre produced, short professional development workshops affect pre-service teachers differently from in-service teachers?

6.2.1 Comparison of changes between pre-service and in-service participants

Both pre-service and in-service participants showed increased levels (or maintenance of the same levels) of confidence and enjoyment in science teaching and an increase in self-efficacy. The greatest difference between the two cohorts was that of the outcome expectancy (STOE) scores, as discussed in section 6.1.1. The ACT in-service cohort showed the greatest gains overall in PSTE, followed by the pre-service teachers and finally the NSW in-service. These differences were not statistically significant between the cohorts (p > 0.05).

The pre-service cohort showed the greatest increase in their confidence in, and enjoyment of, science teaching which is an important contributor to their development of positive attitudes towards science. Enjoyment improves teachers’ science teaching self-efficacy by increasing the desire to engage in science, facilitating an improved understanding of scientific concepts, which should then translate into successful experiences teaching science to a child (Palmer, 2006b; Schoon & Boone, 1998;
Watters & Ginns, 2000). All of the cohorts showed a statistically significant increase in their enjoyment (p = 0.007) and confidence (p < 0.001) in science teaching between periods one and four - however these differences were not found to be statistically significant between the cohorts themselves.

Pre-service participants used the workshop activities during their practicum and shared the resources with their mentors and colleagues once in school. This was an immediate indicator of the influence of the workshops on the pre-service participants’ self-efficacy and teaching practice. Successful science teaching experiences are valuable to the development of pre-service teachers’ teaching practice, and in the development of positive attitudes towards science (Palmer, 2004). For the supervising teachers and new colleagues of the pre-service participants, and the other in-service participants in the current study, the sharing of resources and ideas may have contributed to them attempting new instructional approaches with their students (Darby, 2008) or facilitated the development of a new perspective on science teaching practice (Bianchini & Cavazos, 2007).

6.2.2 How fears and anxieties differed between the two cohorts

The fears and anxieties between the two cohorts were different, which influenced self-efficacy beliefs, as they are at very different stages of their careers. The fears of the pre-service cohort were not so much related to science as to the process of teaching itself, but the workshops did help the pre-service participants feel more positive about their ability to teach science overall. This is further discussed in relation to the participants’ previous experiences in science in section 6.4.

As the pre-service participants began working in schools in the final months of this study, their fears progressed from lesson planning and dealing with parents to student engagement and behaviour management. As described by O’Connell Rust:

…[beginning teachers ] enter their first years…feeling more or less competent to teach the various areas of the elementary curriculum but largely unaware of those organisational, administrative and interpersonal forces that are likely to influence their lives in schools (1994:216).

Chan (2008) also observed these same concerns for both beginning and novice teachers, suggesting that these fears could be associated with the general unfamiliarity of teaching practice in ‘new’ teachers. This is supported by the lack of identification of these same pedagogical fears by in-service teachers in the current study, perhaps indicating their
greater level of comfort with the process and mechanisms of teaching. Schoffner states that these “…common concerns…are understandable for pre-service teachers and the consideration of such concerns does not preclude the uptake of other, more critical, issues” (2008:125). As many of the pre-service participants in the present study acknowledged, there are some things which can only be learnt through experience once out in the teaching workforce, such as learning to deal with parents and writing reports. This is consistent with the opinions of beginning teachers in an earlier study who reported learning to cope with parents and other daily issues only once they started teaching in school, noting “you’d have to learn it by experience as well, and, that isn’t a concern (for me) any more” (Ginns & Watters, 1999:293). Thus the concerns expressed by the pre-service participants in this study are consistent with the ‘rite of passage’ of beginning teachers as described in the literature.

In-service teachers were more likely to feel anxious about specific specialty subjects, such as science, music and art. In the beginning of the current research, just under half of the in-service participants nominated science as their area of least confidence in teaching in comparison to one pre-service teacher. At the completion of the study, only one in-service teacher still nominated science as their area of least confidence. All other participants who had previously nominated science and other specialty subjects still nominated the specialty subjects; but science was no longer an identified concern: the workshops worked.

The nomination of specialty subjects, including science, is consistent with the concerns of in-service teachers associated with the time and resources required to teach these subjects. Time and resource availability are often cited as impediments to science teaching by in-service teachers, and this study was no exception, particularly in the case of the NSW cohort. The use of easily obtained, every day materials in the workshops helped remove this perception of the resources required to teach science effectively. The results obtained for the in-service cohorts in the current study were heavily influenced by the school environments, as will be discussed in greater detail in section 6.5.

**6.3 Do science centre produced, short professional development workshops have differing effects and impacts depending on a teachers’ teaching experience?**

Given the size of the sample used, from a statistical viewpoint the results obtained pertaining to teaching experience can be considered indicative rather than
The greatest gains in self-efficacy (PSTE and STOE) were observed in the 20+ years and 4 - 6 years teaching experience, and the pre-service teacher cohorts. The 20+ year experience cohort had the lowest PSTE at the start of the current study, and the second highest STOE score — the former scale showed great gain, whereas the change in their STOE score was small enough to be almost negligible. The changes on both scales for this cohort are similar to Riggs (1995) who found that teachers with low self-efficacy (PSTE) and high outcome expectancy (STOE) showed an increase in their PSTE scale but remained stable on their STOE results. Riggs’ findings are supported by those of Roberts et al. (2001) who discovered that teachers with the lowest PSTE are most likely to show the greatest impact on their self-efficacy from in-service activities. Yet the same study also showed minimal influence on the STOE scores of participants. This was reflected in the current study with the in-service cohorts showing only very small changes in their STOE scores, showing therefore that the results of this project are consistent with the wider body of literature. The usefulness of the STOE scale in research is further discussed in section 6.7.

The participants with more than 20 years of teaching experience showed the greatest gains in PSTE, although it was still the lowest PSTE score of all the experience cohorts. This is probably because the majority of the teachers with over 20 years of teaching experience came from the ACT in-service participant cohort, the most science fearing cohort in the current study. The pre-service cohort (<1 year experience) began the current study with a similar STOE score to that of the in-service cohorts. They had the highest STOE score of all participants at the end of the study, but had returned to their initial score level. This could be attributed to the fact that by the final sample period, the pre-service teachers were out in school and were beginning to see what they could actually achieve in terms of student outcomes in the classroom, whereas in the first three sample periods their outcome expectancy was largely based on assumptions. Linear mixed model analysis suggests that experience is a statistically significant predictor of score (p < 0.05) however a clear trend was not observed in the current study. In interpreting these results it should be noted that the 20+ years of experience and pre-service groups were also the largest teaching experience cohorts in the study. A study with a larger number of participants in each teaching experience cohort would be needed to confirm these results.

The results for the participants in the other teaching experience cohorts were variable. The only consistent observation was that of the influence of the school environment.
One participant’s outcome expectation score increased once she changed schools, and was teaching a class with fewer behaviour problems. For another teacher, outcome expectancy was limited by the fact that he was teaching at a special needs school. The context within which self-efficacy is being measured was seen to be of greater influence and importance in the current research than the amount of teaching experience, and accordingly is an important factor to consider, as also argued by Ford (1992 in Lumpe et al., 2000) and supported in the literature (see for example Lewthwaite, 2001; Luft, 2007; Tschannen-Moran et al., 1998).

6.4 Does an individual’s previous experience with science influence how they feel about science teaching?

6.4.1 The (in)adequacy of the participants’ science training

None of the participants in the current research had any significant science experience or background. One participant had a keen interest in science and was largely self-taught. All the other participants reported feeling inadequately prepared to teach science, particularly in terms of their science knowledge. This echoes earlier work by Goodrum et al. (2001) and Harris et al. (2005) who both found that Australian teachers, in primary and secondary schools, predominantly felt under prepared and ill equipped to teach science. This has also been reported in the United Kingdom (Murphy et al., 2005), in the United States of America (Dorph et al., 2007) and in Turkey (Bursal, 2008). Internationally, this appears to be a common problem in the profession.

The pre-service participants did not feel that their teacher training had adequately prepared them for science teaching. Every pre-service participant noted that the only thing that really provided adequate preparation was the practicum component of their course, when they were actually out in schools and teaching themselves. This response was usually only elicited in relation to teaching in general, as the majority did not get an opportunity to teach science during their practicum because it was not being covered in the curriculum at that time. This represents the loss of a valuable opportunity for the pre-service participants to consolidate the skills and knowledge they acquired at university. The practicum would have provided them with the opportunity to take the theory of science teaching and turn it in to practice. It also robs pre-service teachers of the opportunity to gain valuable experience and constructive feedback which is necessary for the development of positive science teaching self-efficacy.
This is not unique to the pre-service teacher participants in the current study. Ginns and Watters (1999) found that Australian pre-service teachers typically do not get the chance to apply the strategies that they are taught, and to receive constructive feedback from mentors. This lack of opportunity to teach science often means that pre-service teachers “…are neither able to achieve early success in teaching science nor have the opportunity to implement strategies that will enable them to become effective teachers of science” (ibid:314). A decade has passed since Ginns and Watters’ study, and it seems nothing has changed. This is supported by the results of a search of the literature about initial teacher education in Australia between 1995 and 2004, which found that the criticism of “too much campus based ‘theory’ and not enough school-based ‘practice’ has intensified” (Murray et al., 2008:226). However opportunities to gain such experiences outside of the university environment do exist and can have positive impacts, as discussed in section 6.4.3.

6.4.2 Participants’ perceptions of science teaching based on their experiences as science learners

Each participant reported how their own experience as a science learner influenced their perception of science and ultimately their science teaching self-efficacy beliefs. Most of the respondents recalled experiences in science from their high school years, which for many was also the last time they completed any kind of science education. For the majority of participants, a negative experience in learning science resulted in their disengagement and disinterest in the subject. This translated to a reluctance or lack of confidence to teach science in some of the participants, while for an in-service participant this resulted in complete avoidance of science teaching altogether. This avoidance of science teaching has been observed by other researchers (Harlen, 1997 in Akerson, 2005; Angus et al., 2007; Angus et al., 2004; Stevens & Wenner, 1996) and represents an ongoing challenge for teachers and teacher educators nationally and internationally. This thesis has further shown that a teacher’s experiences as a science learner are major influences on their own science teaching beliefs and practice.

These results are consistent with those of Stevens and Wenner (1996) who found that high school science experiences had far greater impact and influence of pre-service teachers’ science teaching beliefs and practice than any science experience during teacher training. It could be argued that the same is true for in-service teachers. This is counterbalanced by Uzuntiryaki et al. (2010) who found that one of the most influential factors affecting the beliefs and practice of pre-service teachers was their teaching
method course at university. However, if pre-service students are completing their degree feeling under prepared to teach science, and only have negative experiences of science when they were students themselves, then this does not have positive implications for the state of their beliefs and subsequent practice.

In contrast to Uzuntiryaki et al. (2010), none of the participants in the current study identified their teacher education course as being influential on their perceptions of science, or on the way in which they would approach science teaching. Some of the pre-service participants expressed discontent with their educators at university, claiming that they were not sources of motivation, out of touch with what happens in a real classroom and the courses themselves were less than positive influences. These findings are similar to those of Settlage (2000) whose study also found pre-service teachers dissatisfied with their science methods course during their training. This is consistent with the findings of Greenwood (2003) too, who also pushes for further longitudinal studies to examine the incidents and factors that influence the practice of beginning and experienced teachers. Overall, the lack of influence of their teacher training, and the influence of the participants’ own experiences as learners of science, highlights the importance of having effective science teachers in schools, as has been argued throughout this dissertation.

6.4.3 The influence of informal education experiences in science on participants’ science teaching perceptions

Some of the participants mentioned seeing external presenters in science, including the researcher who delivered the workshops used in the present study, as being a source of motivation about science and science teaching. While all participants had positive views of informal education institutions (see 6.6.1), the pre-service participants seemed to gain the most from these experiences. Two pre-service participants nominated the workshops as their greatest influence in teaching. Others commented that if they had not completed these workshops then they probably would not feel confident attempting to teach science at all. Some recalled experiences in informal science education institutions as being influential on their science teaching practice, particularly as sources of ideas and motivation. For one pre-service participant it was her experience teaching at a science education centre that gave her the confidence to teach science when her teacher training did not. Three other pre-service teachers mentioned their experiences at informal science education centres as having positive influences on their teaching, with two
reporting that they actively incorporated ideas for hands-on activities that they had seen at these informal institutions into their own lessons.

This highlights the importance of creating positive science experiences for students and teachers alike, in order to create a future generation of teachers who recall school science with interest rather than fear. Informal science education institutions are capable of providing such experiences as illustrated in the literature (ecsite UK, 2008a; Persson, 1999; Tytler et al., 2008), and by the results obtained in the present study, and so should be considered as one means of addressing this issue.

The results of this research have shown that the science education a teacher receives, from their own time as a school student through to gaining their teaching qualifications, influences their perceptions and subsequent actions as a teacher of science themselves. Hanuscín et al. (2006) propose that the experiences of pre-service teachers as learners of science are one of the biggest influences on their subsequent practice. The present study argues that this could be applied to all teachers, not just those pre-service or beginning.

6.5 Does the environment of the school influence the science teaching self-efficacy of the teacher, or how likely they are to teach science?

6.5.1 The influence of the school environment on participants’ science teaching self-efficacy and practice

The school environment was found to greatly influence a teacher’s self-efficacy, especially the outcome expectancy, highlighting the importance of context when measuring self-efficacy of teachers. This was best demonstrated by the results obtained for Sam who began working in a school in the United Kingdom with a specialist science teacher. Her PSTE scores fell, which could be ascribed to working within a different school environment with a different curriculum structure and general cultural differences. However her STOE scores increased, indicating that she felt that she was capable of achieving desired outcomes for her students. This could be attributed to her own development of general teaching confidence and competence. Additionally, the specialist science teacher explained each of the science classes to her beforehand so she was aware of what her students would be covering in class. Sam identified this sharing with her colleague as a form of science professional development as she felt like she fully understood the scientific information and concepts being taught to her students as a result. This could then increase her confidence in achieving desired outcomes in science with her students, resulting in her elevated STOE score. This is similar to a
finding of Schriver and Czerniak who found “…a distinct relationship between the knowledge levels of teachers related to developmentally appropriate curricula and the corresponding outcome expectancy of the teachers” (1999 in Posnanski, 2002:214). While this does appear to be true, it is equally important to question whether Sam would show the same STOE scores if she was required to teach science herself.

6.5.2 The influence of teachers as colleagues

In-service participants were likely to nominate their colleagues as a positive influence on their teaching. For the ACT in-service cohort in particular, the collegial support of that group was important in sustaining their increased self-efficacy, the drive to try new things in science teaching and in maintaining the enthusiasm and impetus provided by the workshops. This upholds the theory of Penlington (2008) and Garet et al. (2001) who propose that groups of teachers from the same environmental context undertaking the same professional development will likely show greater effectiveness, and sustain the change over a longer period of time, than disparate groups of teachers.

The NSW in-service cohort had a school environment that did not regard science as holding a high status within the overall curriculum, which was revealed in the low means on the school ethos scale in the SCIQ. Despite great enthusiasm during the workshops, the NSW in-service participants did not change their practice, citing resource availability as one of the key impediments to science teaching, as well as time in the curriculum to allow it.

The difference in the extent of the influences on science teaching of the two in-service cohorts can be explained in part by the nature in which they were recruited to participate in the current study. The ACT in-service cohort first came to the researcher’s attention when the principal contacted the science centre to request a professional development session for all of his staff. The principal was the contact for the initial recruitment of staff from the ACT school and was supportive of science. One of the participants from the ACT cohort was the deputy principal. The results from the SCIQ on the professional support scale were generally quite positive, while the school ethos scale results remained more or less neutral.

In contrast, the NSW in-service cohort was recruited via Simone, a science positive teacher who attended an information session at the science centre and picked up an information leaflet about this research project. She then assumed the responsibility for promoting the research amongst her colleagues and recruiting interested participants.
None of the teachers in any position of leadership within the NSW school participated in this research. The SCIQ scores showed that the professional support results for the NSW cohort were lower than those of the ACT, as were the school ethos results. Therefore it can be concluded that the presence or absence of support for science within the leadership body of a school will have a direct influence on the overall school environment and ethos. This is supported by the findings of Riehl and Sipple (1996 in Huang & Fraser, 2009) who found a relationship between the collegiality and administrative support of a school and the subsequent professional and organisational commitment of the school. Lewthwaite (2004) and Ingvarson et al. (2005) further bolster this argument finding that the school environment, and particularly the principal, can influence the quality and success of science curriculum delivery and program outcomes. In other words, a school with a leadership team that supports science teaching and ongoing professional development in science is more likely to value science as an important part of the curriculum and be committed to achieving desirable outcomes in science. Thus, any reform in science education in primary schools needs to target the principals, deputies and science coordinators to ensure that there are numerous drivers of change within the school who are in a position to lead by example. Rowe supports this, arguing that “unless there is total commitment of all staff to new ways of working, reform efforts soon falter” (2003:12).

6.5.3 The influence of teachers as mentors and practicum supervisors

For many of the pre-service teachers, their supervising teachers while on practicum were a particularly negative influence as they were unsupportive or did not allow them to try new things. This lack of support and encouragement is discouraging to a new teacher, and could influence their intention to persist in using constructivist methods to teach science (Kelly, 2000). None of the pre-service participants mentioned observing their supervising teachers conducting a science lesson. Almost all of them mentioned not teaching science while on practicum as it was not part of the curriculum for that semester.

Once they were out teaching in school, many of the pre-service participants praised their supportive colleagues who were assisting them and sharing resources and ideas. The collegial interaction of teachers during professional development is just as important for pre-service and beginning teachers, as it is in these early years of a teaching career that teaching practices are established (Appleton & Kindt, 2002). This support is very
important to helping a beginning teacher establish their teaching beliefs and practices (Hewson et al., 1999b). The selection of appropriate supervising teachers and mentors is also very important, as they should support the beginning teacher’s practice without trying to instate their own practice and beliefs instead.

The results of this project are in agreement with the literature, indicating that the prevailing negative, or even noncommittal, attitudes towards science held by in-service teachers can negatively influence the beliefs and attitudes of pre-service teachers. If left unaddressed, as it often is by a lack of the provision of positive experiences in science, this perpetuates the propensity for primary teachers to minimise or avoid science teaching altogether.

6.5.4 The influence of the perceptions of resources and time

The availability of time and resources available to teach science is an often cited reason for not teaching science in class (Friedrichsen & Dana, 2005; Goodrum et al., 2001; Hopkin & Sharp, 2008; Lewthwaite & Fisher, 2004; Lumpe et al., 2000). This is supported by the comments made by the in-service participants in the current study. Some also identified the Department of Education as being a negative influence on their career as the administrative demands of the Department impinged on their core work as educators. This too is related to time pressures. Any reform which involves new methods of instruction, reporting and/or assessment must take the existing time pressures of the teacher into account (Lumpe et al., 2000), as the results of the current study signify that they are certainly a barrier — be it perceived or actual — to science teaching.

While in many cases lack of time may be a valid impediment, a study by Keys (2005) found that in some circumstances it may not be justified. In a longitudinal study at a school in Queensland, Australia, with a very well supplied, monitored science resource room, Keys found that of the 46 teachers at that school, only three had borrowed any science equipment through the year, one of whom was a participant in Keys’ study. Therefore the provision of any additional resources did not have any influence on the overall effectiveness of science teaching at that school. In the present study, just under half of the in-service participants nominated a lack of resources and time as their greatest impediment to science teaching. An inventory of the available science resources at each participating in-service cohort school was not collected in the current study, so it is not possible to evaluate the validity of resource availability arguments for these
teachers. Given the regular identification of time and resources as a barrier to science teaching in the literature, the use of the available time and resources by teachers warrants further examination.

6.6 Do teachers perceive that there a role for informal science education with teachers?

6.6.1 How teachers perceive informal science education institutions

Every participant in the current study believed that informal science education institutions, such as science centres and museums, have an important role to play with teachers. Irrespective of teaching experience or science background, every participant had some form of interaction with an informal science education program either through school or with their own friends and family.

All of the participants mentioned observing positive impacts on their students after a visit to, or from, an informal science education program. They stated that their students were motivated, engaged and able to recall concepts covered some months later. This corresponds with the findings of Winterbotham (2005 in ecsite UK, 2008a) who found that teachers expected their students to gain skills, and develop enthusiasm and understanding of science a lot more quickly than they would if they were covering the same material in the classroom.

The participants in the current study noted that a visit to a local science centre consolidated their students’ ideas about the subjects they had been talking about in class, or the visit was recalled when a topic that they had seen in the science centre was introduced in class several months later. In both instances, the participants noted that their students were animated and engaged in the topic. This supports the role of science centres as a motivator for visitors to engage in science, as consistently identified in the literature (see for example Persson, 1999).

The workshops used in the present research created a more positive attitude towards science in all of the participants as evidenced by the comments during interviews, changes in practice, and the short survey results. This is an important indicator of the potential impact science centres can have on the larger teaching population. For students to be motivated to learn and engage in science, they need to be taught by teachers who enjoy and are motivated by the subject themselves (Darby, 2005; Palmer, 2008; Rennie et al., 2001). Engaging and inspiring reluctant teachers of science has been identified in the literature as one of the biggest challenges faced by informal science educators.
(Jarvis & Pell, 2005). This thesis has shown that science centres are capable of addressing this challenge, even with short investments of time and resources, and that the positive impacts are maintained for at least 11 months, particularly when they occur within a school environment that is supportive of science.

6.6.2 The influences of the informal education sector

Influences on science teaching beliefs and practice can be found outside the formal education sphere. Four of the participants identified informal science education experiences as being the most influential on their teaching practice, three of whom nominated the workshops used in this study. Others had experiences in informal science education settings and found them to be inspirational and a source of ideas which they employed within their own teaching practice, as well as sharing with their more experienced colleagues. In a profession that appears to be short of inspirational and motivating science experiences and role models, informal science education providers may be an important part of the solution. Just over half of the participants in this study had, or were going to have, some kind of interaction with an informal science education institution during the course of during the current research. Yet none of the participants recalled seeing any professional development offered from any informal science education source. If teachers are not seeing that the professional development programs are being offered by informal institutions, then a valuable opportunity is being missed.

This is supported by the literature which suggests that informal science institutions are underutilised as a professional development resource, largely because they are not “pioneering a route into the classroom” (Phillips et al., 2007:1505), which the results of the present study also suggest. Or there may be offers being made by the informal education institutions but the information is either not reaching the right people or it is being disregarded before it has a chance to get to them. This is a possibility in a school with a leadership team that does not consider science to have a high status in the curriculum. If a principal, or even the science coordinator, does not regard science as important to the curriculum and needs of the students, then these likely points of contact for informal science education institutions are essentially closed doors. Any information may not be passed on to the other teachers on staff, as someone higher up has made a judgement call. A further possibility could be a combination of all of the above factors, as described by the Science and Society consultation process which found that “…teachers…do not feel empowered to use locally available or topical resources or develop local partnerships” (Department for Business Innovation and Skills, 2009:13).
The results presented in this thesis indicate that the informal science education sector is capable of creating enhanced science teaching self-efficacy in teachers. Evidence of this impact is not well understood and largely undocumented in the literature, (Astor-Jack et al., 2007; Melber & Cox-Peterson, 2005). However there are others who firmly believe that the formal education sector could greatly benefit from more involvement with the informal education sector (Department for Business Innovation and Skills, 2009; Stocklmayer et al., 2010). The current research has contributed information and understanding to the field, but as argued by Martin (2004) more needs to be done, particularly examining the outcomes of education that occurs within the nexus of the informal and formal education spheres.

6.6.3 How science centres and museums can work with teachers

The participants in the current study identified three key roles for science centres and museums.

1) Resources and ideas

This was the most nominated role for science centres and museums by the participants. Teachers are receptive to the resources and materials provided by informal science education institutions as they perceive them to be specialists in the field (Xanthoudaki et al., 2007). Aubusson et al. (2010) identified that teachers wanted to receive professional development from ‘expert’ sources. The teachers participating in the current research project believed that science centres were ‘experts’, capable of providing expert knowledge which they lacked, which is consistent with opinions gathered in other studies of teacher needs and informal science educators (Finkelstein, 2005). This is also supported by the results of Rodrigues et al. (2003) who, in a ten month study, found that the knowledge bases of teachers could be promoted through partnerships with subject specialists. The results from the present study support this, showing that science centre developed materials are capable of improving teachers’ science knowledge and science teaching confidence. The pre-service participants in particular reported very positive outcomes from their own experiences in informal science education settings. This thesis has therefore demonstrated that science centres, and arguably other informal science education institutions, are capable of producing content and resources which could facilitate the development of more confident teachers of science.
2) **Science centre/museum as a motivator**

The second role for science centres and museums nominated by the participants was that of motivator. Part of the motivating influence of informal science education is that it provides an experience that is different to that typically found in formal education environments (Falk & Dierking, 1992 in Finkelstein, 2005). In-service teachers in the current study identified science centres as having a motivational role more frequently than the pre-service teachers. It would be reasonable to assume that those teachers with over 20 years of experience are likely to require an extra motivational boost in comparison to those teachers just starting out. However the pre-service participants did mention the motivating influence external presenters in class provided during their teacher training, as well as the motivating influence of the workshops themselves.

External providers of professional development programs are capable of providing new ideas which may be beyond a teacher’s experiences and can be a source of positive reinforcement of existing (desirable) practices and beliefs (Hoban, 1997). The results in the present study show this, with all participants nominating the workshops as being motivating, confidence building and, in three participants’ cases, the most significant influence to date on their teaching practice.

A potentially limiting factor of this model is if the external provider does not take the nature of the school environment into context (Hoban, 1997). To an extent this was shown in the current research, where none of the remaining teachers in the NSW in-service school showed evidence of any real change in practice, typically citing time and resources as barriers. Science was still regarded as a low curriculum priority, illustrated by the school ethos scale results in the SCIQ. Despite the initial enthusiasm and identification of potential opportunities for science in the school, the participants were unable to maintain their motivation as the overall context in which they were operating did not change.

3) **Science centre/museum as trainer**

The provision of professional development and teacher training was the third potential role for science centres with teachers. Interviews with the pre-service participants revealed that the workshops provided them with skills, information and a sense of confidence and competence that they had felt was lacking in their teacher training. In-service participants identified science centres as not only a source of training, but also a
valuable source of specialist information and knowledge that the Education Departments could utilise in the development of science curricula.

From the data collected in the current project, it can be concluded that science centres, and the informal science education sector generally, can provide teachers with skills, knowledge and motivation that sources within the formal education sector cannot. This sentiment is echoed throughout the literature. The National Science Teachers’ Association in the United States of America (1998 in Melber & Cox-Peterson, 2005) highlights the experiences and resources offered by informal environments which serve to enhance professional and personal development. Studies undertaken in Finland have shown how the motivation of students (and therefore it could be argued teachers) can be enhanced by linking schools to science centres for well designed programs (Salmi, 2003 in ecsite UK, 2008a). In the United Kingdom, a Science and Technology Committee inquiry drew 44 submissions from science centres, each detailing the important role of science and discovery centres in supporting schools and the science curriculum through the provision of resources and training (ecsite UK, 2008b).

In blending the formal and informal science education sectors, it is not realistic to think that each classroom based science lesson should resemble an experience in a science centre — the two must be integrated so as to complement each other (Rennie & McClafferty, 1995) where the science centre visit reinforces the content covered in class and vice versa. The same approach must be taken in any professional development or teacher training undertaken by informal science education institutions. The primary aim is to get teachers enthused about science and confident in their own ability to teach science. The teachers can then take ideas from the informal sector and utilise them in the way most appropriate to their classroom setting. The present study has provided additional evidence as to how this can be achieved and further elucidated the role and influence of science centres on teacher training and professional development.

The results obtained in the current study suggest that even short interactions with science centre created professional development content, when combined with the right school environment, are capable of producing changes in attitudes and beliefs of teachers. By interacting with pre-service teachers, particularly as they become beginning teachers, this change in attitudes and beliefs could be instrumental in creating science positive teachers (Schwarz & Gwekwerere, 2006), who are capable of teaching science to students in an engaging and motivating way (Preston et al., 2007). The challenge lies in ensuring the surrounding school environment is supportive of science
and fosters positive science teaching self-efficacy. This is vital to ensure the positive outcomes of any professional development programs, and must be facilitated by supportive policy makers and school administrators (Ingvarson et al., 2005).

6.7 Limitations, recommendations for further research and overall conclusions

6.7.1 Limitations of the current study

The primary limitation of the current study was the small sample size. Research involving teachers is difficult to establish and maintain due to the existing demands on teachers’ time, as documented in the literature (see for example Watters & Ginns, 2000; Woolfolk Hoy & Burke Spero, 2005). Longitudinal studies are also faced with attrition of participants over time. Combining the two within a small geographical area resulted in a limited potential study population. This was mitigated as much as possible through the use of multiple research instruments to gather a richness of data which is not possible within a purely quantitative study. The results obtained in this study are valuable however a longitudinal study with a larger participant cohort would make them even more useful.

More follow up with the participants could increase the worth of the results. The researcher maintained some email contact between sample periods, chiefly to establish dates and times for subsequent sample periods or to update contact details. The participants were always invited to contact the researcher for additional resources or information at any time — an invitation taken up by only two of the pre-service participants. Posnanski (2002) described a similar limitation, surmising that a lack of follow up with his study participants may have negatively influenced the stability and sustainability of the self-efficacy beliefs, as well as any longer term changes in their teaching practice. By accounting for any other science based professional development in the period after the workshops, and not providing any other input to the participants, the results obtained in the current research project can be predominantly attributed to the influence of the workshops. It does beg the question though, what more could have been achieved if more was offered?

As outlined in Chapters 4 and 5, the SCIQ is limited in the depth of data it can provide. At best, it is a means of indicating potential areas of concern in a school environment, or as a mechanism to confirm or expand on data and inferences collected via other sources. Participants in the current study were uncomfortable answering questions about their
colleagues, either due to not knowing their colleagues’ attitudes and capabilities or perhaps feeling somewhat judgemental. This resulted in many neutral responses, an ‘I don’t know’ equivalent, which can be difficult to interpret. Quite a few participants also commented on the repetitive nature of the SCIQ, and this was a scaled down version with a lot of the repetition already removed. The developer of the instrument acknowledges that the SCIQ does have limitations (Lewthwaite & Fisher, 2004) and as such recommends that it be used in conjunction with other research methods. A multiple method approach is certainly preferable for any research of this nature, as no one instrument could hope to capture all of the information relevant to studies of human beliefs and actions (McLoughlin & Dana, 1999; Palmer, 2004; Park & Oliver, 2008; Singh & Shifflette, 1996). Despite its limitations, the SCIQ remains valuable as it is one of the few instruments available to researchers that attempt to quantify the myriad factors that comprise and influence the school environment and the teachers who work in them.

6.7.2 Interpreting the results from the STEBI scales — issues to consider

The contradictory findings of the current study potentially signify a weakness in the STEBI instrument, specifically in the STOE scale. It could be the difficulties associated with defining the outcome expectancy scale, as described by both previous researchers (Bursal, 2008; Gibson & Dembo, 1984) and the developers of the STEBI instruments (Riggs & Enochs, 1990). The complexity of defining and measuring a teacher’s outcome expectancy arises from the fact that it is trying to get a personal answer about factors teachers feel are beyond their control. For example, if a teacher has students with a poor science background and low motivation levels, then the teacher feels as though these circumstances are beyond their influence and they may not be able to achieve the desired outcomes. This is further supported by Dellinger et al. who argue that “when outcomes are externally controlled or relegated to chance and not due primarily to ability, self-efficacy beliefs provide little information in predicting behaviours” (2008:754). In comparison, the items comprising the PSTE scale, such as the ability to answer student questions, are factors that a teacher can directly control and influence. These are more likely to be consistently rated in teachers’ responses in the STEBI instrument and will provide more meaningful results.

The use of the STOE scale has been criticised for its inconsistent viewing and interpretation by those completing the STEBI instruments (Bursal, 2008). Posnanski states that “it is also possible that the STEBI A instrument does not adequately measure...
outcome expectancy beliefs…” (2002:214). The use of the STEBI B instrument with pre-service teachers has been found to have a low reliability. Mullholland et al. (2004) have attributed this to the evolution of teaching roles in modern classrooms. They believe that the STOE emphasises teacher centred approaches, whereas teacher preparation programs are now encouraging student-centred teaching approaches. Given that beginning teachers have been found to be teacher-centred in the early years of their teaching experience, irrespective of what and how they have been taught to teach (Marso & Pigge, 1989; Reitano, 2004; Sanders et al., 1993), it is possible that Mullholland et al’s. (2004) opinion may only be partially accurate. Theirs may be a more plausible explanation for the results obtained with experienced teachers and the STEBI A instrument, rather than the STEBI B.

For the purpose of interpretation of the results in the current study, it appears more likely that the complexity of the STOE construct is the main contributing factor where results are difficult to interpret. However Mullholland et al. (2004) rightfully assert that if science teaching is evolving then science teaching efficacy must also be considered as undergoing redefinition too. It cannot continually be measured as a static concept. This could indicate a need for the development of a more appropriate scale to measure outcome expectancy, or the development of a new instrument altogether. It also highlights the importance of gathering data via a variety of methods, examining personal and external factors and influences to allow cross checking and more accurate interpretation of the results.

6.7.3 Recommendations for further research

Based on the present study’s results, teacher preparation and ongoing teacher training is a key issue that needs to be addressed. Much of the student negativity and apathy towards science observed today will invariably translate to negative and apathetic teachers of science in primary schools tomorrow. People need positive learning experiences in science in order to want to engage in science. Informal science education institutions can, and do, play a part in providing these experiences to the wider public, but their impact in teacher professional development and teacher training is largely uncharted.

This thesis has shown that science centre produced, short professional development workshops are capable of motivating and engaging teachers in science. Further studies are required to look at how places like science centres and museums can work with
teacher educators, particularly in universities, to assist in the training of new teachers in science. This thesis has also illustrated the strong influence the school environment has on teachers’ beliefs. Further studies following pre-service teachers through their final years of their training, whatever training pathway they take, into their first years of teaching are required. Little is understood about the formation and durability of the beliefs of beginning and novice teachers, and how these beliefs are influenced. Future studies in this area must be longitudinal to measure any changes in beliefs and subsequent practice as the teachers move from pre-service to beginning to novice teacher. Any future studies examining teachers’ beliefs should also take into consideration the context in which the teachers’ operate to maximise the usefulness of results.

When measuring the impact of any professional development or training intervention, additional methods of verification of teaching practice, such as videos of classes and classroom observation, should be used. Additionally, in order to fully observe the impacts of an intervention, student outcomes should also be examined to determine the extent to which teacher practice is influencing student achievement. Existing studies have already examined teachers’ understanding of the use of constructivist approaches in education (see for example Peers et al., 2003; Talanquer et al., 2009). Future studies should continue to do so to ensure that hands-on activities are not used in isolation from the development of inquiry skills and conceptual understanding in science. Inclusion of aspects like these in research will provide a more thorough understanding of how professional development manifests in practice.

Given the propensity of teachers to cite the availability of time and resources as constraints to science teaching, future studies of science teaching and teachers should include an inventory of the science resources available to study participants. Understanding the resource availability would provide insight into the status of science within the school itself, as well as whether the teacher is not teaching science based on an actual or perceived resource inadequacy. Some form of measurement of classroom time usage, be it through classroom observations by a researcher or from a video taped class, would also be beneficial. This would assist researchers in understanding how long teachers need to devote to aspects of teaching, such as behaviour management, which could impede science lesson delivery. Through observations such as these, researchers would be able to work from a much more practical understanding of the context within
which teachers work, enabling them to draw more accurate conclusions as to what works and what does not in any proposed teacher reform initiative.

Self-efficacy continues to be a useful construct to predict teacher behaviour; however the results obtained in this study, and others, indicate a weakness within the STOE scale of the STEBI instruments. Measuring expectations is a complex task, and as teacher training and student populations change, it stands to reason that expectations will also change. Therefore the STOE scale needs to be revisited to ensure that it measures outcome expectancy in a manner appropriate to prevailing educational practice and training, to allow the STEBI to continue to be used as an effective instrument in science education research.

6.7.4 In conclusion

Chapter 1 outlined the aim of the current study, which was to determine if science centre produced, short professional development workshops were capable of influencing the science teaching self-efficacy of primary school teachers, and to identify the extent to which this was influenced by external factors.

The results obtained in this thesis showed that four hours of science centre produced professional development workshops were capable of increasing the science teaching self-efficacy of the majority of participants, with these increases still measurable for at least 11 months. The workshops were instrumental in creating more confidence and enjoyment in science teaching for all participants, which was particularly noticeable in the pre-service cohort who felt largely under prepared for science teaching prior to the workshops.

Pre-service teachers gained important mastery skills and positive experiences in science. This facilitated the development of positive levels of science teaching self-efficacy that may not have been realised through their teacher training alone. Experienced teachers were just as likely to show increased science teaching self-efficacy; however their school environment was a major factor in determining how this increased self-efficacy influenced their teaching practice.

This thesis clearly demonstrated that the science education experienced by the participants of this study was highly influential in the development of their own perceptions and beliefs about science that they, in turn, take to the classroom. This was just as applicable to newly graduated teachers as it was to those who have been teaching for over 20 years. The results of this thesis also showed that science centre produced
professional development activities are capable of inspiring, supporting and training teachers in order to help them teach science more effectively. These positive effects can be maintained within a school environment which is supportive of science and science teaching.

Overall, this thesis demonstrated that the informal education sectors could enact positive reforms within science education, but only if the context in which teachers must operate is taken into account and reform efforts adapted accordingly. It is time to use whatever resources are available to put the enjoyment back into school science if we ever wish to have a scientifically literate and engaged society. If educators and policy makers are serious about science education reform, it is time for them to acknowledge the contribution the informal education sector can make.
References


Bellamy, E. (2007, 30 January 2007). Teachers tell why they will move on. Canberra Times,


222


---. (2004). "Are you saying I'm to blame?" Exploring the influence of a principal on elementary science delivery. Research in Science Education, 34, 137-152.


Liberty Science Center. (unknown). Gateway at Liberty Science Center: Alternate route certification for science teachers. Liberty Science Center, Jersey City, New Jersey.


Wellcome Trust. (2006). Believers, seekers and sceptics: What teachers think about continuing professional development (pp. 6).


Appendix A: Modified Research Instruments

Science Teaching Efficacy Belief Instrument A (STEBI A) for in-service teachers

This survey was completed at all sample periods by the in-service participants and at the fourth and final sample period by the pre-service participants. At the final sample period the pre-service participants had completed their qualification and were employed in schools making them beginning in-service teachers.
Science Teaching Efficacy Belief Instrument*

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.

SA = Strongly Agree  
A = Agree  
UN = Uncertain  
D = Disagree  
SD = Strongly Disagree

1. When a student does better than usual in science, it is often because the teacher exerted a little extra effort.  
2. I am continually finding better ways to teach science.  
3. Even if I try very hard, I don’t teach science as well as I do most subjects.  
4. When the science grades of students improve, it is most often due to their teacher having found a more effective teaching approach.  
5. I know the steps necessary to teach science concepts effectively.  
6. I am not very effective in monitoring science experiments.  
7. If students are underachieving in science, it is most likely due to ineffective science teaching.  
8. I generally teach science ineffectively.  
9. The inadequacy of a student’s science background can be overcome by good teaching.  
10. The low science achievement of students cannot generally be blamed on their teachers.  
11. When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher.  
12. I understand science concepts well enough to be effective in teaching elementary science.  
13. Increased effort in science teaching produces little change in some students’ science achievement.  
14. The teacher is generally responsible for the achievement of students in science.  
15. Students’ achievement in science is directly related to their teacher’s effectiveness in science teaching.  
16. If parents comment that their child is showing more interest in science, it is probably due to the child’s teacher.  
17. I find it difficult to explain to students why science experiments work.  
18. I am typically able to answer students’ science questions.  
19. I wonder if I have the necessary skills to teach science.  
20. Effectiveness in science teaching has little influence on the achievement of students with low motivation.  
21. Given a choice, I would not invite the principal to evaluate my science teaching.  
22. When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand.  
23. When teaching science, I usually welcome student questions.  
24. I don’t know what to do to turn students on to science.  
25. Even teachers with good science teaching abilities cannot help some kids learn science.

Science Teaching Efficacy Belief Instrument B (STEBI B) for pre-service teachers

The pre-service participants completed this survey in the first three sample periods as they were still attending University and not yet qualified teachers.
(Preservice) Science Teaching Efficacy Belief Instrument
(Bleicher, B, 2004; modified from Enochs and Riggs, 1990)

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.
SA = Strongly Agree, A = Agree, UN = Uncertain, D = Disagree, SD = Strongly Disagree

1. When a student does better than usual in science, it is often because the teacher exerted a little extra effort. SA A UN D SD
2. I will continually find better ways to teach science. SA A UN D SD
3. Even if I try very hard, I will not teach science as well as I will most subjects. SA A UN D SD
4. When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach. SA A UN D SD
5. I know the steps necessary to teach science concepts effectively. SA A UN D SD
6. I will not be very effective in monitoring science experiments. SA A UN D SD
7. If students are underachieving in science, it is most likely due to ineffective science teaching. SA A UN D SD
8. I will generally teach science ineffectively. SA A UN D SD
9. The inadequacy of a student’s science background can be overcome by good teaching. SA A UN D SD
10. The low science achievement of students cannot generally be blamed on their teachers. SA A UN D SD
11. When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher. SA A UN D SD
12. I understand science concepts well enough to be effective in teaching elementary science. SA A UN D SD
13. Increased effort in science teaching produces little change in students’ science achievement. SA A UN D SD
14. The teacher is generally responsible for the achievement of students in science. SA A UN D SD
15. Students’ achievement in science is directly related to their teacher’s effectiveness in science teaching. SA A UN D SD
16. If parents comment that their child is showing more interest in science, it is probably due to the child’s teacher. SA A UN D SD
17. I will find it difficult to explain to students why science experiments work. SA A UN D SD
18. I will typically be able to answer students’ science questions. SA A UN D SD
19. I wonder if I will have the necessary skills to teach science. SA A UN D SD
20. Given a choice, I will not invite the principal to evaluate my science teaching. SA A UN D SD
21. When a student has difficulty understanding a science concept, I will usually be at a loss as to how to help the student understand. SA A UN D SD
22. When teaching science, I will usually welcome student questions. SA A UN D SD
23. I do not know what to do to turn students on to science. SA A UN D SD
Science Curriculum Implementation Questionnaire (SCIQ)

This survey was given to the in-service participants at each of the four sample periods. The pre-service cohort only completed this survey in the fourth and final sample period as this was the first time in the study that they were employed in schools.
Appendix A: School Environment Survey
Science Curriculum Implementation Questionnaire (SCIQ)
(After Lewthwaite and Fisher 2004)

Please complete both sides of this sheet

There are 38 items in this questionnaire. Think about how well the statements describe the school environment in which you work and indicate to what extent you agree or disagree with the statement, as it pertains to your school.

Indicate your answer on the score sheet by circling:
SD if you strongly disagree with the statement;
D if you disagree with the statement;
N if you neither agree nor disagree with the statement or are not sure;
A if you agree with the statement;
SA if you strongly agree with the statement.

If you change your mind about a response, cross out the old answer and circle the new choice

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Teachers at this school have a good understanding of the science knowledge, skills and attitudes they are to promote in their teaching.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>2. Teachers have a positive attitude to the teaching of science.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>3. The school is well resourced for the teaching of science.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>4. Teachers at this school are adequately prepared to teach science.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>5. I think that the school and its staff (including head teachers/principal) recognizes the importance of science as a subject in the overall school curriculum.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>6. I don’t feel like there is enough time in the school program to fit science in properly.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>7. Teachers at this school have a sound knowledge of strategies known to be effective for the teaching of science.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>8. I think that teachers at this school are reluctant to teach science.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>9. I think that teachers at this school are confident science teachers.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>10. This school has a culture that positively influences the teaching of science.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>11. I don’t think there is enough time in the school week to do an adequate job of teaching the requirements of the science curriculum.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>12. Teachers here have a sound understanding of alternative ways of teaching scientific ideas to foster student learning.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>13. The teachers here have a strong motivation to ensure science is taught at this school.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>14. Teachers at this school have ready access to science materials and resources.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>15. I believe that teachers at this school are competent teachers of science.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>16. The school places a strong emphasis on science as a curriculum area.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>17. The school curriculum is crowded. I believe science suffers because of this.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>18. I think that the other teachers offer a lot of support to other teachers who find science difficult to teach.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>19. Teachers at this school are secure in their knowledge of science concepts pertinent to the science curriculum.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>20. Teachers at this school have a positive attitude to science as a subject in the overall school program.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
</tbody>
</table>
21. Science has a high profile as a curriculum area at this school.
22. Teachers at this school have the opportunity to undertake professional development in science.
23. Science is a subject at this school that teachers want to teach.
24. The science resources at the school are not well organized.
25. Teachers at this school have positive perceptions of their competence as science educators.
26. I believe that science has a high status as a curriculum area at this school.
27. Teachers here believe that there is not enough time in the overall school program to teach science.
28. I think that teachers at this school are supported in their efforts to teach science.
29. Teachers at this school have a good background knowledge for teaching science.
30. Teachers at this school have a positive attitude to science as an essential learning area.
31. The equipment that is necessary to teach science is readily available.
32. It seems that teachers at this school are adequately prepared to teach to the requirements of the science curriculum.
33. Science as a curriculum area is valued at this school.
34. Teachers possess the necessary knowledge required to teach science effectively.
35. Teachers at this school are motivated to make science work as a curriculum area.
36. Teachers at this school have a negative self-image of themselves as regards their ability to teach science.
37. Science is regarded as an important subject in the school’s overall curriculum.
38. Time is a major factor inhibiting science program delivery at this school.
Appendix B: Interviews - indicative areas of questioning

*Questions marked with * were asked at the first interview only.
*Questions marked with # were asked at the second interview only.

*What factors do you think influenced your decision to study teaching?

*How much science have you studied or been involved in? Include school subjects, university subjects and any work (paid or unpaid) that involved science or was at a scientific institution.

What, if any, science based professional development/excursions/experiences have you participated in since the workshops? Where were they, who delivered them, what was the aim?

How much science have you taught in your class/pracs so far? Is this likely to change? Why, why not?

*[For pre-service participants only] - How important were each of these factors (will be read individually to allow for individual verbal response) to you as a student in terms of making you feel comfortable to teach science?

- Your teacher educator (ie uni lecturer)?
- Science content knowledge (science facts)?
- Science pedagogy (how to teach science)?
- Science activities?
- Children’s views of science (ie how they viewed or responded to science in the classroom)?
- The process of investigating scientifically?
- Reflection (either with others or individually after classes you participated in or taught)?
- Learning environment (during uni classes or in your own classroom)? (after Howitt 2007)
*What would you say has had the biggest positive influence on you during your teaching career/teacher training? This can be something or someone from within or external to the school/university.

*What would you say has had the biggest negative influence? This can be something or someone from within or external to the school/university.

What do you feel most confident about in teaching?

What do you feel least confident about in teaching?

If you could have one thing that would help you to teach science, what would it be?

#Do you think there is a role for science centres and museums with teachers? Please explain your answer.
Appendix B: Example of interview transcript

Q1. What factors do you think influenced your decision to become a teacher?
I’m a swimming instructor outside of unit and it’s a very rewarding job teaching, no matter what it is. A lot of kids come from very hard families, and I was one of those kids, so I guess I’m motivated to make sure those kids know they can achieve as well.

Q2. How much science have you studied or been involved in? Include school subjects, university subjects and any work (paid or unpaid) that involved science or was at a scientific institution.
Whatever I’ve got at unit, only one subject was very practical…I don’t feel that one subject was enough to equip me to teach science in school so I was very grateful for the workshop. Other than that, only what I taught last year in forensic science and in swimming we look at the biomechanics of how our bodies move in the water so there’s a bit of science there… I remember doing a couple of science experiments in primary school. I attempted one semester of biology in college…I got asked to leave…yeah, it didn’t work out! But we did actually go on some science [excursions] but it was mainly to do with classification of animals, species, I don’t remember much of it. That’s about all the science experience I have.

Q3. What, if any, science based professional development/excursions/experiences have you participated in since the workshops? Where were they, who delivered them, what was the aim?
None.

Q4. How much science have you taught in your class so far? Is this likely to change? Why, why not?
Last year I taught a lot of forensic science. This year the school I’m at is particularly interested in integrated units so science has been embedded but it’s more of the technology side of things. We’ve been doing media and its effects on us, like our decisions, so it’s been more of a technology focus than a science focus. So not as much science this year as I would have liked to but we’re about to head into a unit on natural phenomena so hopefully that will open a few more doors.
Q5. How important were each of these factors (will be read individually to allow for individual verbal response) to you as a student in terms of making you feel comfortable to teach science?

- **Your teacher educator (ie uni lecturer)?**
  I didn’t really learn much so not very comfortable. I guess what they were trying to do was educate us as adults and give us strategies on how to educate students. But I think there were a lot of assumptions that we knew basic science concepts…so we were meant to know stuff about the solar system and the human body, which I didn’t. We had this one test; I’m usually a pretty good uni student. I’m the type who’d read the textbook inside out, and I sat there and almost cried in this test, I had no idea what it was about so yeah, there was a lot of assumed knowledge.

- **Science content knowledge (science facts)?**
  When I taught forensic science last year I went and borrowed children’s books on the topic and read them so I knew the content well in order to teach it, particularly when you’re taking about being comfortable welcoming students’ questions - well you have to welcome them, whether you’re comfortable or not, and if I have to say “sorry, I’m not sure I’ll have to go and find the answer to that”, so I’d want to make sure that I’m standing up there feeling confident about my science content knowledge.

- **Science pedagogy (how to teach science)?**
  You get taught backwards design, this design, that design but it’s all a bit up in the air. I’m really not sure. It seems that what we were shown was not very specific to science because there needs to be some form of application back to real life and explicit teaching and the practical side of things but it all just seemed very muddled.

- **Science activities?**
  After the workshops I feel a bit more confident in how to run them [science activities]. I liked how it was an already prepared environment. The instructions were there and also the explanations relating to real life and I found that really useful.

- **Children’s views of science (ie how they viewed or responded to science in the classroom)?**
  We looked at children’s misconceptions of science but they don’t only apply to children because some of them, I though! So I can definitely relate to the kids. Growing up with
science for me was very much a “once every fortnight on a Friday afternoon” thing, it wasn’t a very important thing.

- The process of investigating scientifically?
  I understand the procedure of a basic experiment, but that’s what I’ve seen as a one off, it’s not been an ongoing process into one concept so I don’t know how confident I feel about it.

- Reflection (either with others or individually after classes you participated in or taught)?
  It can reveal what went wrong and what I can do better next time. Reflection with the kids is generally referring back to “how does this apply to the big picture” and that’s really important for kids to make those links…for them to make these further links with those concepts is really important.

- Learning environment (during uni classes or in your own classroom)?
  In our classroom where we did forensic science last year…we had a big wall where we’d hang the kids work so I guess in that environment they were really immersed in what they were doing, which was good. The learning environment at uni as I said assumed a lot of prior knowledge and that made me feel quite uncomfortable. I remember one particular session where there were stations set up, and it had little cards and you did a little experiment and then explained what was happening. But even some of the terminology on those cards - I was like “who’s got a glossary?” I didn’t really understand what it was all about.

Q6. What would you say has had the biggest positive influence on you during your teacher career/training? This can be something or someone from within or external to the school/university.

My lecturers who are practical, who have actually been in schools and who are not dinosaurs - they’ve been in schools in the last ten years and they know what we’re up against. Lecturers that give us strategies that we can actually use in the classroom are probably the best things, the most positive things. Also, supportive prac teachers. Unfortunately this time around I didn’t have a very supportive one but in first and third year pracs I had very supportive teachers so seeing them in the workforce, loving what they do was a very positive influence.
Q7. What would you say has had the biggest negative influence? This can be something or someone from within or external to the school/university.
I guess having a prac teacher that doesn’t really let you develop your own style of teaching. You get in there and they encourage you to try new things, but it means not stepping outside the square or test anything out or really just deliver all my lessons I’d already planned. So that’s kind of a shame sometimes. Also when you meet those teachers…who go “oh well, you thinks it’s hard now, wait until ten years time when you’re thirty and wondering what happened to your twenties”. Yeah, thanks for that! So I guess teachers’ comments.

Q8. What do you feel most confident about in teaching?
Providing the kids with authentic learning experiences. For this media unit we’re doing at the moment I’m getting the kids to evaluate products so they can make responsible decisions as consumers (one product, three different brands). Making it as real life as possible so the kids can transfer it into something useful.

Q9. What do you feel least confident about in teaching?
Behaviour management. I felt more confident last year. I don’t know what it was, maybe they were more responsive. This year I feel like I’m just going through behaviour strategies like toilet paper - which one will actually work on the kids today? It’s probably my weakest point.

Q10. If you could have one thing that would help you to teach science, what would it be?
I guess it would be some sort of course that covers all these basic concepts that kids are going to be expected to learn in school, and all the basic dos and don’ts - how you should and shouldn’t approach it. The teachers would be learning these concepts as well as how they would be taught to the kids - killing two birds with one stone. Run more workshops - please! Seriously, the unis are failing to provide proper science units and we’re just going to have this generation of teachers that are just going to come out with …you know…they’re just not going to teach science. I’m still hesitant and I had the workshop that you did. If I was a student and I hadn’t done the workshop you did I doubt that I’d be teaching science. In the new ELA document I have no idea what we’re teaching the kids. In science it seems all ‘fluffy’ anyway.
**Anything else to add?**

I’ve applied to teach in rural NSW and I wondered about resourcing in terms of equipment to do science in class. I’m used to the “big, specialist equipment” requirements. After your workshops I started thinking about the kinds of things you used in the different experiments, and it was all really simple stuff, like paddle pop sticks, and it made me realise that even in rural schools we could get simple stuff like that pretty easily and if that was all we needed to do science, then that was doable.
Appendix C: Workshop activities

The following is an excerpt from the different workshop activities. Each activity in each of the workshops was presented in a similar manner.

Can you use air to hit a target? - Physics workshop
Can you make a balloon tuba? - Sound and music workshop
Can you make a water Genie? - Fluids workshop
What is the Greenhouse Effect? - Climate Change workshop
Can you use air to hit a target?

Science concept:

Pressure

► You’ll need:
  ● Empty soup can
  ● Balloon
  ● Scissors
  ● 2 rubber bands
  ● Strips of paper
  ● Candle
  ● Matches
  ● Blu tac

Time required: 30 minutes

What to do:
Cut the top and bottom ends of the can to make an empty cylinder.

Cut the end off a balloon. Stretch the remaining portion (the top of the balloon) over each end of the can and fasten using the rubber bands.

Cut a small hole (approximately 2cm in diameter) in the middle of one of the balloons.

Gently tap the other balloon to make air shoot out of the hole at the other end of the can. Test that the air is coming out by having a friend place their hand in front of the can.

Hang some strips of paper to act as targets. The paper will move if the air hits them.

Attach the candle to a table using the blu tac. Light the candle and try to blow it out by directing the air flow from the can towards the candle.

What’s happening?
Hitting the balloon forces air forwards. When it reaches the other end of the can, air is pushed out of the small hole at high pressure. The air flow can be directed to act on something, such as the paper or the candle. The small hole ‘funnels’ the air toward the candle like a cannon.
Can you make a balloon tuba?

Science concept:
Vibrations

► You’ll need:
- A section of pvc piping, about 20mm in diameter and 20-30 cm in length
- A balloon
- Packing tape

Time required: 10 minutes

What to do:
Use the packing tape to attach the balloon over one end of the PVC piping.
Blow through the other end of the piping to blow up the balloon. Hold the air inside the balloon.
Stretch the balloon to one side of the piping to form a skin over the pipe opening.
Slowly move the balloon, allowing a small amount of air to flow out through the tube. This should make the skin vibrate.
Try stretching the balloon and releasing it. How does this affect the sound? What other materials could you use?

What’s happening?
The section of balloon that forms the skin over the end of the pipe vibrates as air blows out of the balloon.
This vibration causes the air inside the tube to vibrate and therefore produce a sound.
Can you make a water Genie?

Science concept:
Temperature can change the density of water

► You’ll need:
● A tall clear container eg tall spaghetti storage container
● Hot and cold water
● Small, clear glass bottle
● Food colouring
● String or ribbon

Time required: 10 minutes

What to do:
Tie a length of ribbon or string around the top of the small glass bottle. The string should be longer than the tall container.

Fill the small glass bottle with cold water, add some drops of food colouring.

Fill the tall container with cold water until about half full.

Lower the glass bottle down to the bottom of the container of cold water. What happens to the hot water?

Repeat with a small bottle filled with hot water mixed well with a few drops of food colouring.

What happens this time? Why does it do this?

What’s happening?
The hot water is less dense than the cold water so it rises to the top of the tank and forms a layer over the cold water. Eventually the water will cool down and sink to the bottom again.
What is the greenhouse effect?

Climate change concepts:
- The greenhouse effect is natural and due to heat-trapping gases in the atmosphere.
- The greenhouse effect has been enhanced by human activity like burning fossil fuels, tree clearing and farming cows and sheep.

What you’ll need
- A glass jar
- Strong lamp (120 watt) or a sunny spot
- 2 thermometers

Time required: 30 min

What to do
1. Place two thermometers in front of the lamp or in the sun and record the temperatures of both.
2. After a few minutes cover one thermometer with a glass jar (you may need to stand the thermometer up).
3. Record the temperatures of both thermometers every minute for at least 10 min.

What’s happening in this activity?
The heat energy from the lamp or sun passes through the glass and some of this energy is trapped inside. This warms the air inside which is unable to mix with the cooler air outside the jar. The glass simulates the layer of greenhouse gases in the atmosphere that trap heat energy.

What’s happening across the planet?
Greenhouse gases trap heat from the sun in our atmosphere. This is a natural process keeping the average global temperature at around 16°C. Without the natural greenhouse effect the average temperature across the planet would be -17°C, meaning the world would be covered in ice!

Humans have been producing large amounts of several greenhouse gases: mainly carbon dioxide (CO$_2$), methane and nitrous oxide. These occur naturally in the atmosphere, but are now at levels higher than any time in the last 650,000 years. The increase in greenhouse gases is caused by burning large amounts of fossil fuels for industry and transport. Clearing large areas of forest has also contributed to the increase.

The unnaturally high concentration of greenhouse gases currently in the atmosphere is causing more heat to be trapped. This is called the enhanced greenhouse effect. The enhanced greenhouse effect has caused the average surface temperature of the Earth to rise 0.76°C since 1850.

This may not sound like much, especially since the temperature in a classroom can change by 10°C or more in one day. But the average temperature of the whole planet does not change like the temperature inside a classroom. In fact the global average temperature is very stable, and would not change 10°C over a day, month, year, decade or even thousands of years!
Appendix D: Participant information and certificate

Email to Prospective Participants (pre-service)

Would you like more confidence, ideas and resources to teach science? Would you like some free professional development?

If you answered “yes” to all three of these questions then I would like to hear from you.

I am studying the perceptions primary school teachers have about science and their self assessed ability to teach it. This research is being conducted as part of a Doctor of Philosophy (PhD) qualification from the Australian National University.

You have been selected as a potential participant because you are a final year Bachelor of Education (Primary) student. Participation in the project is purely voluntary, and you can withdraw at any time.

In participating in this research you will be asked to attend four short (one hour) science workshops which utilise hands-on activities and simple everyday materials. These workshops will form the basis of the research and questioning.

If you participate in this research project, you will be asked to respond to four different survey sets over a period of not longer than 18 months. These surveys will take the form of written responses and closed questions. None of the surveys will take longer than twenty (20) minutes to complete. You will also be asked to participate in two interviews about your teaching experiences. Interviews won’t exceed one hour in length.

A guide to the different surveys and their time line is provided here:

<table>
<thead>
<tr>
<th>Survey</th>
<th>Time Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial efficacy survey</td>
<td>Feb/Mar 08</td>
</tr>
<tr>
<td>Series of 4 professional development workshop sessions</td>
<td>Mar - June 08</td>
</tr>
<tr>
<td>Immediate follow up survey</td>
<td>June 08</td>
</tr>
<tr>
<td>End of year survey and interview</td>
<td>October 08</td>
</tr>
<tr>
<td>End of first semester following year survey and interview</td>
<td>May/Jun 09</td>
</tr>
</tbody>
</table>

Your agreement to participate will involve you signing a consent form and answering questions about your experiences in the science workshops; your feelings and attitudes towards science and your ability to teach the subject.
One aspect of this study is to examine the influence, if any, of a longer term exposure to informal science education practice. You may choose to undertake a work placement within an informal science education centre – such as Questacon – where you can be involved in the development and delivery of a science education programme, or an alternative project (where possible) which you feel would benefit your teaching skills. Participation in this aspect of the research will not influence the number of surveys or interviews you will be requested to complete or create any further workload for you; however your responses will be compared to those who do not undertake a work placement in a similar environment.

You may withdraw from participation in the project at any time, and you do not need to provide any reason. If you decide to withdraw from the project, information you have provided will not be used.

Would you be interested in being involved in this study? Would you like more information? Please send a reply to merryn.mckinnon@anu.edu.au including a phone number and I will send more information to you.

Many thanks for your time and I look forward to hearing from you.

Kind Regards,

Merryn
Information Sheet for Participants

Primary Science Professional Development Research Project

I am studying the effects, if any, of professional development (PD) workshops delivered by an informal science education institution on pre-service and in-service teachers. I am also interested in the transition that students make from pre-service to in-service teachers. This research is being conducted as part of a Doctor of Philosophy (PhD) qualification from the Australian National University.

Why is this research relevant?
Current research has identified that the amount of science being taught in primary schools is very low, which then has flow on effects once students reach high school and beyond. One of the key issues that has been identified as a direct reason for science not being taught in primary schools is the level of confidence primary teachers have with science subjects. This could be due to a lack of familiarity with science, negative prior experiences with science (either in their own time as a student or when they attempted to teach it to a class) or the simple perception that science is simply “too hard”. It may also be affected by factors in the school environment in which teachers work.

This study will identify the key factors and characteristics of sustainable successful outcomes and best practice arising from science centre or museum ‘interventions’. It will also aim to identify key sources of self efficacy in pre-service teachers, and how the school environment in which they begin their teaching career influences their self efficacy and perception of teaching in general. This study will be able to provide some useful information for end users (ie other science centres, teacher educators and agencies) in terms of:
- longitudinal data on ‘impacts’ of informal science PD which is largely lacking;
- A set of indicators and definitions relevant, and broadly applicable, to further evaluation conducted in the science centre/museum field, if not within the education arena as well;
- Elements of professional development workshops which can be implemented and used, successfully, to influence practice in schools and classrooms.
- Sources of self efficacy for pre-service teachers and factors which may positively or negatively influence this self efficacy.

These outcomes and outputs are quite ambitious, but even some progress towards the achievement of any of these would still provide important information to PD practitioners, or indeed act as a base for further research in the field.

What does the research involve?
You have been selected as a potential participant because you are a final year primary education student. Participation in the project is purely voluntary, and you may withdraw at any time.
In participating in this research you will be asked to attend four short (one hour) science workshops which utilise hands-on activities and simple everyday materials. These workshops will form the basis of the research and questioning.

If you participate in this research project, you will be asked to respond to up to four different survey sets over a period of up to 18 months. These surveys will take the form of written responses and closed questions. None of the surveys will take longer than twenty (20) minutes to complete. You will also be asked to participate in two interviews about your university experience and your initial teaching experiences. Interviews should run for less than one hour.

A guide to the different surveys and their time line is provided here:

<table>
<thead>
<tr>
<th>Survey</th>
<th>Time Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial self efficacy survey</td>
<td>Feb/Mar 08</td>
</tr>
<tr>
<td>Series of 4 professional development workshop sessions</td>
<td>Mar - June 08</td>
</tr>
<tr>
<td>Immediate follow up survey</td>
<td>June 08</td>
</tr>
<tr>
<td>End of year survey and interview</td>
<td>October 08</td>
</tr>
<tr>
<td>End of first semester following year survey and interview</td>
<td>May/June 09</td>
</tr>
</tbody>
</table>

Your agreement to participate will involve you signing a consent form and answering questions about your experiences in the PD workshops; your feelings and attitudes towards science and your ability to teach the subject; and your teaching experiences in your first year out.

One aspect of this study is to examine the influence, if any, of a longer term exposure to informal science education practice. You may choose to undertake a work placement within an informal science education centre – such as Questacon – where you can be involved in the development and delivery of a science education programme, or an alternative project (where possible) which you feel would benefit your teaching skills. Participation in this aspect of the research will not influence the number of surveys or interviews you will be requested to complete or create any further workload for you; however your responses will be compared to those who do not undertake a work placement in a similar environment.

You may withdraw from participation in the project at any time, and you do not need to provide any reason. If you decide to withdraw from the project, information you have provided will not be used.

The results of this study may be reported to government agencies and may be published in academic journals, books or conference proceedings. However, the names of individual participants or position titles will not be reported in connection with any of the information obtained. If you wish to receive a copy of the results at the completion of this study, this can be provided to you.
Are there any risks if I participate?
I do not intend to seek any information in interviews which is particularly sensitive or confidential. It is possible that because the cohort of participants is relatively small, others may be able to guess the source of information provided in surveys, even though it will not be attributed to any person. Accordingly, it is important that you do not provide information which is of confidential status, or which is sensitive or defamatory.

Following, you will find contact names and phone numbers in case you have questions or concerns about the study.

Contact Names and Phone Numbers.

If you have any questions or concerns about the study please feel free to contact:

Merryn McKinnon, Centre for the Public Awareness of Science, Phone: 0407 663 330, email: merryn.mckinnon@anu.edu.au

Or Dr Rod Lamberts,
Deputy Director,
Centre for the Public Awareness of Science
Australian National University
Tel: 6125 0747
Email: rod.lamberts@anu.edu.au

If you have concerns regarding the way the research was conducted you can also contact the ANU Human Research Ethics Committee:

Human Ethics Officer,
Human Research Ethics Committee,
Australian National University.
Tel: 6125 7945.
Email: Human.Ethics.Officer@anu.edu.au

**Emails and information sheets for both pre- and in-service participants were the same except for reason of selection as a potential participant which stated: ‘You have been selected as a potential participant because you are a primary school teacher in the ACT’ or ‘…because you are a final year primary education student’. All other aspects remained the same.**
Certificate

Each of the participants was presented with one of these certificates at the completion of the study, as well as a $50 voucher for an educational book store.
Appendix E: Individual PSTE and STOE scores for each participant

### PSTE Scores from each survey period

<table>
<thead>
<tr>
<th>Participant</th>
<th>Teaching Experience</th>
<th>Period 1</th>
<th>Period 2</th>
<th>Period 3</th>
<th>Period 4</th>
<th>Difference in score between P4 and P1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paula</td>
<td>20+</td>
<td>34</td>
<td>31</td>
<td>39</td>
<td>34</td>
<td>0</td>
</tr>
<tr>
<td>Valerie</td>
<td>20+</td>
<td>40</td>
<td>44</td>
<td>44</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Kerrie</td>
<td>20+</td>
<td>30</td>
<td>49</td>
<td>46</td>
<td>52</td>
<td>22</td>
</tr>
<tr>
<td>Elizabeth</td>
<td>20+</td>
<td>32</td>
<td>40</td>
<td>39</td>
<td>43</td>
<td>11</td>
</tr>
<tr>
<td>Lorraine</td>
<td>20+</td>
<td>32</td>
<td>48</td>
<td>37</td>
<td>46</td>
<td>14</td>
</tr>
<tr>
<td>Brian</td>
<td>20+</td>
<td>49</td>
<td>47</td>
<td>48</td>
<td>54</td>
<td>5</td>
</tr>
<tr>
<td>Susan</td>
<td>15 - 20</td>
<td>58</td>
<td>65</td>
<td>62</td>
<td>61</td>
<td>3</td>
</tr>
<tr>
<td>Hayley</td>
<td>20+</td>
<td>42</td>
<td>43</td>
<td>45</td>
<td>45</td>
<td>3</td>
</tr>
<tr>
<td>Simone</td>
<td>15 - 20</td>
<td>46</td>
<td>57</td>
<td>51</td>
<td>48</td>
<td>2</td>
</tr>
<tr>
<td>Tanya</td>
<td>4 - 6</td>
<td>53</td>
<td>53</td>
<td>57</td>
<td>56</td>
<td>3</td>
</tr>
<tr>
<td>Lisa</td>
<td>4 - 6</td>
<td>40</td>
<td>47</td>
<td>52</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Anita</td>
<td>20+</td>
<td>42</td>
<td>43</td>
<td>42</td>
<td>47</td>
<td>5</td>
</tr>
<tr>
<td>Paul</td>
<td>1 - 3</td>
<td>48</td>
<td>52</td>
<td>52</td>
<td>50</td>
<td>2</td>
</tr>
<tr>
<td>Anthea</td>
<td>&lt; 1</td>
<td>34</td>
<td>36</td>
<td>44</td>
<td>44</td>
<td>10</td>
</tr>
<tr>
<td>Kendra</td>
<td>&lt; 1</td>
<td>32</td>
<td>46</td>
<td>44</td>
<td>35</td>
<td>3</td>
</tr>
<tr>
<td>Jaeda</td>
<td>&lt; 1</td>
<td>52</td>
<td>57</td>
<td>55</td>
<td>55</td>
<td>3</td>
</tr>
<tr>
<td>Kate</td>
<td>&lt; 1</td>
<td>36</td>
<td>51</td>
<td>50</td>
<td>52</td>
<td>16</td>
</tr>
<tr>
<td>Peter</td>
<td>&lt; 1</td>
<td>52</td>
<td>51</td>
<td>38</td>
<td>48</td>
<td>-4</td>
</tr>
<tr>
<td>Vanessa</td>
<td>&lt; 1</td>
<td>49</td>
<td>50</td>
<td>58</td>
<td>61</td>
<td>12</td>
</tr>
<tr>
<td>Lauren</td>
<td>&lt; 1</td>
<td>40</td>
<td>52</td>
<td>51</td>
<td>49</td>
<td>9</td>
</tr>
<tr>
<td>Sam</td>
<td>&lt; 1</td>
<td>40</td>
<td>49</td>
<td>38</td>
<td>35</td>
<td>-5</td>
</tr>
</tbody>
</table>

**Key**
- 20+ years teaching experience
- 15 - 20 years teaching experience
- 4 - 6 years teaching experience
- 1 - 3 years teaching experience
- Sourced from STEBI B
- Pre-service
## STOE Scores from each survey period

<table>
<thead>
<tr>
<th>Participant</th>
<th>Teaching Experience</th>
<th>Period 1</th>
<th>Period 2</th>
<th>Period 3</th>
<th>Period 4</th>
<th>Difference in score between P4 and P1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paula</td>
<td>20+</td>
<td>30</td>
<td>28</td>
<td>28</td>
<td>38</td>
<td>8</td>
</tr>
<tr>
<td>Valerie</td>
<td>20+</td>
<td>34</td>
<td>26</td>
<td>30</td>
<td>30</td>
<td>-4</td>
</tr>
<tr>
<td>Kerrie</td>
<td>20+</td>
<td>28</td>
<td>27</td>
<td>26</td>
<td>21</td>
<td>-7</td>
</tr>
<tr>
<td>Elizabeth</td>
<td>20+</td>
<td>35</td>
<td>34</td>
<td>39</td>
<td>39</td>
<td>4</td>
</tr>
<tr>
<td>Lorraine</td>
<td>20+</td>
<td>43</td>
<td>36</td>
<td>39</td>
<td>36</td>
<td>-7</td>
</tr>
<tr>
<td>Brian</td>
<td>20+</td>
<td>33</td>
<td>39</td>
<td>38</td>
<td>42</td>
<td>9</td>
</tr>
<tr>
<td>Susan</td>
<td>15 - 20</td>
<td>36</td>
<td>38</td>
<td>34</td>
<td>29</td>
<td>-7</td>
</tr>
<tr>
<td>Hayley</td>
<td>20+</td>
<td>39</td>
<td>38</td>
<td>37</td>
<td>37</td>
<td>-2</td>
</tr>
<tr>
<td>Simone</td>
<td>15 - 20</td>
<td>36</td>
<td>40</td>
<td>31</td>
<td>31</td>
<td>-5</td>
</tr>
<tr>
<td>Tanya</td>
<td>4 - 6</td>
<td>30</td>
<td>27</td>
<td>31</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>Lisa</td>
<td>4 - 6</td>
<td>32</td>
<td>30</td>
<td>34</td>
<td>32</td>
<td>0</td>
</tr>
<tr>
<td>Anita</td>
<td>20+</td>
<td>36</td>
<td>32</td>
<td>35</td>
<td>38</td>
<td>2</td>
</tr>
<tr>
<td>Paul</td>
<td>1 - 3</td>
<td>31</td>
<td>34</td>
<td>32</td>
<td>30</td>
<td>-1</td>
</tr>
<tr>
<td>Anthea</td>
<td>&lt; 1</td>
<td>36</td>
<td>39</td>
<td>38</td>
<td>38</td>
<td>2</td>
</tr>
<tr>
<td>Kendra</td>
<td>&lt; 1</td>
<td>38</td>
<td>36</td>
<td>40</td>
<td>29</td>
<td>-9</td>
</tr>
<tr>
<td>Jaeda</td>
<td>&lt; 1</td>
<td>40</td>
<td>44</td>
<td>44</td>
<td>41</td>
<td>1</td>
</tr>
<tr>
<td>Kate</td>
<td>&lt; 1</td>
<td>36</td>
<td>42</td>
<td>40</td>
<td>42</td>
<td>6</td>
</tr>
<tr>
<td>Peter</td>
<td>&lt; 1</td>
<td>33</td>
<td>32</td>
<td>34</td>
<td>28</td>
<td>-5</td>
</tr>
<tr>
<td>Vanessa</td>
<td>&lt; 1</td>
<td>29</td>
<td>32</td>
<td>40</td>
<td>34</td>
<td>5</td>
</tr>
<tr>
<td>Lauren</td>
<td>&lt; 1</td>
<td>34</td>
<td>38</td>
<td>32</td>
<td>27</td>
<td>-7</td>
</tr>
<tr>
<td>Sam</td>
<td>&lt; 1</td>
<td>29</td>
<td>37</td>
<td>36</td>
<td>36</td>
<td>7</td>
</tr>
</tbody>
</table>

**Key**
- 20+ years teaching experience
- 15 - 20 years teaching experience
- 4 - 6 years teaching experience
- 1 - 3 years teaching experience
- Sourced from STEBI B
- < 1 Pre-service