Science and Mathematics Education Centre

The Use of Information and Communication Technology-based

Science Resources by New South Wales Stage 3 Primary

School Teachers

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Doctor of Philosophy
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Candidate Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number #SMEC-30-12.

Signature:

Anne Therese Galvin

Date: 24 January, 2017

Abstract

Earlier studies have confirmed that, for some time, there has been concern in many sectors about science teaching in primary schools: a situation partly attributable to generalist primary teachers' limited science backgrounds. The use of Information and Communication Technology (ICT) resources can now potentially be utilised by these teachers to enhance their science content knowledge, partially off-setting the deficit in their science backgrounds.

The principle aim of this study was to investigate the use of ICT-based science resources by teachers of Stage 3 students in NSW schools to enhance their science content knowledge to better inform their science lesson delivery. Relationships between the frequency of ICT resource use, teachers' educational backgrounds and their confidence in teaching science were investigated. A mixed research methodology informed by a predominantly Interpretivist epistemology was employed to collect data from 31 schools - both metropolitan and provincial - and 47 teachers. Sufficient data to provide triangulation of the results was collected through principal and teacher surveys, the completion of logs of ICT-use for supplementing science content knowledge and interviews conducted with 10 teachers. Several existing instruments were employed in their entirety or a modified form such as Riggs' and Enochs' (1990) Science Teaching Efficacy Belief Instrument and a section from the OECD's 'Spring 2007 Teacher Background Questionnaire' (2007) respectively. All data was further analysed for any differences between teachers in the metropolitan and provincial schools.

The findings indicated that, in many schools, the teaching of science did not enjoy a high status; and, in many cases, was over-shadowed by the pursuit to address student literacy and numeracy/English and mathematics standards - conceivably an impact of high-stakes testing? While a large proportion of the teachers had a relatively limited science background, did not demonstrate high efficacy beliefs, and identified the need to enhance their science content knowledge, the majority did not participate in professional learning courses or activities to enhance that knowledge. This latter

situation was, in combination with other factors, partially a reflection of the lack of formal professional learning opportunities addressing primary science currently available.

It was concluded that teachers were not engaging, to any substantial degree, with the wide range of available ICT-based science resources to enhance their science content knowledge. A pamphlet comprising suggested ICT-based science resources - some of which were used by the participants - was designed. This will be distributed to participating schools and any interested parties at the conclusion of the research. The use of such resources should be of interest and consequence to the generalist primary school teacher who is obliged to teach science; and whose professional obligation it is to know the content of the subject areas to be taught. Enhanced science content knowledge should contribute toward better preparing the teachers of Stage 3 students to effectively and engagingly deliver the primary science curriculum.

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Chapter 1: Introduction

1.1 An Overview

This study investigated the use Information and Communication Technologies (ICT)-based science resources by the teachers of Stage 3 students in New South Wales (NSW) for the purpose of educating themselves in science content in order to enhance their existing knowledge. It was conducted in three phases. The first phase involved a broad overview of the demographics, philosophies and cultures of a sample of primary schools in relation to science teaching in those schools. It also examined the intrinsic and extrinsic factors that could affect teachers of upper primary grades and their science teaching. With the rapid development of ICT-based resources - and the increase in ease of access to them - comes an opportunity for primary school teachers to increase their personal scope and depth of science content knowledge. The second and the third phases investigated the use of ICT-based science resources being accessed by teachers in the participating schools to enhance their science content knowledge, and to what extent this was being done. The data were analysed for any patterns between teachers in metropolitan and provincial schools in the research focus areas.

1.1.1 Introduction to Science Teaching in Primary Schools

Prinsley and Johnson (2015) emphasise the combined importance of science, technology, engineering and mathematics (STEM) to the prosperity of world economies in the twenty-first century. They assert that "STEM education begins in primary school, and here teachers make a serious difference. It is great teaching, more than any other attribute, which accounts for the success of the world's best performing economies" (p. 1). In Australian primary schools, the teaching of science has left much to be desired both in the average time per week spent teaching in the Science and Technology Key Learning Area (S&T KLA) (Angus, Olney, & Ainley, 2007; Morgan, 2012) and the quality of some of the teaching itself. It is not an

unusual occurrence for NSW primary teachers, upon meeting secondary science teachers in professional or other settings, to comment that they dislike teaching science and have a desire to minimise the amount of teaching that they conduct in that subject area. The reasons for this situation are varied but can be partly attributed to the limited science background of primary teachers. This can result in a deficit in science content knowledge and pedagogy, and limited confidence in teaching the KLA (Fitzgerald, Dawson, & Hackling, 2013). Fensham states in his 2008 UNESCO-commissioned report on Science Education Policy-Making that "the key difficulty facing primary science education in most countries is the fact that the persons who become primary teachers, as a whole, lack the confidence in - and the knowledge of - science to teach it as intended" (p. 37).

During a science-teaching career of over 35 years, the researcher has noted that it is not unusual for students beginning the high school phase of their NSW education to have quite different science education backgrounds and experiences. The students' backgrounds vary considerably in both breadth and depth of knowledge and practical experiences. This is despite the fact that all students should have experienced the same science curriculum and achieved similar outcomes by the end of their primary school education.

In the context of this research, the Great Schools Partnership's 'The Glossary of Education Reform - for journalists, parents & community members' (http://edglossary.org/) definition of 'content knowledge', as it is applied to primary school teachers, is used: "the facts, concepts, theories, and principles that are taught and learned, rather than to related skills - such as reading, writing, or researching - that students also learn". Dinham has been reported in the press as stating that the majority of primary teachers in Australia, who had either not studied science or only pursued the subject at low levels to the end of high school in Year 12, were science avoiders (Ferrari, 2014). In reference to teachers who teach science at the secondary level, and reflecting society's interest in education issues, in an article written for *The Age* newspaper entitled 'Testing times for Science and Mathematics', Cook (2003) quotes the then president-elect of the Science Teachers Association of Victoria, Roger Morgan, as saying that "many [teachers] may not understand basic concepts and, as a result, students develop misconceptions". This statement holds equally true

for generalist primary teachers who are required to teach science. In a paper relating to science teaching in NSW metropolitan primary schools, Forbes and Skamp (2014) commented on the situation by stating that "transforming, or even tweaking, how science is taught in primary schools is fraught with challenges. A significant hurdle is to ensure that science is being taught at all ..."(p. 1).

For the purpose of this research, Afolabi and Abidoye's (2011) definition of ICT is used. They define ICT as "the usage of electronic devices such as computers, telephones, internet and satellite systems to store, retrieve and disseminate information in the form of data, text images and others" (p. 114). The enhancing of teachers' science content knowledge, whether through the use of ICT-based resources or other means, ultimately assists teachers in communicating basic science concepts, providing well-informed science lessons to their students, and the necessary depth to lead student inquiry-based learning and discussions arising from it. This goal is in the best interests of delivering to primary students an optimal science education.

1.1.2 The Research

It is important to establish a primary school's culture with respect to its teaching priorities. It is possible that a school's philosophy and/or culture could either encourage or discourage some teachers from teaching science and limit their capacity to engage in different forms of Professional Learning (PL). It is "essential to identify the factors that might foster or hinder [enhancing teacher learning and development] … if meaningful continuing professional development of teachers is to occur and flourish" (Flores, 2004, p. 299) in schools. The enhancement of content knowledge is just one facet of this professional learning and development. Therefore, in Phase I of my research, it was necessary not only to ask questions relating to whether the teachers in this study were using ICT-based science resources to enhance their science content knowledge, but also to ascertain in what contexts these teachers worked. When teachers perceived that their science content knowledge was inadequate and needed to be improved, they were asked to identify any resources that they used to enhance their content knowledge.

Phases II and III, which examined the use of ICT-based science resources by participating teachers to enhance their science content knowledge, were conducted using surveys, log-keeping and teacher interviews. Aspects of the primary schools' cultures, including the prioritisation and status of subjects and the time allocated to teaching KLAs, were investigated. A teacher working in a school in which a subject has low priority and the time allocated to teaching that subject is minimised, might find these conditions a disincentive to excel in teaching that subject. These latter phases were conducted, additionally, to collect more data on the teachers' science backgrounds, their participation in professional learning activities and other data relating to their schools' cultures. Furthermore, Phases II and III were designed to gain information on and around the opportunities that might have been available to the teachers to enhance their science content knowledge. In turn, these opportunities - or lack thereof - could impact their science teaching and whether or not they sought to enhance their science content knowledge at all. These phases were also designed to discern any differences in the patterns of ICT-based resource usage that might have existed in the targeted groups in metropolitan and provincial schools.

1.2 New South Wales Education System

The overall framework of education in NSW follows a three-tiered model which is similar to that of other Australian states: primary, secondary and tertiary education levels. Students typically begin primary schooling in NSW in the year that they attain six years of age. This first level is termed 'Kindergarten' which precedes Year 1 - the first of six other 'year' levels before transitioning to secondary (or high) school. As noted in the Australian Schools Directory (June, 2014), three major providers service education in NSW: the State Government (67%), the Catholic Education System (18%) and the Independent Schools Sector (15%).

NSW students progress through successive defined 'stages' of learning starting in primary and continuing through the secondary school years. There is a total of six numerically identified stages and each encompasses two years of schooling. An additional stage, Early Stage 1 - referred to as 'Kindergarten' - is of 1 year's duration. Stage 1 encompasses Years 1 and 2; Stage 2 includes Years 3 and 4; etc.

with the final Stage being Stage 6 which comprises the final two years of secondary education, Years 11 and 12. These relationships are summarised in Table 1.1. Stage 3 teachers are of direct relevance to this study. Students of this Stage, in Years 5 and 6, are typically between ten and twelve years of age.

The Board of Studies NSW (BOS NSW) - as it was known at the time that this research was begun - was a government organisation which, among other objectives, oversaw matters of curriculum, assessment, registration and education policy in NSW primary and secondary schools. In early 2014, this organisation amalgamated with the NSW Institute of Teachers to form the Board of Studies, Teaching and Educational Standards New South Wales (BOSTES NSW). This Board also oversaw protocols relating to teaching standards and accreditation. Again, in early 2017 the latter board was renamed the NSW Education Standards Authority (NESA).

Table 1.1. *Stages and school years through primary and secondary schooling in NSW.*

Level		Primary			Secondary		
Year	Kindergarten	1 & 2	3&4	5&6	7&8	9&10	11&12
Stage	Early Stage 1	1	2	3	4	5	6

The other NSW organisation of direct relevance to the governance of primary schools and, therefore, to this research is the NSW Department of Education and Communities (NSW DEC). This body oversees the provision of state-funded education. On July 1, 2015 it underwent a name change to the NSW Department of Education (NSW DoE) as a result of a number of NSW State Government administrative changes. The NSW DEC/DoE governs schools referred to as 'State' schools in NSW.

1.3 Background to the Research Problem

1.3.1 Science Teaching in Perspective

There is a good reason to desire and implement a sound primary school curriculum in which a sound science component is embedded. Peers, Diezmann, and Watters,

(2003, p. 1) state that "in Australia and elsewhere governments, science educators, and teachers themselves, have expressed concern about the teaching of science in primary schools". Tytler outlined possible ways of re-imagining science education to address what he described as "the current crisis in science education" (2007, p. 76), not just in the Australian context but around the world. Peers further elaborated that:

> … high quality teaching of both science and literacy in Australian primary schools is a national priority in order to develop scientifically literate citizens who can contribute to the social and economic well-being of Australia and achieve their own potential. A community with an understanding of the nature of science and scientific inquiry will be better equipped to participate in and contribute to an increasingly scientific and technological world. (2006, p. 1)

In an address to the Australian National Press Club, Cory, the incumbent President of the Australian Academy of Science at that time, stressed the importance of a scientifically literate Australian society by saying that:

> … [if] I were science minister, I'd work with the education minister to ensure that Australia invests in quality science and maths education at all levels - from kindergarten right through to post-grad university level, in order to improve science literacy and build our future skilled workforce ... [and that] ... the understanding of science is perhaps more imperative than ever before. (Creagh, 2013, p. 129)

"International studies show that relatively few Australian primary school students reach high standards of mathematics and science achievement" (Masters, 2009, p. v). Koul (2010, p. 289) contends that "building a culture of interest in science will enable Australians to cope with a future that will be very much dependent on science

and technology". Koul's research reinforces Master's (2009) finding and cites a number of studies which show that, on the international scene, "Australian primary science achievement levels are significantly lower than Singapore, Taiwan, Hong Kong, Japan, Russia, Latvia, England and the USA" (2010, p. 289).

It can be argued, that it is important that all members of a society be scientifically literate in order to make sense of, and cope with, scientific and technological developments. The Organisation for Economic Co-operation and Development's (OECD) (1999) definition of scientific literacy is having "the capacity to use science knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it though human activity" (Hackling, Goodrum, & Rennie, 2001, p. 13). A sound foundation for scientific literacy can be provided through the primary school science curriculum. In its paper on 'Science Engagement and Education', the Prime Minister's Science, Engineering and Innovation Council's (PMSEIC) Working Group states its belief that "to achieve a science-literate society, a strong foundation in primary school is essential. Australia needs primary teachers who are confident about teaching science, and have the time and resources to do so effectively" (2003, p. 12).

1.3.2 Factors Affecting the Teaching of Science in Primary Schools

Throughout the literature, a number of major factors affecting primary science teaching in schools have been identified. In the United Kingdom, Murphy and Beggs (2005, p. 7) revealed that "the overall lack of science background knowledge, confidence and training to teach science effectively were significant issues". Dinham has stated that students "in primary [school] are being taught by people lacking confidence in the area ... and children's attitudes to maths and science are formed in primary school" (Ferrari, 2014). Other important issues identified included the lack of resources - including time (Fitzgerald et al., 2013), an over-crowded curriculum (Gess-Newsome, 1999) and the impact of preparing for high stakes tests (Dulfer, Polesel, & Rice, 2012). Ardzejewska, McCaugh, and Coutts (2010) also note additional factors such as the principal's philosophy of primary schools, the role of

the primary teacher and his/her desire to provide an enriching curriculum within the school, and the principal's concern for standards and accountability.

1.3.3 Current Situation in NSW

The literature supports the claim that the teaching of science and technology - which is an Australian education priority (Peers, 2006; Australian Education Council, 2015) - is currently allocated minimal teaching time and is taught by teachers who, in many cases, do not have a strong scientific knowledge base (Kenny, Hobbs, Herbert, Jones, & Chittleborough, 2014). Although there is a range of relatively recent ICT-based science resources which have become available to support teachers in their teaching of science and in their content enhancement, some teachers are possibly unaware of their existence or do not access them for any number of reasons. As Veal and McKinster stated, the deepening of expert knowledge in science "promotes the idea of a teacher as a life long learner" (1999, p. 11). The effective use of ICT-based science resources to enhance science content knowledge is important to the generalist primary school teacher who is obliged to teach science.

1.4 Research

1.4.1 Research Objectives and Significance

The many sources which could possibly contribute to a primary school teacher's content knowledge during his/her career are shown in Figure 1.1. This is drawn from the researcher's own experience as an educator combined with ideas attained through reading the most recent literature on this topic. Not all sources contribute equally, nor do all contribute at the same time.

The use of ICT-based resources is but one of the avenues through which teachers could enhance their science content knowledge. In relation to accessibility issues for some ICT, the Australian Bureau of Statistics (ABS, 2014) reports that, on average for the 2012 - 2013 period, 86% of Australian households had internet connectivity.

Of these, metropolitan households had 88% access and this decreased for remote/very remote households to 79% access. There are no data available as yet for the years immediately following this data set; that is, for the years during which the research was conducted. However, as the ABS's graphical presentation of data shows a gradual increase in household internet use since 2006, an extrapolation of the graph suggests that the data for 2013 - 2015 would have been higher than for the previous period. All of the schools in this research reported that they had internet access; although sometimes it was not reliable. This information, in combination with the ABS statistics on household accessibility, indicated that all of the teachers in the study probably had access to internet-based ICT at school and at home. Participants were asked in the surveys to identify any accessibility issues.
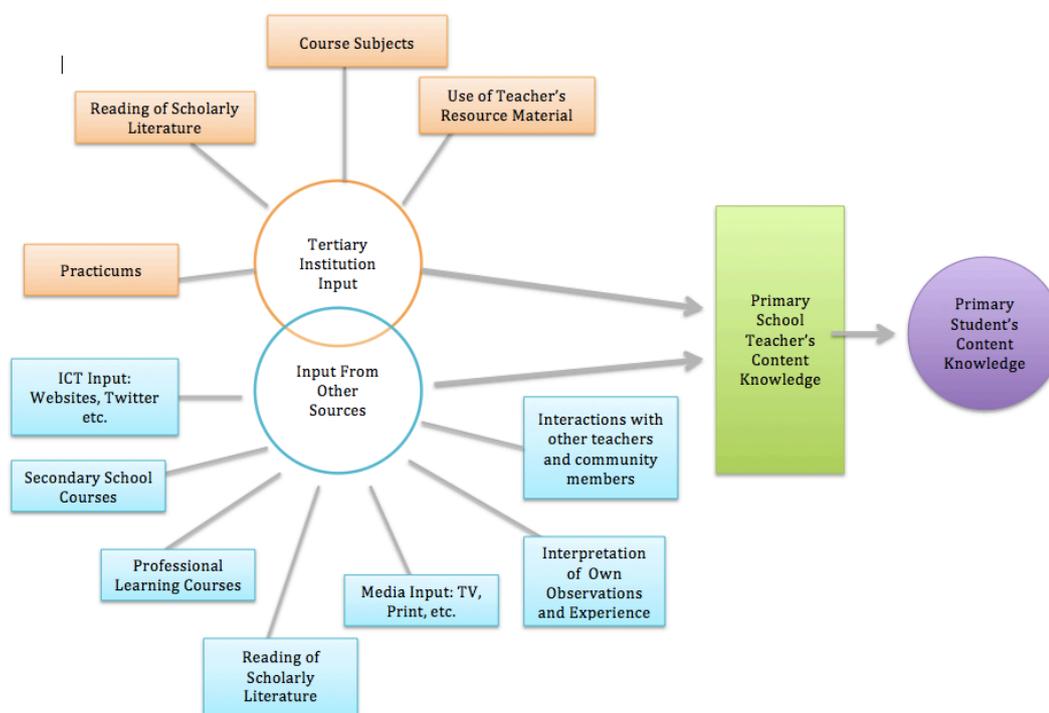
Figure 1.1. *Sources of science content which could potentially contribute to primary school teachers' content knowledge.*

This study aimed to establish the context in which the teachers were working - their school's culture. This included: the school's demographics, prioritisation of subjects and availability of professional learning opportunities - which might have had some influence on the teachers' purposefulness and needs to enhance their science content knowledge. The teachers' self-efficacy in relation to their science teaching and their education backgrounds were also investigated. Possible differences in the usage of ICT-based science resources between teachers in metropolitan and provincial areas

were examined and the reasons for any such differences explored. Factors affecting primary teachers' use of ICT-based science resources were also identified and discussed.

This study is of importance because it elucidated the extent to which a targeted group of primary teachers of Stage 3 students used different modes of ICT-based science resources through self-directed learning to assist themselves in 'learning' the subject matter to enhance their own science content knowledge. It identified whether these teachers had varying levels of self-efficacy - or confidence - in their ability to teach science to Stage 3 students, worked in schools with different cultures in relation to teaching science, and were subject to other factors affecting their science teaching and professional learning and development. It augments the current body of knowledge by discerning, for this cohort, the participants' science backgrounds; the time the teachers spent teaching science to their Stage 3 students; and the types of science-related professional learning which were available and engaged in during the period leading up to the research.

During the research, a list of ICT-based science resources appropriate to enhancing science content knowledge for teachers of Stage 3 students was compiled using information from the participating teachers and other sources. This list is to be made available to the participating schools and other interested parties. As Creswell states, "participants have the right to gain something from a study" (2008, p. 12). Recommendations are made regarding building an awareness among teachers of the need to improve the science content knowledge of those with limited science backgrounds.

Further, recommendations are made on ways to improve primary teachers' science content knowledge in relation to: the implementation of the 'new' Australian Curriculum; teacher professional learning and teacher initial education training. Other possibilities, for example, ways of working with members of the community to assist teachers who have limited science content knowledge, have also been examined. It is suggested that more research needs to be done on the impact of high-stakes testing on the teaching of subjects such as science, which are themselves not directly tested in the annual NAPLAN high-stakes testing programme. Further

research into teachers' self-directed learning and the factors which affect it - with respect to science content learning for primary school teachers - has been suggested. The effectiveness of the teacher's use of ICT-based science resources was also discussed. This research is also of importance in that it demonstrates that, for the teachers in my study, there continues to be difficulties in relation to their science content knowledge and to the teaching of science in primary schools.

It can be argued that having a sound knowledge of one's subject matter is one of many attributes that are imperative for being a successful teacher. Ball and McDiarmid (1990) have noted that much research is dedicated to aspects of teaching other than teachers' content knowledge and its acquisition. For example, research on teacher beliefs and efficacy; how teachers relate to students in the classroom; pedagogy; and pedagogical content knowledge to name just a few. However, they state that "to ignore the development of teachers' subject matter knowledge seems to belie its importance in teaching and in learning to teach" (1990, p. 1). This study makes a further contribution to the body of research relating to teachers' knowledge of their subject matter.

1.4.2 Conceptual Framework of the Research

From where do primary school teachers get their required science content knowledge? Figure 1.1 identifies the potential sources of science content through which primary school teachers can acquire such knowledge. Some of this derives in a direct way from their time in tertiary institutions as pre-service teachers or in further education studies whilst in service. The teacher's school background and other inputs which can be formal or less-formal also contribute. In contrast, some content knowledge will be derived vicariously by "being exposed to, and making meaning of, another's experience" (Myers, 2015) through the teacher's own observations and experiences, and through his/her interactions with other primary teachers, associates and members of their community who bring with them some degree of science expertise. There will be variation in both the size of the inputs and between the inputs themselves which have contributed to each teacher's science content

knowledge. Any deficits need to be supplemented by the science content knowledge inputs from other sources.

Figure 1.2 is a graphical representation of the plan for this research and shows the processes followed during the design of this research. There exists a body of knowledge or existing information relating to primary school teachers, their teaching of science and the contexts in which they work. The literature relating to these issues was critically reviewed in order to identify any gaps in this existing knowledge and information. A gap was identified relating to how primary school teachers might seek to improve their science content knowledge, whether or not they engage in this pursuit and the factors influencing this. The research questions were designed to answer an over-arching question: do primary teachers of Stage 3 students use ICT-based science resources to enhance their own science content knowledge?
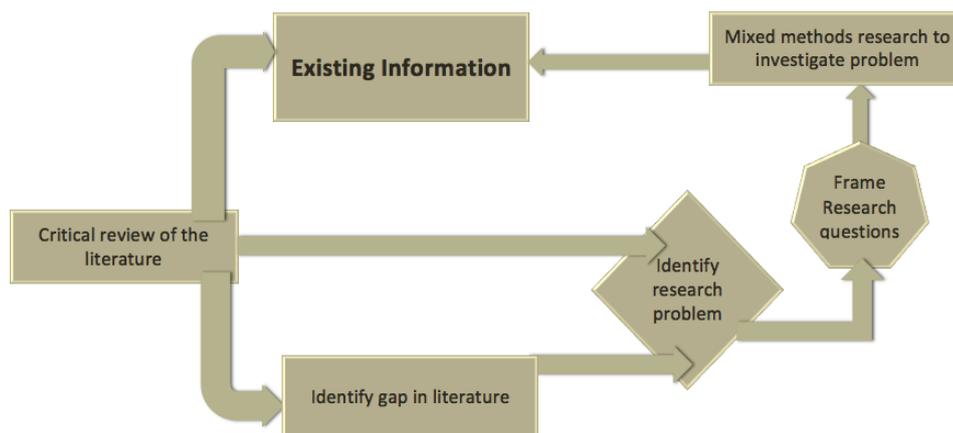
Figure 1.2. A graphical representation of the plan of this research.

1.4.3 Research Questions

As stated above, the primary aim of this study was to investigate the use of ICT-based science resources by teachers of Stage 3 students in NSW schools to enhance their science content knowledge. Each of the research questions was designed to contribute data towards establishing the context in which the teachers worked, their own confidence in relation to their science teaching, the professional learning in which they had engaged, what ICT-based science resources were available at the

time of the research and how often the teachers engaged with these resources to enhance their own science content knowledge. Each of the research questions also provided the framework for the design of the surveys and the interview questions.

The study addressed the following research questions:

Qn. 1. What is the current status of the teaching of science in Stage 3 in NSW primary schools?;

Qn. 2. What is the level of teachers' self-efficacy with respect to teaching science?;

Qn. 3. Do teachers participate in Professional Learning activities to supplement their science content knowledge?;

Qn. 4. What ICT-based and other science resources are available to and/or used by both metropolitan and provincial NSW Stage 3 teachers to supplement their science content knowledge?; and

Qn. 5. How often do teachers explore available ICT-based science resources to enhance their science content knowledge?

Therefore, in combination, the responses to these research questions contributed data relating to the intrinsic and extrinsic factors which might, to some degree, have influenced whether or not the teachers sought to improve their science content knowledge and how they did this.

1.4.4 Placing the Study into Context

The NSW school curriculum is based on the six stages indicated above. For each of these, there is a prescribed syllabus for a number of Key Learning Areas (commonly referred to in the NSW education community as 'KLA's). These syllabi each have a defined aim with "a set of objectives and outcomes, expressed in terms of knowledge and understanding, skills, values and attitudes" (NSW DEC, 2013b, para. 2).

In primary school - from Early Stage 1 to the end of Stage 3 - learning focuses on six KLAs: English; Mathematics; Science and Technology (S&T); Human Society and its Environment, Personal Development, Health and Physical Education, Creative

Arts, and Languages. During the time in which this research was conducted, the NSW S&T syllabus was still being used before the phasing-in of the Australian National Curriculum which began in 2014.

For the purposes of the NSW curriculum, "science is concerned with finding out about the world in a systematic way" (BOS NSW, 1993, p. 1) and "technology is concerned with the purposeful and creative use of resources in an effort to meet perceived needs or goals" (BOS NSW, 1993, p. 1). The KLA is, therefore, designed to equip learners to be active and informed participants in the 21st century, which is dependent upon science and technology. The scope of this research was confined to investigating the science aspect of this KLA.

1.5 Overview of the Research Method

In the initial phase of the research, a sample of principals and teachers in NSW primary schools was surveyed to gain an overview - among other aspects - of the schools' philosophy/policy related to teaching science; the factors affecting the teaching of science in those schools; the types of professional learning in which they engaged; and how much time was spent devoted to this at the Stage 3 level. Participating teachers from the schools were asked to identify any resources that they used to supplement their science content knowledge. In the second phase, one or more teachers of Stage 3 students in each of the participating primary schools were surveyed more extensively with the aim of examining the teachers' education backgrounds; their confidence in teaching science; and then, more specifically, their use of ICT-based science resources to enhance their own science content knowledge. In the third phase, a number of teachers whose tertiary education background did not include a major in any of the sciences, were interviewed to further elicit data related to their school's culture in which they were required to function as teachers, and the use of ICT-based science resources used by them to enhance their science content knowledge.

Schools were selected using stratified random sampling based on the NSW DEC's and Catholic Education Offices' regions and the schools' sector classification

(ideally State Government, Catholic Systemic and Independent). The Australian Curriculum, Assessment and Reporting Authority's (ACARA, 2013) 'My School' website - which provides up-to-date profile information on around 9,500 Australian schools - was used to determine each school's classification as either 'metropolitan' or 'provincial'. In each phase, the researcher aimed for approximately equal representation from each of these classifications and, ideally, with these schools equally drawn from the State Government, Catholic Systemic (which, henceforth, will simply be referred to as 'State' or 'Catholic', respectively) and Independent sectors.

In all instances, teachers were invited to participate in the study via mail-out, email or direct contact with their principal and follow-up telephone calls and/or emails. A cross-linked coding identification process was employed between Phases I, II and III to enable the researcher to re-contact participants from the previous phases for participation in successive phases and, where necessary, to co-ordinate their responses. After data had been collected and analysed, all identifiers were removed to ensure the anonymity of the participants and the schools. The surveys, logs and interviews undertaken were designed to gather data in relation to each of the research questions.

1.6 Overview of the Thesis Structure

The thesis is structured and presented as six chapters relating to aspects of the research followed by a list of references cited in the text and graphics. Additional information to supplement that shown and discussed in the thesis chapters is presented in an Appendix.

1.6.1 Chapter 1 - Introduction

An overall introduction to the study's background, aims and significance is provided in this chapter. The research is set within a conceptual framework and the research

questions are identified. This chapter also places the research in context and a summary of the research method is briefly outlined.

1.6.2 Chapter 2 - Literature Review

Chapter 2 reviews literature related to this research available during the time over which the research was conducted - up to and including the finalisation of that chapter. The literature review provides a summarised, theoretical basis for this research and a critical review of the current literature of the time that allowed the researcher to identify the research problem - an area not previously addressed in the literature - and relates it to previous findings.

1.6.3 Chapter 3 - Research Methods

The research methodology and underpinning research paradigms, ontology and epistemology are identified and discussed in this chapter. The research method and design are also described and include details of the study sample, research administration and the type of data analyses used. Details of instruments used to collect the data are described.

1.6.4 Chapter 4 - Results

This chapter presents the systematically integrated results of Phases I, II and III of the research; this includes both qualitative and quantitative data. The findings are presented in a sequential form which develops an overall picture of the participating schools starting with their size and demographics and their cultures relating to science teaching and progressing to their teachers' educational and teaching backgrounds and efficacy beliefs. These data define the background setting in which the teachers must work. The results are subsequently structured to elucidate the teachers' practices with respect to their use of ICT-based science resources to

enhance their science content knowledge. Much of the data derived from the surveys, logs and interviews are presented in tabular format for easier access.

1.6.5 Chapter 5 - Discussion

Chapter 5 comprises a discussion of all results stemming from each of the three phases of the research. The discussion themes - aligned with each of the research questions - integrate results collected from the survey, log and interview data gathered from the participating principals and teachers.

1.6.6 Chapter 6 - Conclusion

The key findings of this research are presented in this chapter in addition to their contribution to the literature. The limitations of the research are briefly examined; some recommendations are suggested for change; and suggestions for possible directions of future research leading on from the findings of this study are addressed.

1.6.7 References

A bibliography is provided identifying all resources used throughout the thesis. This is based on the American Psychological Association's (APA) 6th Edition referencing format.

1.6.8 Appendices

The Appendices contains samples of ethics approval documents from the governing bodies of participating schools and samples of correspondence related to the research. These include a letter introducing and inviting principals to allow their teachers to participate in the research, information sheets for the principals and teachers and corresponding consent forms. Copies of the survey questions for Phases

I and II, the Phase III interview protocol and questions are also incorporated in the appendices in addition to some data tables not included in the preceding chapters. A list of resources compiled from the survey data and completed logs is also included.

1.7 Chapter Summary

An overview of the research has been given in this chapter. The background which gave rise to the research was identified so the research could be placed into context. The five research questions were itemised and set against a conceptual framework. The research methods were outlined and were followed by a brief overview of the content of each of the chapters following this introductory chapter.

Chapter 2: Literature Review

2.1 Introduction

This chapter comprises a review of literature addressing the broad problem of science teaching in primary schools and the factors which interplay and influence that teaching. Some of these factors include a range of intrinsic and extrinsic factors which might operate either directly or indirectly on the teachers themselves. Some of the issues surrounding how teachers might employ self-directed learning using ICT to enhance their science content knowledge are reviewed. Additionally, some of the scenarios that might assist current in-service teachers to overcome their deficit in content knowledge are also covered.

The successful teaching of science in primary schools is a complex challenge which has many dimensions. Teachers depend "on their professional knowledge which has two kinds of sources: content knowledge and teaching skills" (Karami, Karami, & Attaran, 2013, p. 36) - the latter sometimes being referred to as pedagogical content knowledge. Hipkins and English (1999) suggest that the teaching, the learning, the context of the science - that is, the curriculum - and the science itself are some of the dimensions that must be considered in addressing this issue. They consider that "as in any complex dilemma, it can be helpful to select one dimension to explore at a time" (p. 3). Consistent with this approach, the one facet of primary school science teaching that was investigated in this research was teacher science content knowledge and its enhancement - where needed - using ICT-based science resources.

The literature review firstly explores the importance of science to society and, therefore, the reasons for teaching science - with particular reference to teaching primary school students - and the issues relating to the contexts in which primary school teachers work. Such issues can influence the status of science in a primary school and, therefore, how much science might be taught. For example, a principal's influence on school policy and teaching, the time spent teaching science, teachers' self-efficacy with respect to their science teaching and the impacts of standardised

and high-stakes testing, and related societal issues are reviewed. Subsequently, the literature relating to why generalist primary teachers who are required to teach science need to have sound science content knowledge, and the related issue of teacher pre-service training are examined. The literature related to primary teachers enhancing their own science content knowledge is reviewed. Finally, some of the literature, which offers some possible solutions that could be employed to assist teachers to enhance their science content knowledge, is also included. The status quo is initially addressed in the international context followed by the state of affairs in the Australian context. Longitudinal research and other studies conducted over past decades have also been included to highlight whether or not improvements in some areas have been protracted and/or ongoing. For some of the components of the literature review, there is a large body of research and in others - such as how primary teachers might enhance their own science content knowledge using ICT-based science resources - there is very little. Do they, in fact, seek to do this? The research aims to answer this question in relation to the participating teachers.

2.2 Why Teach Science in Primary School? - Producing Scientifically Literate Citizens

In its 2012 White Paper, the Commonwealth of Australia makes an aspirational statement that "by 2025, Australia will be ranked as a top five country in the world for the performance of [its] students in reading, science and mathematics literacy and for providing our children with a high-quality ... education system" (Department of the Prime Minister and Cabinet, p. 15). It is stated by Danielsson and Warwick (2014, p. 1) that "in the broadest sense, the goal for primary science teacher education could be described as preparing these teachers to teach for scientific literacy". They further contend that the quest to make this goal possible for primary teachers relies upon a number of factors which include each teacher's own science content knowledge and self-confidence.

In his review of the concept of scientific literacy, Laugksch (2000) notes that it is a

"deceptively simple term … [which is underpinned by] … assumptions, interpretations, conceptions, and perspectives of what the term means, what introducing the concept should achieve, and how it is constituted. It is therefore not surprising that the concept of scientific literacy is often regarded as diffuse, ill-defined, and difficult to measure" (p. 90).

Murphy and Beggs (2005) discuss and exemplify usage of the term 'scientific literacy' in a number of contexts. Among these is its metaphorical use in which it can refer to an attribute possessed by a person who is well educated and informed in science. In its application as a motto, the term can serve to "unite science educators behind a single statement representing the purpose of science education" (p. 86). The term has been used in the United States of America (USA) for more than four decades and has slowly gained usage in Australia and the United Kingdom (UK) in relatively recent times. Murphy and Beggs concurred with Hurley's viewpoint put forward in 1998 that the term had come to denote the "public understanding of science" (2005, p. 86). The OECD's definition of scientific literacy quoted in the Introduction chapter is a very suitable working definition and fits well with NSW S&T KLA curriculum outcomes. Murphy and Beggs' overall conclusion, that 'scientific literacy' embodies the "minimum scientific knowledge and skills required to access whatever scientific information and knowledge is desired" (2005, p. 86), intermeshes nicely with the OECD's definition. In the narrower context of primary school science education, then, 'scientific literacy' encompasses basic scientific knowledge and its related skills which allow students to be educated in science - at their own developmental level - to the extent that it will eventually, and cumulatively, inform their participation as well-educated citizens (MCEETYA, 2006).

Fensham recounts the transition of general science education in the secondary schools of many countries from the 1950s into the 1960s which saw a shift in focus of the societal demands which had previously focused on providing an education for those interested in following science-based careers to a focus on the needs of a changing society. These changes highlight ways in which societal needs are the

reflection of societal changes, the rapidly expanding volume of knowledge and the changing applications of that knowledge; changing societal values; and changes in "intellectual outlook" (Fensham, 2016, p. 166). There was, correspondingly, a shift from providing a science education for those intending to seek prospective employment in science-related pursuits to a science education for all students. By the 1990s, the disciplinary approach to science had gradually filtered down into primary school science curricula.

In 1988, Fensham proposed a model based on what he argued were the "six types of societal demand" (Fensham, 2016, p. 168), which influenced the changes in school science at that time. These proposed societal influences and tensions which influence science education in schools is modelled graphically in Figure 2.1 (Fensham, 2016, p. 169). Fensham (2016) contends that the magnitude and, hence the influence, of each of these six demands depicted in the model vary with time and, correspondingly, this results in changes in the direction of school science education. Fensham admits that, while the relative influences of these six demands are still relevant and vary, there are more drivers which contribute varying influences. As society changes, the influence of "other technical and environmental groups in the education system" (2016, p. 169) which operate independently cannot be discounted. Despite the shifts in emphasis in science education over the last five decades, one of the ultimate and enduring goals is to produce a well-informed, scientifically literate citizenry rather than preparing students for science-based occupations.

On the international scene, The English Department for Education's Framework Document notes that "a high-quality science education provides the foundations for understanding the world" (Department for Education, 2013, p. 136) and further acknowledges that "science has changed our lives and is vital to the world's future prosperity and all pupils should be taught essential aspects ... of science" (p. 136). Science is taught in English primary schools as one of three core subjects in addition to up to eight 'foundation subjects'. Similarly, the corresponding Welsh document published in 2008 by the Department for Children, Education, Lifelong Learning and Skills notes that "Science contributes to the Curriculum Cymreig [Welsh Curriculum] by the use of contexts that are relevant to learners' lives in Wales" (p.

8). Again, Science is a core subject and is taught with up to nine other primary subjects - reportedly, a relatively over-crowded curriculum.
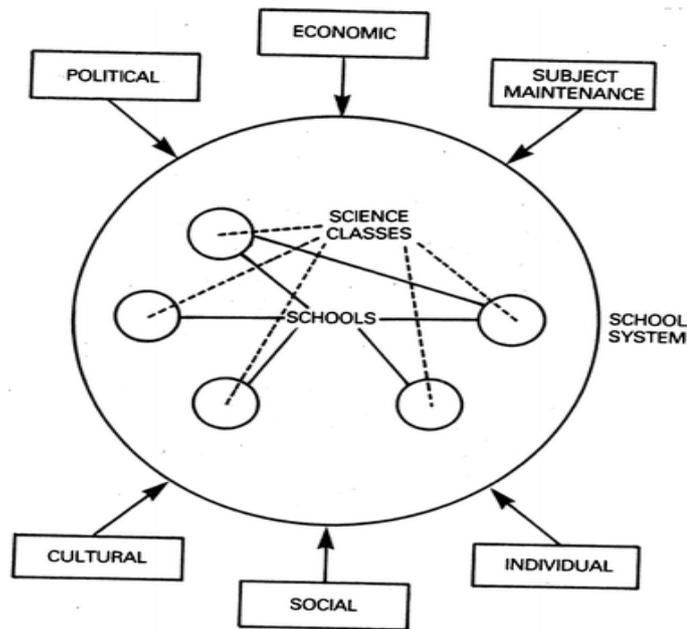
Figure 2.1. A model of the competing societal demands on school science education (from Fensham, 1988). From "The Future Curriculum for School Science: What Can Be Learnt from the Past?" by P. Fensham Research in Science Education. 46, p. 169. Copyright 2016 by P. Fensham.

In a study published in 1991 by Kahle, Anderson and Damnjanovic comparing the attitudes of primary school teachers teaching Grades 4 and 5 in the USA with those in Australia, both cohorts ranked the goal of interesting children in science as their first priority for science teaching. Each of these groups also ranked the relevance of science to daily life within their top four reasons. However, the goals of providing students with scientific knowledge and preparing them for science in their later years of education were, respectively, ranked 9 and 11 by the Australian group compared to 3 and 4 by their American counterparts. Interestingly, the researchers believed that the disparity between the Australian and American rankings for these latter two goals might have been due to the impact of low student achievement in competency-based science testing and the negative publicity that these results generated in the USA and internationally. This attention subsequently influenced the focus of primary teachers in the USA. The impact of both standardised and high-stakes testing is discussed in a later section of this chapter.

The importance of teaching science in Australia as part of the process to produce well-informed citizens has been documented in the literature. "In Australia and elsewhere governments, science educators, and teachers themselves, have expressed concern about the teaching of science in primary schools" (Peers et al., 2003, p. 1). Peers further states in 2007 that:

> … high quality teaching of both science and literacy in Australian primary schools is a national priority in order to develop scientifically literate citizens who can contribute to the social and economic well-being of Australia and achieve their own potential. A community with an understanding of the nature of science and scientific inquiry will be better equipped to participate in and contribute to an increasingly scientific and technological world. (p. 1)

Primary teachers who teach science, therefore, have an important role to play in the achievement of this goal.

The typical Australian primary teacher is a generalist who must, among other duties, effectively deliver a curriculum across a relatively large number of subject areas. Fitzgerald et al. note that defining just what makes a teacher 'effective' is "very elusive" (2013, p. 983) but argue that effectiveness is judged differently by the various stakeholders in school education and varies according to their "experiences and opinions" (2013, p. 983) and what they value. Determining teacher effectiveness also depends upon the context in which the teacher is teaching. Their school community, its culture and its aspirations, in addition to the teachers' own beliefs and teaching practices, are some factors which can influence the judgement about whether or not a teacher is effective. "Current understandings acknowledge the complexities that shape teaching and learning by exploring and identifying the teaching attributes and behaviours, and learning outcomes, which are valued" (Fitzgerald et al., 2013, p. 983). They acknowledge that a teacher's effectiveness develops as a result of the interplay of their practices and beliefs in the context in

which they operate: "there is no one way of being an effective practitioner of primary school science" (2013, p. 1000). Therefore, for the purposes of this research, teacher 'effectiveness' can partly be gauged by success in achieving the outcomes that contribute towards students' ultimate development towards being scientifically literate citizens, which is an outcome valued by society.

In Australia, expectations for generalist-trained primary school teachers are high. Not only are they faced with the enormous task of teaching a number of subjects across six KLAs, but also with classroom organisation, organising other peripheral programmes - such as learning to swim and participation in cultural competitions - and managing a classroom full of children who can have diverse personalities, cultural backgrounds and learning needs. To further illustrate this point, during interviews conducted with English pre-service primary teachers on various teaching-related themes, Danielsson and Warwick (2014) list particular quotes from the pre-service teachers to exemplify the themes that they explored. One student teacher, speaking to the theme of 'challenges with primary teaching - teaching diverse subjects' - states "that's the struggle in primary teaching, to teach all those students in all those subjects, and they all have very different abilities" (p. 303). In the S&T KLA, there is a further expectation that these generalist teachers are able to teach across the different disciplines within the subject of science such as biology, chemistry, geology and environmental science. Carr and Symington summarise the findings of much research when they acknowledge that "there is general agreement that primary teachers have a rather limited understanding of science" (1991, p. 39). Therefore, it is important that primary teachers have a sound grounding in science in order to assist them in the effective delivery of the science component of the S&T KLA

2.3 Teaching Science in Primary Schools - Broader Scenario

In the context of the NSW primary school education system, my research focused on whether upper-primary Stage 3 teachers with limited science content knowledge seek to improve that knowledge through the use of current, and usually readily available,

ICT-based science resources. Such resources can now be found on the internet and through diverse social media such as 'Twitter', 'Facebook' and 'Pinterest'.

One of the broader goals of all education is to produce citizens who can participate in their society in an informed manner. To this end, it is desirable to produce citizens who are effective communicators with a range of skills. Scientific literacy is, therefore, of great importance in contributing towards achieving the broader goal. This goal is to counter the research evidence from the 1980s and 1990s which indicated "widespread scientific ignorance in the general populace" (Osborne, Simon, & Collins, 2003, p. 1049).

One of the more notable recent trends in education in Australia, as in the rest of the world, is the decline in the numbers of students who are studying science through to the end of their secondary education, subsequently progressing into their tertiary studies and following science based careers (Gillies & Nichols, 2015; Kennedy, Lyons, & Quinn, 2014; Osborne et al., 2003). Gillies and Nichols have discussed this trend and pose that it "possibly exists for a number of reasons, not the least being primary teachers' lack of confidence in being able to teach science" (2015, p. 172). This recent phenomenon works against the goal to raise scientific awareness and literacy both for primary school teachers and the community at large.

Primary teachers who have sound science content knowledge on which to draw are more effective teachers in that area (Smithey, 2008). This is in addition to having a well-developed professional knowledge which encompasses pedagogical content knowledge, teacher self-efficacy and positive attitudes towards science teaching, classroom practice, etc. Aubusson et al. summarise some of the factors which have been shown in other studies to act as barriers and work against teachers who might have all of the attributes described above and who are trying to deliver the S&T KLA effectively. These "include resources, a lack of time for teacher preparation, poor access to science and technology specific professional development" (2015, p. 8). All of these factors, which impact on primary school teachers in a positive or a negative way, are addressed in the literature review.

The status of science as a subject in any one primary school - which can often be a reflection of the principal's and/or its governing body's and/or parental and community priorities - will further have an impact on science teaching in that school. Pressures, which can be imposed by sources external to the school system or to particular schools, can also be major influences on the status of science in that school. Such pressures can include, but are not limited to, the imposition of an over-crowded curriculum by governing bodies - in which many subject areas are taught and life experiences are delivered. The pressures associated with society's perceptions of broader school student performances in standardised testing such as the OECD's Programme for International Student Assessment (PISA) and meeting individual school's targets in high-stakes testing such as in Australia's National Assessment Program - Literacy and Numeracy (NAPLAN) might also exert pressures. The culmination of these factors could be that the time devoted to science teaching is often less than is prescribed or desirable. This possibility is discussed in a later section. Teachers who are not supported in their science teaching might develop low self-efficacy, and attitudes towards the teaching of science might decline.

During the process of designing and developing the current Australian National Curriculum, the National Curriculum Board entered into a consultation process in which all stakeholders - professional and the broader community - were able to submit feedback and contributions, using varying formats, to be taken into account in the development of the 2009 Framing Paper Consultation Report (FPCR) (National Curriculum Board (NCB)). Section 5.3 of the FPCR relating to the "representation of the science curriculum across the stages of schooling" (NCB, 2009a, p. 11) states that "while the section discussing the 'relevance of science learning' was supported [by the submissions], the problem identified for primary schools was more to do with the absence of science being taught rather than with the relevance of what is being taught" (NCB, 2009a, p. 11).

The appropriate training of teachers in their pre-service years is a critical start to the process in order to produce teachers who have a sound content knowledge base, and to equip them with the necessary skills to be effective primary teachers. Once they are employed as teachers, there should be ongoing, further professional learning and development to sustain and enrich these skills; and to further enhance their science

content knowledge. However, it has long been established that these issues do not seem to have been addressed fully through pre-service teacher-training courses producing new-career teachers with inadequate science content knowledge. These issues are addressed in a later sections. Many primary teachers do not seem to attend professional development in the science domain.

There is a number of possible solutions which could be used to alleviate the problems in schools emanating from teachers having limited science content knowledge: improving the teacher-training courses themselves; the employment of specialist science teachers in schools; the utilisation of mentors and/or community members with specialist science skills; the establishing of communities of practice either within or between schools; and the provision of, and access to, a broad range of science resources - in every sense of the word - both within and from outside the school. Ultimately, it falls to the teacher, as part of his/her professionalism, to take ownership of his/her own learning to ensure that there is some appropriate preparation and in-classroom strategies adopted to compensate for any shortcomings in science background. The status of science and the effectiveness of science teaching in primary schools can be improved, at least in part, by addressing the factors which are major impacts on teachers' science content knowledge.

2.4 Status of Science in Primary Schools and Teachers' Science Content Knowledge

Figure 2.2 identifies the many factors - and, where applicable, their relationships to each other - which can potentially influence the teaching of science in a NSW primary school. These factors can be direct or indirect, intrinsic or extrinsic. Some of these influences reflect the six societal demands noted by Fensham (2016). Of relevance to this current study is the inter-relationship between teachers' science content knowledge and the status of science in primary schools and the other factors which can influence each of these. Teacher science content knowledge, the status of science - in primary schools and the broader community - and the other factors referred to in Figure 2.2 are discussed in this and the following sections.

Teachers operate in primary schools which have their own particular cultures and aspirations, and which might or might not be well resourced for the teaching of science. For the purposes of this literature review, it is informative to review the status of science in the participating schools. There is a large body of research relating to the status of science in primary schools and primary teachers' science content knowledge.

As editor of a book exploring approaches to the education of primary school teachers in science and mathematics published by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) in 1993, Harlen notes that "many, perhaps most, primary teachers have received from their own education a legacy of failure or at least dissatisfaction in relation to science" (p. 9) and that both science and mathematics in many societies are popularly perceived as being difficult subjects. Teachers, who are members of these societies, have a tendency to share this view (Harlen, 1993). Therefore, they can have a negative opinion about science and, if they are teachers who are not particularly confident because of their background, then they can subsequently pass on such negative attitudes to their students through their approach to teaching. The influence of the environments in which students live and learn on the development of their attitudes is supported by the literature review conducted by Osborne et al. (2003) on attitudes towards science .

International studies have found that science has a low standing in many primary schools and much of this - in many cases - is a result of deficits in primary teachers' background knowledge. Some of these studies are discussed below to highlight this point. Among 15 issues identified by Murphy and Beggs were "lack of knowledge/expertise/confidence/training of teachers" (2005, p. 81), which was ranked at the top of the list and, ranked further down the list were an "overloaded science curriculum" (equal 6th); "primary not geared for science" (8th); and "science imposed on teachers" (equal 9th) (2005, p. 81).

In his 2008 doctoral thesis on the purpose of science education in England, Wales and Northern Ireland and how primary teachers understand the nature of science, Lunn (p. 1) highlights the findings of other studies by noting that "there is a
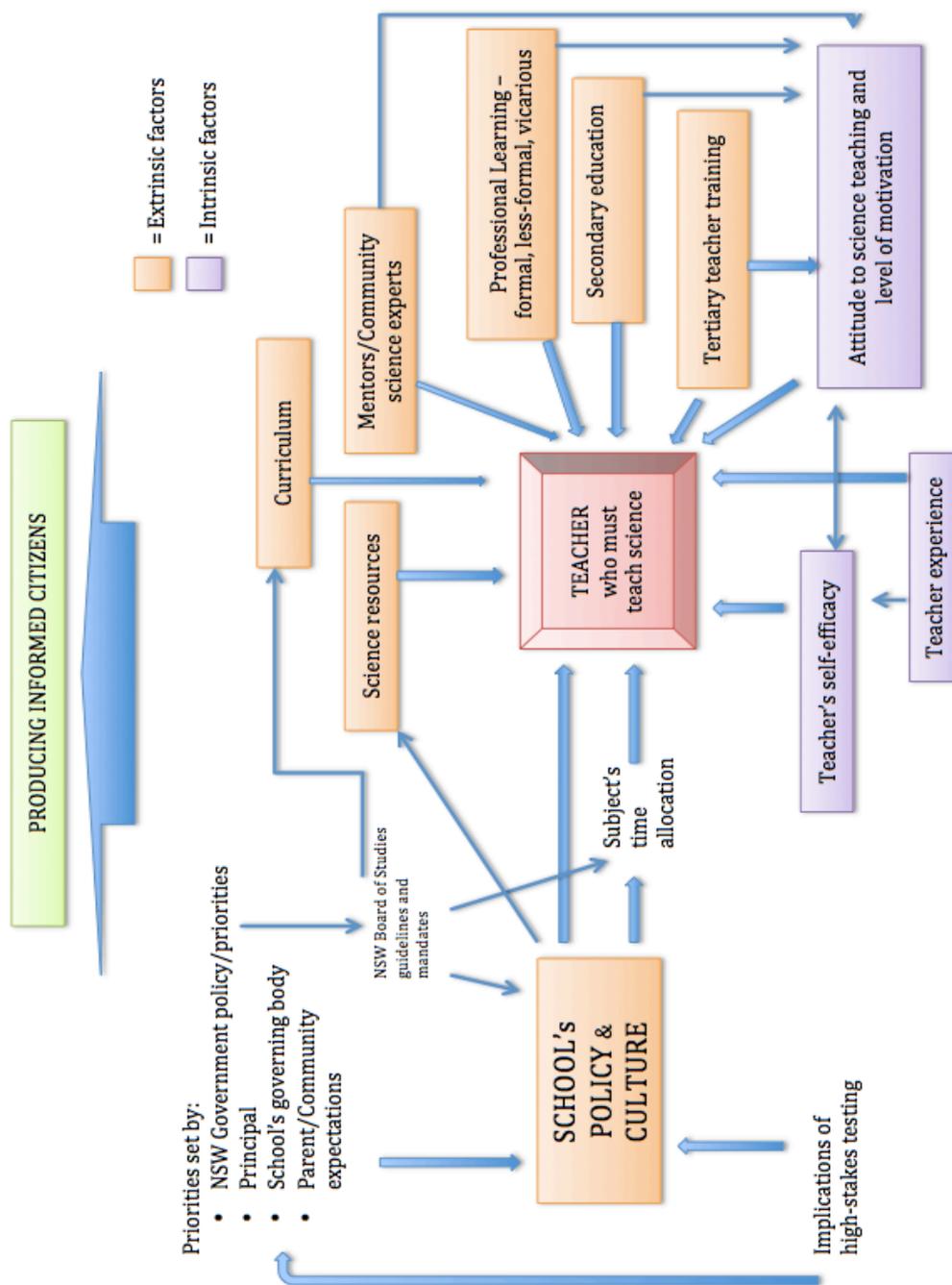
Figure 2.2. Factors influencing the teaching of science in a NSW primary school based on the researcher's professional experience and from multiple literature sources.

problem with primary science; the problem arises from a deficit in the teachers' subject knowledge". Lunn further notes that, even at the time of his research, "the opinion of many policy-makers and educationalists seems to be that 'generalist'

primary teachers cannot do justice to the science element of the curriculum, through lack of subject knowledge" (2008, p. 1). Smith notes that the inquiry-based science curriculum implemented since 2003 in the West of Ireland, was hoped to enliven primary science, develop students' key skills and enable "the acquisition of scientific knowledge" (2015, p. 216). He describes continued concerns highlighted through a recent body of local research related to this curriculum which include "teachers' lack of confidence and competence teaching science, insufficient content and pedagogical knowledge" (p. 216). Research in other countries has produced similar findings as noted below.

Across the Atlantic, similar concerns to those in the West Ireland context have been expressed. Compared with other states in the USA, California is often cited as its country's leader in the field of science and technology and its broader community is well resourced in the science and technology arenas (California Council on Science and Technology (CCST), 2010). Despite this, the profile of science in Californian elementary schools does not mirror this lead. Even Californian students typically perform at or below the nation's average in science. For example, in the 2005 national assessment, 50% of Fourth Grade students scored either at, or below, the national proficiency benchmark. The report attributes this to two reasons which are directly related to this study; and both can negatively impact the status of science in schools. One of the reported reasons is the diminished time spent on teaching science in elementary classrooms - which is more fully discussed in a later section. The other reported reason is that there is "evidence that elementary teachers are less well prepared to teach science than other subjects" (2010, p. 2). According to this report, teachers' supervisors commented that the teachers whom they were overseeing were more ready to teach mathematics or reading - which approximately equates to literacy in the Australian context - compared to teaching science for which they were less adequately prepared. The teachers themselves reported that they felt even less prepared to teach the subject than their school supervisors had perceived them to be. Conversely, these perceptions could also possibly be symptomatic of schools in which science teaching already has a low status. Viewed over a long period to time, this can evolve into a 'chicken-and-egg' argument (CCST, 2010).

There have been some interesting results on teachers' perceptions on their adequacy to teach science. In the Kahle et al. (1991) study discussed above, primary teachers in the USA rated their background knowledge of biology to be significantly superior for teaching biology-related subject matter than for topics related to physics and the earth sciences. This is comparable to the Australian group in the same study, who held a very similar opinion about having enough expertise to teach about flora and fauna compared with other topics related to, for example, physics. Interestingly, a greater number of male teachers felt that they were better prepared to teach physics-related topics such as energy and matter. However, both groups nominated the biological topics as their preferred area of interest. Danielsson and Warwick (2014) also found that, within the small group of pre-service teachers who participated in their UK study, biology was the subject that these teachers reportedly enjoyed the most.

Further to teachers' perceptions of their adequacy to teach science, Alexander, Rose and Woodhead stated - in a 1992 report commissioned by the British Government - that a large proportion of teachers in primary schools were not equipped to deliver subjects effectively and there was a shortage of teachers who had specialist expertise. They recommended that this lack of specific and detailed content knowledge or curriculum expertise - in addition to other needs - should be catered for during initial training, induction and in professional learning courses. "Schools have an obligation to help the new teacher extend the competencies acquired in initial training. … primary teachers must have a firm grasp of the subject matter which the National Curriculum requires" (Alexander et al., 1992, p. 42). Alexander et al. concede, though, that it is highly unlikely that, given their generalist pre-service training, primary teachers would have the expertise to teach all subjects to the required depth. The addition of science as one of the major subject areas to the National Curriculum (of England, Wales, and Northern Ireland) put further strain on the expectations for primary teachers and the amount of curriculum expertise which they needed to embrace. Alexander et al. (1992) noted that, prior to this, the teaching of science in a very large number of schools had largely been neglected if teachers so desired. Thus, the status of teaching science was diminished in those schools.

In the USA, it is also acknowledged that many generalist primary teachers begin their teaching careers with a very weak science knowledge base (Schwarz et al., 2008). "Elementary school science teachers [in the USA] are lacking in content preparation especially in the physical sciences" (Fulp, 2002, p. 9). Allen refers to the example of The University of California's Professor Coburn telling his undergraduate education students that "people in general don't like science, and elementary school teachers are no different from the rest of the general public" (2006, p. 2) and that it is "no wonder that [elementary] teachers tend to treat science as an afterthought" (2006, p. 2). Again, the practice of undervaluing and avoiding the teaching of science can continue a downward trend in the status of science in a primary school.

Similar patterns of primary teachers' lack of science content knowledge are echoed in other parts of the world. Two studies conducted in sub-continental India and Turkey exemplify this point. In the Indian context, the draft Curriculum Framework for Quality Teacher Education published in 2009 by the National Council for Teacher Education states that quite a large number of the country's nearly 3 million primary school teachers are undertrained in all teaching areas. In discussing future directions for high quality teacher education for the huge Indian education system, it is pointed out that, at the time of writing, in-servicing of teachers was minimal - or in some cases non-existent - and left much to be desired. The education of both pre-service and in-service teachers needed to be reinforced by self-initiated learning in addition to attending professional learning courses and continuing formal education. These factors which all contribute towards teacher development are crucial in the changing scheme of Indian education at all levels. The introduction of compulsory science through many of the grades is just one of a myriad of proposed changes which will greatly affect primary teachers in India and the status of science in their schools. It has been reported that, in more recent times in India, "science education [still] needs to be strengthened in terms of methods of teaching [and] teacher quality" (Shukla, 2005, p. 55) across the country. In 2017, it is noted that the Indian Government and some other organisations and institutions are endeavouring to "change the scene of science education in India" (http://www.indiaeducation.net/science/current-scenario.aspx, para. 6). This

eventuality might lessen the teachers' dependence on in-service and formal education and self-initiated learning to compensate for deficits in teacher education.

Although the scope of their study was limited to a sample of Turkish Second Grade primary students, Dokme and Aydinli (2009) found that, contrary to their expectations, the performance level of basic science process skills among the students surveyed was not as high as they had anticipated. They proposed that having a high level of process skills is necessary to assist with the learning of science concepts as they are now taught after the latest Turkish curriculum reform. One of the reasons that researchers suggest to account for this lower level of necessary skill is primary teachers' inadequate qualifications in the area of science. Again, the same area of concern emerges in different parts of the world. Teachers' self-initiated learning could assist in compensating for deficits in their content knowledge. Australian primary teachers are not exempt from the need to compensate for content knowledge deficits. In its statement on professional learning, the NSW DoE clearly states that self-initiated learning is indicative of a teacher's professional commitment (2017a, para. 6).

Stevens and Davis acknowledge the impossibility of primary school teachers having extensive content knowledge across all of the subject areas that they are expected to teach; and that, even though the amount of science content needed by these teachers is extensive, "science content knowledge is often at the bottom of the list" (2007, p. 2). They cite a number of findings by others which highlight the lack of science content knowledge as being the reason for the reluctance of new primary teachers to teach science. According to Stevens and Davis, "for many, teaching science is one of the most difficult aspects of [primary teachers'] work" (2007, p. 28) as a result of their often limited science content knowledge.

Very similar findings to those reported internationally have been found in the Australian context. A 1989 pre-service primary teacher education review relating to science and mathematics teaching revealed that the majority of the teachers studied had "negative attitudes to science and to its teaching and learning" (Department of Employment, Education and Training (DEET), p. 37). This attitude was later reflected in the amount of science teaching conducted in their classrooms. From the results of a study conducted in 1990, Grindrod, Klindworth, Martin, and Tytler

elucidated that the pre-service teachers participating in their study considered that a combination of "lack of content knowledge, the crowded school curriculum and problems associated with managing resources and equipment" (1991, p. 151) were the predominant features which were contributing to the minimal degree to which science was being taught in the study sample.

Still in the Australian context, Jane, Martin, and Tytler (1991) commented on the 1985 research of Owen, Johnson and Welsh in which science lecturers of pre-service teachers in Victoria, observed that most of the pre-service teachers - particularly the females - had limited academic backgrounds in science in addition to negative attitudes to the subject. Similarly, research by Jane et al. (1991) determined that the background of the female pre-service teachers participating in the study was predominantly biological science and that the males tended more towards the physical sciences. Grindrod et al. (1991) also found that, of the pre-service teachers whom they had studied, the majority by far had a more positive self-perception of their biological science knowledge and a very low perception of their knowledge of the physical sciences. These results have again been mirrored by the findings of other studies such as those of Skamp (1991) which again demonstrated that the biological sciences were dominant in teachers' backgrounds compared with the physical sciences. In the same study, Skamp found that this trend continued for teachers who had been out of teacher training, on average, for 14 years and who had not engaged in many science-related professional learning opportunities during the ten years prior to the study.

The outcomes of a 1994 study conducted in Australia with 148 pre-service teachers - 108 of whom were female - further reinforce these findings. In this study, Farnsworth and Jeans found that, although many of the students had some degree of positive attitude towards the teaching and learning of science during primary school years and saw "value in all domains of science for children [in primary school]" (1994, p. 369), they were concerned that their interest in the physical sciences was quite low. Farnsworth and Jeans postulated that this might be the result of experiences in the teachers' secondary school years and was an area which needed rectification.

In another Australian case study undertaken some years ago, Henderson suggests that a "lack of structure [in the science curriculum] may be one factor which is preventing science from holding the position it deserves in the primary school curriculum" (1992, p. 192) compared to English and mathematics courses which are very structured and, therefore, more easy to follow. He further questioned whether or not the language of science that is embedded in some teaching frameworks is too difficult to follow for teachers who have little science background. This inability to follow a curriculum framework would ultimately have a negative impact on the status of the teaching of science in their schools. More recent curricula developed for teachers in NSW have progressively overcome some of these difficulties through more explicit documentation.

Further to the context of primary science education in the Australian state of Victoria, an audit by the Victorian Auditor-General was published in 2012. This audit reported on 102 primary school teachers who were surveyed with respect to their perceptions/knowledge of various aspects of science and mathematics teaching. The audit revealed that only low percentages of the teachers self-reported these aspects as either 'good' or 'very good'. The percentages are summarised in Table 2.1. From the table, it can be seen that less than 48% of the teachers stated that their science content knowledge and other aspects of science teaching were, at best, good or very good. The audit reports that "teacher quality has emerged as the most urgent issue facing government schools in their challenge to improve science ... education" (2012, p. 22). In an article discussing more current concerns for the status of science in Australian primary schools, Crook and Wilson (2015) state that even the most recent proposal by the then minister for Education, Christopher Pyne, to make science compulsory for all students - up to and including year 12 - "needs to include long-term plans for improving the status of science in primary schools and ensuring teachers have the requisite support" (para. 2). One of the challenges relating to increasing the status of science in schools highlighted in this piece is that "most [primary teachers] lack the training and experience to teach science, and a deep understanding of the subject and experimentation. Many feel under-confident in science" (para. 9).

Both international and local Australian studies into teacher science content knowledge and the status of science teaching in schools suggest that having teachers with a low level of science content knowledge, and who might therefore resist teaching science in their schools, can be a contributing factor to the low status of science in those schools. Crook and Wilson (2015) reflect this notion by stating that "the declines in science participation are longstanding and will have fed into the teaching profession" (para. 10). There might also be a reciprocal relationship, whereby schools in which the status of science is low might not encourage or inspire teachers to self-initiate cycles of learning through which the teachers might seek to enhance their own science content knowledge.

Table 2.1. Percentage of teachers stating that their knowledge of aspects of science … is good or very good. Adapted from "The Science and Mathematics Participation Rates and Initiatives Report (2012)" by the Victorian Auditor-General's Office, 2012, p. 29, Fig. 3D. Data used with permission from The Victorian Auditor-General's Office.

Aspect of Science Teaching	Primary School Teachers (%)
Science content	47.5
Science pedagogy/instruction	38.6
Science curriculum	40.0
Integrating ICT into science	38.0
Assessing students in science	39.0
Improving students' critical thinking or problem solving skills	43.6

2.5 Measuring Student Learning and Trends in Science Education

"Children should have the knowledge and skills to attain the required targets laid down in national curricula" (Murphy & Beggs, 2005, p. 86). Measuring student learning is a key process of education as it informs stakeholders of students' academic progress - or lack thereof. Students' test results can also be used as an indicator of a school's overall progress in certain curriculum areas and is sometimes used as a positive promotional tool for, or a negative promotional tool against, the school. While a discussion of testing itself is not directly relevant to this study, the impact of some testing regimes, which are either internationally- or nationally-based,

can have a bearing on the teaching of science in some schools. It is, therefore, important to review the literature on this topic in relation to the kinds of information that governments, communities and schools gain from the analysis of such test results; and to consider the impact that these results might have on a school and the education outcomes that it might prioritise. Such school priorities might impact on the teaching of some subject areas and is, therefore, relevant to this research.

There is a number of testing regimes - both international and national - employed for gauging the level of student competence in certain subject areas (such as science and mathematics) and/or targeted competencies or skills (such as literacy and numeracy). One such study is the Trends in International Mathematics and Science Study which is often referred to as TIMSS (Martin, Mullis, Foy, & Stanco, 2012). The TIMSS and PIRLS International Study Center (n.d.) identifies TIMSS as a four-yearly cyclical international testing regime which produces "comparative assessments of student achievements in mathematics and science" (para. 1) … to "enable participating countries to make evidence-based decisions for improving educational policy" (para. 2). Students in Years 4 and 8 in over 60 countries participate, and trends have now been reported for over 20 years (n.d., sub-section 1). Relevant to this research are the reporting of results which include "measuring the effectiveness of the educational systems in a global context, identifying gaps in learning resources and opportunities [and] pinpointing any areas of weakness and stimulating curriculum reform" (n.d., para 2). By way of example, in England where, according to the 2011 TIMSS survey in which 52 countries participated at the Fourth Grade level, science results have declined since 2007 - although they remained above the international average. Her Majesty's Inspectorate of Education's (HMIe) 'Improving Scottish Education' report of 2005 reported on areas relevant to improving Scottish education and focussed on the improvement of the effectiveness of science education in primary and secondary schools there. The report states that "pupils continue to under-achieve [in mathematics and science] at the upper stages of primary" (2005, p. iii).

A similar pattern has been detected in Australia. Masters (2009, p. v) notes that "international studies show that relatively few Australian primary school students reach high standards of mathematics and science achievement". Results of the 2006 National Year 6 Science Assessments in Australia showed an increase from 40.6% to

45.7% of students who had performed below the national proficiency standard (MCEETYA, 2008). Figure 2.3 shows the advanced benchmark performance results of students from each Australian state/territory in comparison to results for neighbouring Singapore for the 2007 TIMSS testing: the NSW results are notably lower than Singapore's. Analyses of the 2011 TIMSS survey data documented by Martin et al. (2012) show that Australian students' test results were below that of 23 countries - which included most of the participating countries of the Asian region, England and the United States of America - but was six places above the TIMSS Scale Centrepoint. The average Year 4 student in Australia - one year level below NSW Stage 3 students - scored markedly lower than any of its equivalent cohorts did in the 1995, 2003 and 2007 testing rounds. Australia also showed overall declines at both the advanced and high levels. Further to this, the TIMSS 2015 testing cycle (TIMSS and PIRLS International Study Center, n.d.) indicates that Australian Year 4 students performed statistically higher in that year than their predecessors in the previous testing round in 2011. However, further analysis indicates that, over the testing cycles from 1995 to 2015, Australian students on average have shown no overall improvement-trend (n.d.). In an Australian Council for Education Research (ACER) media release on November 29, 2016, it is acknowledged that data from this most recent round of TIMSS testing supports this trend noted above and "reveals no improvement in the performance of Australian students" (2016b, para. 1).

This report quotes the ACER Director of Educational Monitoring and Research, Dr. Thomson, as summarising the overall Australian results: " … science achievement of Years 4 and 8 students over the past 20 years has flat-lined, while many other countries have improved" (2016b, para 2.). On average, 8% of the Australian Year 4 students compared to 37% of the Singaporean cohort achieved the advanced benchmark (Thomson, Wernert, O'Grady, & Rodrigues, 2016). In the November 29, 2016 report, Thomson puts the trend into perspective and highlights the education community's concern by further stating that "Australia's performance in TIMSS 2015 is a wake-up call" (ACER, 2016b, para. 4) and acknowledges that, relative to other countries, we are "actually slipping backwards" (ACER, 2016b, para. 4).

This primary science pattern is consistent with students' senior school years as mentioned. In a paper delivered at the 2014 ACER Research Conference, Lietz,

Darmawan, and Aldous (2014) compared 15-year-old Australians' performances in science in the OECD's Programme for International Student Assessment (PISA) in 2012. The purpose of the PISA testing is to assess the extent to which students "have acquired some of the knowledge and skills that are essential for full participation in
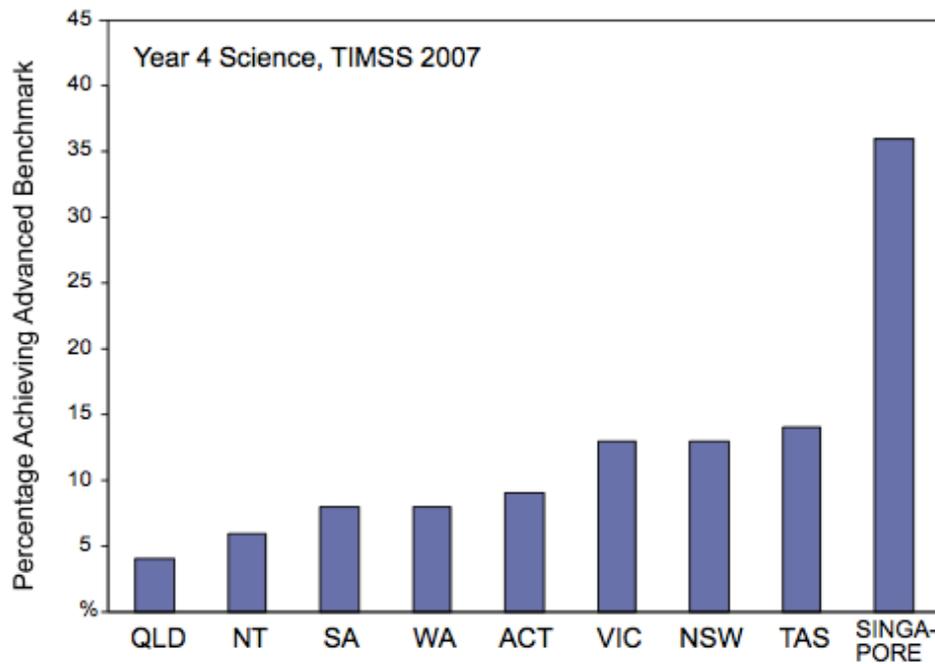
Figure 2.3. Percentage of [Australian] Year 4 students achieving the advanced benchmark in science [in the 2007 TIMSS]. From A Shared Challenge: Improving Literacy, Numeracy and Science Learning in Queensland Primary Schools, p. 21 G Masters, (2009). Copyright 2009 The Queensland Government (Queensland Dept. of Education).

society" (ACER, 2016a, para 1). It is not only concerned with testing reading, mathematics and science literacy skills but also key curriculum knowledge and skills which are considered to be of importance after students leave school and into adulthood. The ACER media release of December 6, 2016 on the performance of Australian students in the 2015 PISA testing round highlighted the concern around preparing students for their lives after they leave school. Analysis of the 2015 PISA test results "now makes clear that the science, reading and mathematics achievement of Australian students is in absolute decline" (ACER, 2016c, para. 2). The same release notes great cause for concern because the results indicate "not only that Australia is slipping backwards relative to other countries, but that we are getting worse at preparing our students for the everyday challenges of adult life" (para. 1).

Some impacts of students' regionality also became apparent through analysis of the PISA data. The 2012 PISA results for science also showed that student performance in this test "consistently and significantly increases with the size of the population base in which schools are located from village to large city" (ACER, 2014, para. 4). The 2015 PISA results show the same regional pattern within Australia with metropolitan school students performing "significantly higher than students from provincial schools and remote schools" (Thompson, de Bortoli, & Underwood, 2017, p. 26). Such general patterns of increasing student science performance across Australia from low- to high-population areas could be cause for concern among educators as they seek to lift the capabilities of students in all regions of the country. 'Low' to 'high' population areas in Australia can, generally speaking, parallel trends seen in moving from provincial to very large country towns and into metropolitan areas. Can there be implications then of a very general, overall trend from provincial through to metropolitan areas in the level of science achievement of students from these areas? The 2015 PISA results also indicate that, while students from metropolitan schools, on average, performed "significantly higher than the OECD average … the average performance of students in remote schools was significantly lower than the OECD average" (Thompson, de Bortoli & Underwood, 2017, p. 26). The same authors also report that the average performance of provincial students is not "significantly different" (p. 26) compared with other OECD students. Following from this, might there also be differences in the status of science moving from very small provincial schools through to those in large metropolitan areas? Could the teachers' relative professional isolation in NSW provincial areas also be a contributing factor? The problem of professional isolation is addressed in a later section of this review chapter.

The PISA data showed trends in students' performances comparing the large metropolitan centres with increasingly smaller centres and into rural areas. Therefore, in this research, the participating schools and their teachers were categorised as metropolitan or provincial, and their data were analysed for any differences between them in the focus areas studied. The literature on performance data for NAPLAN high-stakes testing was also reviewed for similar and other trends.

2.5.1 Negative Impact of High-Stakes Testing on Teaching Primary School Science

As previously noted, standardised testing such as PISA and TIMSS has been used in many countries for some time. Additionally, some countries engage in testing regimes which are referred to as 'high stakes' testing. Minarechová (2012) notes that the term 'high-stakes' test usually refers to standardised achievement tests which are administered on a national or state-wide basis and that "high-stakes testing consists of a series of tests in which the results evaluate schools, teachers and pupils" (p. 82). She cites the National Assessment Program - Literacy and Numeracy (NAPLAN) as an example of high-stakes testing in Australia. Minarechová cites Heubert and Hauser's earlier assertion that such tests "are increasingly seen as a means of raising academic standards, holding educators and students accountable for meeting those standards and boosting public confidence in schools" (2012, p. 83). To highlight this point, Supovitz (2009) describes research published in 2000 which reported that large-scale, high-stakes testing was implemented in at least 21 countries between 1974 and 1999. Some of the countries using such testing at that time included the United Kingdom (West, 2010), the United States of America (Amrein & Berliner, 2002; Yeh, 2005), some Canadian provinces (Burger & Krueger, 2003); Sweden, Spain and Portugal (Supovitz, 2009), and Australia (Minarechová, 2012). A large body of work has reflected on the number of positive and negative impacts of high-stakes testing and Sahlberg (2010) claims that, after 20 years of "high-stakes and test-based accountability policies in England, the United States and parts of Canada and other countries, the gap between proponents and opponents ... is widening" (p. 58). Carlone, Haun-Frank, and Kimmel (2010) also comment that, at the time of their study, "the cracks of opportunity to create new meanings of science teaching might be a little wider than they might be if science were a part of the high-stakes testing equation across all grade levels" (p. 963).

The most often-cited negative impacts of high-stakes testing include those on student and teacher wellbeing; a narrowing of the curriculum of the area being tested; and a contraction of the amount of time devoted to other curriculum areas which are not tested - such as, for example, science, the social sciences and physical education. In 2001, a teacher in one Californian elementary school explained that, because of the

frustration over time taken to prepare students for a particular high-stakes examination, the teachers at her school voluntarily taught an extra, unpaid half an hour each day to give themselves time to teach science and social studies (Amrein & Berliner, 2002). Also in the USA, Pringle and Martin (2005) reported that the pending implementation of high-stakes science testing in the state of Florida in the USA brought about an expected recognition by primary teachers that they needed to teach science. However, this recognition did not emerge from the teachers' perception of the importance of children learning science but, rather as reported by the teachers, because of the negative consequences of the fear of failure and/or possible sanctions accompanying such failure in the testing cycle.

There are, therefore, concerns relating to negative impacts of high-stakes testing which have the potential to adversely affect - for example, by narrowing the broader curriculum and less time spent teaching science - the teaching of science in primary schools. The NAPLAN diagnostic tests have been administered annually in Australian schools since 2008. Minarechová (2012) claims that they became 'high-stakes' tests with the creation of the 'My School' website in 2008, which is open to the public and includes descriptive, demographic and other data relating to every school in Australia. The NAPLAN-performance data are also included for every Australian primary and secondary school. Dulfer et al. (2012) found that the teaching profession in Australia viewed NAPLAN as high-stakes testing and note that this finding confirmed the earlier views of other researchers reported in the years immediately preceding their study. Caldwell, in reference to the use of NAPLAN and the 'My School' website, noted that "Australia became isolated in the international community for proceeding with an approach that had been abandoned elsewhere as country after country moved ahead with a more enlightened approach" (2010, p. 53). The Australian Government in 2017, and into the foreseeable future, is still implementing NAPLAN testing.

In its 'NSW 2021 - A Plan to Make NSW Number One' (September, 2011), the NSW Department of Premier and Cabinet lists seven targets to improve students' education and learning outcomes - identified as 'Goal 15'. Two of these targets are to improve literacy and numeracy standards of Years 3, 5, 7 and 9 students and raise them to a level beyond that set for the nation's reading and numeracy standards. In

particular, targets aim to maximise student numbers attaining the top two performance band levels in these competencies. Part of the rationale for this is that "students with sound literacy and numeracy skills are more likely to remain at school longer, complete their Higher School Certificate and continue to tertiary education" (2011, p. 31). The implementation of the NSW Literacy and Numeracy Action plan is one strategy named to assist in realising this goal. Under this plan, the NSW Government aimed to spend "$24 million dollars in 2012 [and beyond] to hire 200 full-time-equivalent teachers to target underperformance in literacy and numeracy across the government and non-government sectors" (NSW DEC, 2012b, para. 1). Whilst these goals are certainly worth aiming for and achieving, no reference at all is made to science education or to education in other specific subject areas. Neither is there any reference to the impact that spending more time working with students solely on their literacy and numeracy skills will have on the teaching of these subjects - assuming that they are not being taught across all KLAs.

In a report on consultation outcomes of the Literacy and Numeracy Action Plan framework published by a Ministerial Advisory Group in 2012, it is acknowledged that, in 2011, students in NSW - which had the highest participation rates in NAPLAN - continued to perform well in comparison to their peers in other Australian states in the assessments. These students were achieving rankings in the top three bands based on "mean scores and percentages in the highest band on all ... NAPLAN assessments" (NSW DEC, 2012a, p. 3), with a couple of exceptions in high school writing tasks. The Advisory Group, nevertheless, recommended that there was a case for further improvement particularly for the students who had been performing either just above or below the national minimum standard. This Advisory Group states that "with stronger literacy and numeracy skills students are better able to engage effectively in a broader range of subjects and can better acquire those higher order skills vital for learners in the 21st century" (2012a, p. 4). Is the goal to improve students' literacy and numeracy capabilities impacting on the teaching of curriculum KLAs such as S&T in primary schools?

Dulfer et al. conducted the first Australian national study of the impacts of the NAPLAN assessment regime involving over 8,300 teachers and principals across Australia. Staff from NSW and ACT schools constituted 34% of the sample and 55%

of the total sample were primary school teachers (2012, p. 11). The results show that over 80% of these teachers felt that the preparation for the NAPLAN tests impacted on a curriculum which is already considered to be overcrowded, while 59% of the teachers considered that such preparation led to less time for other subjects which fall outside the scope of these standardised tests. It was noted in the study that the majority of respondents agreed that NAPLAN was a "school ranking tool or a policing tool" (Dulfer, 2012, p. 8). The results of each NAPLAN testing round are widely publicised in the Australian media which, in turn, can fuel community debate around the subject and, rightly or wrongly, influence community opinion. Mather (2012) reported in the media on the same study. This media coverage reflects societal interests in issues surrounding NAPLAN. Mather (2012) summarised responses from more than teachers 7345 teachers (Dulfer et al., 2012, p. 27) related to NAPLAN's negative impacts on curriculum and teaching practice. Figure 2.4 shows a summary of some of the responses from the survey as presented and published in the Mather article. (The data are also available in the Dulfer et al. report on page 27). Of importance to this study are the following negative impacts as shown in the Dulfer et al. report figure: 83% of participants (n = 7375) strongly agreed/agreed that NAPLAN impacted on an already-crowded curriculum (2012, p. 27); 76% (n = 7371) strongly agreed/agreed that NAPLAN reduced the importance of other curriculum areas (p. 28); 69% (n = 7385) strongly agreed/agreed that NAPLAN has the effect of reducing the time for teaching subjects not specifically tested; and, 76% (n = 7319) strongly agreed/agreed that NAPLAN motivated them to focus on what is tested by NAPLAN. Mather (2012) further notes that Dulfer - who was at that time a lecturer within the University of Melbourne's Education Policy and Leadership Unit - had called for a public debate on the negative impacts of NAPLAN and that the tests' importance had been "blown out of proportion" (para. 13). Dulfer et al. note that NAPLAN's "introduction has been a source of debate and argument. That debate continues to rage" (2012, p. 4).

Further pressure on teachers to put maximum effort into realising desirable NAPLAN results comes from many parents - and the community at large, including the commercial media - who perceive this testing as an indicator of a child's school's performance. Dodd adds to the debate by noting that this places principals and teachers "under pressure to put NAPLAN results above all else" (2012, para. 5).

Anecdotal evidence suggests that this is certainly the case across many Australian primary schools.

Teachers slam testing

Survey of NAPLAN impact on curriculum and teaching practice(%)

■ Strongly agree ■ Agree ■ Disagree ■ Strongly disagree
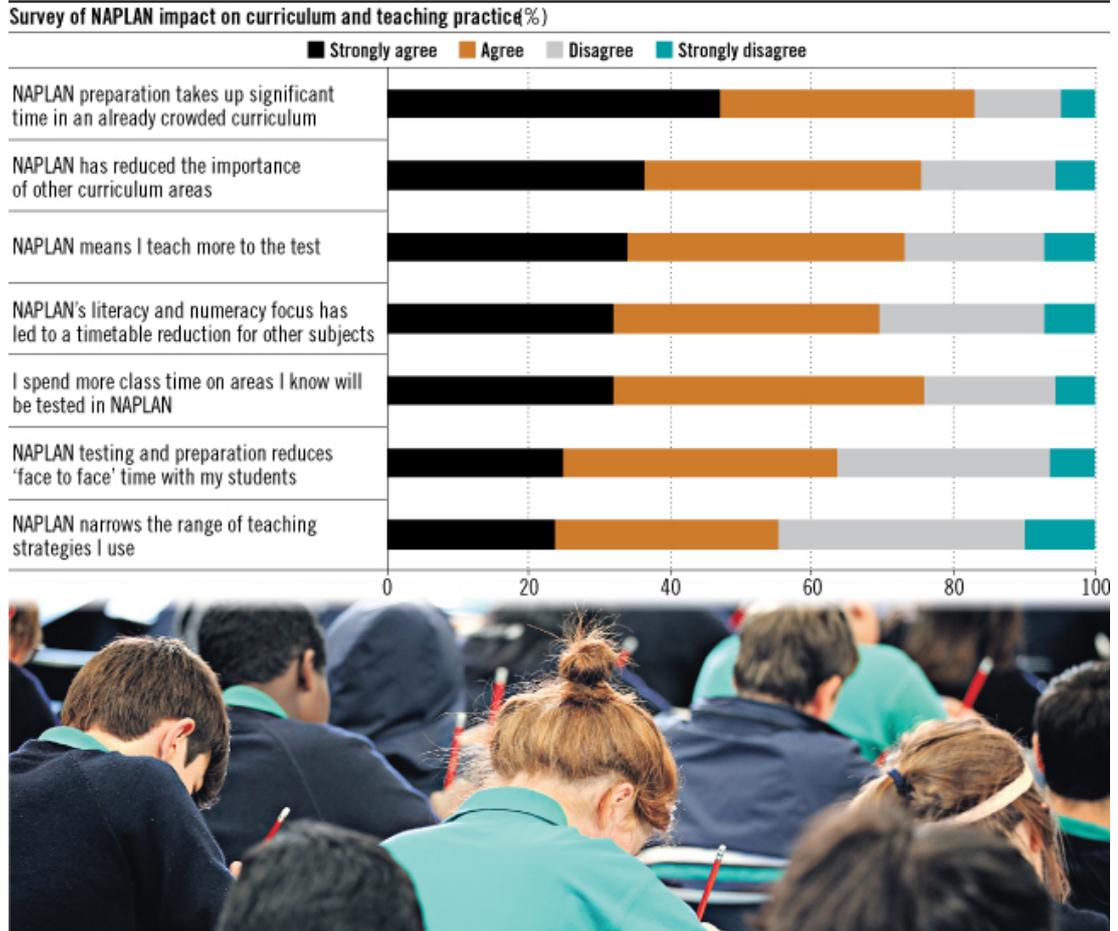
Figure 2.4. Teachers slam testing. Survey of NAPLAN impact on curriculum and teaching practice (%). From "NAPLAN Dominates Teaching", The Financial Review, by J. Mather, November 26, 2012. Copyright 2012 by Fairfax Syndication.

In research relating to test-based accountability, Stecher (2002) lists a number of positive and negative effects of high-stakes testing on students, teachers, administrators and policy makers. Among the negative effects are three which are relevant to my study: "encourages teachers to focus more on specific test content than on curriculum standards"; "causes administrators to reallocate resources to tested subjects at the expense of other subjects"; and "leads teachers to engage in inappropriate test preparation" (2002, p. 86). That is, teaching specially addresses the subject matter and skills to be tested. While there are some positive impacts that could be identified across the four domains, the majority of them relate to the subject

matter and skills being tested - such as "provides students with better information about their knowledge and skills" and "helps teachers identify content not mastered by student and redirect instruction" (2002, p. 86).

Stecher makes an important point that positive and negative impacts cannot be weighed-up against each other to determine an overall net impact as many of the impacts are measured using different units. For example, instructional time impacts are measured in hours whereas resulting curriculum changes would need to be measured in other units. Stecher concludes, however, that many of the changes that are precipitated by the results of high-stakes testing appear to "diminish students' exposure to curriculum" (2002, p. 100). For instance, and relating to my study, some non-tested subjects can be the subject of decreased teaching-time allocation. By way of example, Stecher cites a 2001 study in which the time allocated to teaching science across the participating schools was reduced by approximately 58% in comparison with reading, writing and mathematics teaching times, which were increased by 55, 70 and 60% respectively (2002, p. 92). Sahlberg (2010, p. 52) notes the research findings of Au (2007), Berry and Sahlberg (2006), Nichols and Berliner (2007), Loeb et al. (2008) and Shirley (2008) which show that high-stakes testing regimes are, among other things, narrowing curricula. Through their analysis of the responses of 8,314 Australian primary and secondary teachers to their survey on the impact of NAPLAN testing on curriculum and pedagogy, Polesel, Rice, and Dulfer (2014) also note the narrowing of curricula as a result of the testing, as well as reduced time spent teaching subjects not tested by NAPLAN, and other negative impacts.

In Thompson's study (2014), the aim was "to explore the impact of NAPLAN from the perspective of teachers" (p. 65) and investigate a number of possible areas of impact of NAPLAN. A total of 941 Australian teachers, 715 (76%) of whom were primary school teachers, participated. In the area relating to curriculum and pedagogy, "31% of the responses spoke of the impact of NAPLAN on curriculum and pedagogical choice in schools. Primarily, these responses focused on pressure to teach to the test and a narrowed curriculum focus" (p. 73) - negative impacts of this high-stakes testing. These findings are again echoed by Burger and Krueger (2003), Klenowski and Wyatt-Smith (2012) and Thompson and Harbaugh (2013).

In a report commissioned by the Australian Primary Principals Association (APPA) and conducted and published in 2013 entitled 'Primary Principals: Perspectives on NAPLAN Testing & Assessment', it was found that, among a number of both positive and negative impacts attributable to NAPLAN, "some schools are experiencing a skewing of the curriculum/pedagogy, ... by devoting class time to NAPLAN preparation" (p. 10). In this report, one principal stated:

> … Teachers, despite knowing that they should not be teaching to the tests, do alter the regular curriculum delivery to 'train' the students in the peculiarities of the tests. Much time is given over even in the previous year to NAPLAN, to enable the students to have the best opportunity to demonstrate their skills and knowledge. (p. 15)

Two thirds of the 1,353 principals surveyed said that preparation time for NAPLAN was allotted in their schools with most allocating up to 3 hours per week with 10% devoting time for preparation in excess of one school term - usually around 10 weeks. Some of the principals' responses imply, however, that this preparation extends well into the year prior to the testing. This same report found that around 57% of principals said that less time is spent by their teachers each week teaching subjects [such as the S&T KLA] which are not tested by NAPLAN, with 17% professing to spend significantly less time on teaching these subjects.

Thompson and Harbaugh (2013) reported preliminary survey findings from research which they conducted with Western Australian and South Australian teachers. Responses to questionnaire items related to reduced class time spent on curriculum areas not tested by NAPLAN, indicated that, in both states, teachers agreed that the curriculum was narrowed and they spent less time on these curriculum areas. Thompson and Harbaugh's (2013) findings support the NAPLAN impacts stated in Figure 2.4: teachers felt that they were spending less time on curriculum areas not tested by NAPLAN - such as science - because they had chosen to teach to the tests

or had been instructed to do so. This phenomenon - in which what is to be taught is determined by what becomes valued because it is being assessed - is referred to as "washback" (Cheng & Curtis, 2004, p. 3) and can result in the narrowing of the curriculum as teachers teach their pupils in preparation for an upcoming test. The results of some studies relating to the effects of washback are found in Cheng (1999), Luxia (2005) and Wall and Anderson (1992). As briefly noted above, Klenowski and Wyatt-Smith (2012) have similarly found that some of the unintended consequences of the NAPLAN testing are the narrowing of the primary school curriculum as teachers focus on what is to be tested and that curriculum areas which are not to be tested become neglected. Reid (2010) echoes these findings. Luke (2010) also comments on reported findings that 'teaching to the test' has resulted in the decline of challenging and relevant knowledge in a large number of schools. It is further stated that the more some schools seek to increase their students' success in standardised assessments, the greater is the disregard for parts of the curriculum which are not formally assessed. This situation can also apply to washback for NAPLAN testing. The washback related to the preparation for NAPLAN and the repercussions if results do not meet community and school expectations could then have a negative effect on the teaching of science to Stage 3 students and, therefore, on the status of science in the researched schools.

It is of interest in relation to this research to note that every three years since 2003, a National Assessment Program - Science Literacy (NAP-SL) sample assessment has been administered to small samples of Year 6 students at randomly selected schools throughout Australia. Such tests are intended to provide a snapshot of students' performance in this area. Civics and Citizenship Literacy and Information and Communication Technology Literacy are similarly tested in the intervening years. In its fourth report on Year 6 science literacy and based on the triennial NAP-SL cycle results since 2003, ACARA noted that there had not been any changes in "national performance levels, in terms of both average student achievement and the proportion of students performing at or above the defined Proficient Standard in scientific literacy" (2012, p. xi). The report showed that the Proficient Standard level was met or exceeded by only 51.4% of Year 6 student participants. Whereas, overall, 80% of students indicated in the survey accompanying the test that they had a positive inclination towards learning science at school, achievements based on regional

differences were similar to those of the annual NAPLAN testing cycles in that students in the metropolitan areas achieved the highest mean scores. This finding is consistent with the reported data for the 2012 PISA testing cycle (Thomson, de Bortoli & Buckley, 2013). ACARA (2012) noted that these scores are statistically significantly different from those of students in provincial and more remote areas. Therefore, while we could conceivably have a student cohort that is ostensibly interested in science, it is not achieving highly in the areas tested by NAP-SL and this is particularly conspicuous in provincial areas. Whether or not, though, the NAP-SL testing has had any impact - positive, negative or a washback effect - on the areas discussed above, such as a narrowing of the curriculum and teachers spending more time teaching in preparation for the annual NAPLAN tests, remains to be seen over time. No new data are currently available.

In late 2016, the Australian national results for TIMSS and PISA were released. A largely negative journalistic frenzy ensued across all forms of public news media in NSW as a result of the findings and their implication for students - both during and after their school years in all Australian states. However, to balance the negative publicity and commentaries, Riddle and Lingard (2016) stated that "the challenge for policymakers, schools and teachers is how to respond to increasing pressure to lift test results on PISA, TIMSS and NAPLAN, while also addressing…" (para. 30) the other factors which also impact on student learning in order to give students "access to a meaningful education" (para. 30).

2.6 Time Spent Teaching Science in Primary Schools

Riggs and Enochs (1990) found in studies conducted overseas that primary school teachers do not place a high priority on teaching the science curriculum and many exhibit a reluctance to teach science. Hill, Hayworth, and Rowe (1998) state that "science is one of the areas of the curriculum where primary schools perceive the greatest decrease in time allocation" (as cited by Koul, 2010, p. 289). Fitzgerald et al. (2013) have further revealed that this situation is not exclusive to the Australian education environment. From the literature, they identified some of the factors which influence the time spent in teaching primary science as "limited [science] content

knowledge and low levels of confidence in teaching the subject matter, particularly in the area of physical sciences" (2013, p. 2).

In the USA, it was found that the new emphasis - and related pressures - on mathematics and reading scores after the introduction of the testing regime implemented as a result of the No Child Left Behind (NCLB) Act of 2001 resulted in a decrease in the time spent on the teaching of subjects other than mathematics - including science. This is another example of a high-stakes testing regime. Nationally, 32% less time was spent on teaching elementary science and, in California, even less time was being spent at this level (CCST, 2010). This report further notes that, in the 2001/02 school year, elementary teachers spent, on average, 226 minutes per week teaching science while, in 2006/07, this dropped to an average of 126 minutes per week. In one Californian district, 16% of teachers reported spending no time teaching science. These teaching times are in stark contrast to the recommended 300 minutes per week for the Grade 4 - 6 level reported by Loucks-Horsley in 1990 (cited by Gess-Newsome, 1999). Explanations for this lack of time spent teaching science according to Gess-Newsome include, among other things, "insufficient science content knowledge; limited resources, ... an overly crowded elementary curriculum; and low levels of science self-efficacy"(Gess-Newsome, 1999, para. 2) in addition to diminished student interest in the subject. Tilgner (1990) found that "most elementary teachers, if required to select a speciality area, would gravitate toward the language arts" (cited by Gess-Newsome, 1999, para.14). Gess-Newsome points out that these factors - in addition to "pervasive accountability measures for reading and mathematics [but not science]" (1999, para. 12) - contribute to this relatively low amount of time spent teaching science. As Carlone at al. (2010) state is a study conducted in the USA, "science is an ever-increasingly marginalized part of the elementary curriculum" (p. 963)

The state of California is a leader in science and technology in the USA; and it has been acknowledged on a national level, that science is deemed to be important in primary schools. However, Dorph et al. reported in 2007 that, compared to all other States, Fourth Year students in California ranked only second last in the 2005 National Assessment of Education Progress test. In the 2007 California standards testing round, just 37% of that state's students were deemed to be proficient in

science. In the rationale for his 2016 course entitled 'A Process Approach to Science' designed for pre-service elementary teachers at California State University, Coburn states that:

> … many elementary teachers don't teach much science. The fraction of class time devoted to science is less than it should be - even in the minds of many teachers themselves. Part of the problem lies in the fact that teachers don't like science very much, don't feel confident in their science knowledge, and don't know how to teach science effectively. (2016, para. 1)

This statement reflects the findings of many researchers. In their 2007 study of the science education of primary students in California's Bay Area, only 46% of students were deemed to be proficient in the 2007 testing round. Several reasons were put forward by the authors to account for the students' poor achievements. Among these are the following familiar and recurrent reasons: "the current status of science education is weak: science education is of inconsistent and often poor quality; Bay Area schools spend too little time teaching the subject; and many teachers are unprepared [because of limited skills] to teach science" (Dorph et al., 2007, p. 2). This unenviable situation, compounded by a lack of time and science teaching skills, is consistent with the situation in which teachers spent extra, unpaid time teaching science to their students as noted above (Amrein & Berliner, 2002).

The graph in Figure 2.5 shows the proportions of time spent teaching science to K-5 students in Californian elementary schools (Centre for the Future of Teaching and Learning at WestEd, 2011a). The report revealed that the amount of time spent teaching science did increase from Kindergarten to Fifth Grade and suggested that this was possibly because science is tested in Fifth Grade. Notwithstanding this, just under 60% - that is, the majority - of the students were still only receiving less than 120 minutes of science each week and around 10% spent less than 30 minutes on science each week. This report notes that "despite public will and the opinion of educators and experts, science is not a priority in Californian public elementary

schools ... the quality of science learning is too low" (Centre for the Future of
Teaching and Learning at WestEd, 2011b, p. 4).

Exhibit 2-3
Time Spent on Science Instruction in Elementary School
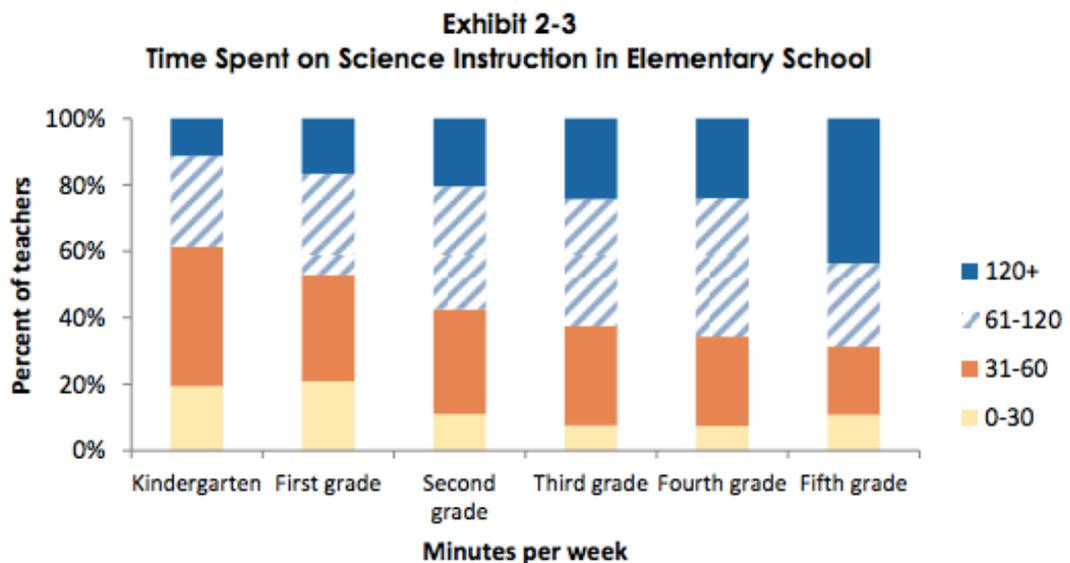
*Figure 2.5. Time spent on science instruction in [Californian] Elementary School. Adapted from "High Hopes -
Few Opportunities". The Centre for the Future of Teaching and Learning at WestEd, 2011a, Exhibit 2-3, p. 14.
Copyright 2011. The Regents of the University of California.*

Across the Atlantic, in his 1988 article on the National Curriculum of England and
Wales, Gillard notes that the official line regarding how much time was to be spent
on each subject being taught in English and Welsh schools was not overly
prescriptive, but that primary teachers should devote the majority of their teaching
time to English, mathematics, and science. In their 2005 report, Murphy and Beggs
reported that 9% of primary teachers in the United Kingdom were spending between
30 and 60 minutes per week teaching science: the majority spent between 60 and 120
minutes per week; and 27% registered that they taught science for more than 120
minutes each week. When primary school teachers were asked, for the Murphy and
Beggs report, their opinion about the importance placed on specific subjects at their
school, their response was that English (79%) and mathematics (74%) rated most
highly. The perception of 13% of the respondents, however, was that no other subject
rated more importantly than science.

In the HMIe report of 2005 on 'Improving Achievement in Science in Primary and
Secondary Schools' in Scotland, some longstanding and significant weaknesses
relating to the underachievement of students in upper-primary levels were noted. One

of these was that "science lacked a clear place in the curriculum, and [lessons were] too infrequent to enable pupils to make connections with earlier work" (2005, p. 13). Weaknesses were thought to arise in some primary schools "when staff were unclear about the science, including key knowledge and skills" (2005, p. 34) which they needed to teach their students.

Anderson summarised the general scenario in New Zealand primary schools. As derived from international studies on trends, the amount of science teaching in the middle primary school years, was as little as 6% of the total teaching time. Might the impact of this proportion of teaching time spent on science be reflected in levels of student achievement in science? Year 5 students' achievement in New Zealand has been found to be "significantly lower than in other OECD countries" (Anderson, 2015, p. 396).

Are the international findings discussed above indicative of other education jurisdictions around the world including Australia? Angus et al. (2004) noted that, in Australian primary schools, over half of the allocated teaching time is generally dedicated to teaching and learning - that is, giving greatest emphasis - in the Key Learning Areas (KLAs) of mathematics and English. This situation is in line with NSW Government policy. In guidelines published in its NSW Primary Curriculum Foundation Statements (2006), the Board of Studies NSW (BOS NSW) recommended that the teaching of English and mathematics take up 45 - 55% of total teaching time. This is because literacy and numeracy, which are taught more intensely through English and mathematics, are considered to be the building blocks of learning. As noted by the NSW DEC, "while they [i.e., literacy and numeracy] are not and should not be the sole focus of school education, they are the building blocks of learning" (NSW DEC, 2011, para. 7). In comparison, the proportion of time recommended for teaching science and technology is 6 - 10%. (These percentage times translate to approximately 1.5 to 2.5 hours in the average teaching week.)

In a 2001 national review conducted by Hackling et al., it was found that no science was being taught in some primary schools. Hackling et al. (2001, p. 158) also noted that teachers reported only 59 minutes of science teaching per week and that there was much variation between teachers and between schools. From data collected in

their 2003 survey from 160 primary schools from all Australian states and across all education sectors, Angus, Olney and Ainley (2004) snd Angus, Olney, Ainley, Caldwell et al. (2007) found that only 51 minutes ($\sigma = 45$) (2007, p. 17)) - or 3% of total teaching time - for Years 5 and 6 students out of a possible 1,505 minutes in the nominated week were allocated to the teaching of science. They further contend that the amount of time allocated to the teaching of science has not, overall, been increased since the 1920s. They refer to what they deem to be "one of the most robust findings in research on teaching … that students' learning of concepts and skills is tied directly to the amount of time allocated: the more time the better the performance" (2007, p. 15) and further elaborate that "the amount of time allocated for a particular learning area is indicative of its importance in the totality of the curriculum" (2007, p. 15).

As a further example of what seems to typify the amount of time spent teaching science in Australian schools, Masters (2009) notes the findings of Martin et al. (2008) from their analysis of the 2007 TIMSS testing round. They report that, across Australia, teachers of Year 4 students are expected to spend a little over two hours each week teaching science - compared with 4.5 hours per week teaching mathematics. However, the reported average time spent teaching science around Australia is closer to 1.2 hours per week which approximates to 5% of total teaching time available. This average places Australia within a group of countries which
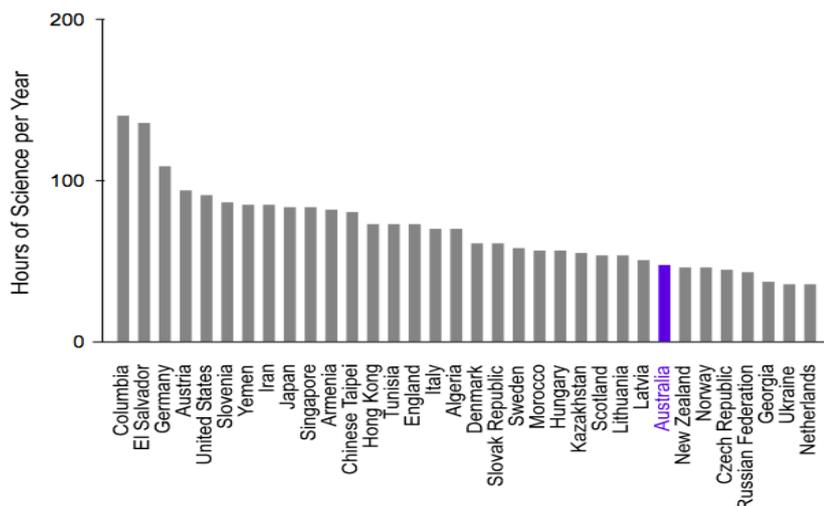
Figure 2.6. The number of hours spent teaching science in a large number of countries including Australia. From A Shared Challenge: Improving Literacy, Numeracy and Science Learning in Queensland Primary Schools, p. 93. G. Masters, (2009). Copyright 2009 The Queensland Government (Queensland Dept. of Education).

spend the lowest amount of time teaching science at this level as illustrated in Figure 2.6. If the recommended time was used teaching science, then Australia would be placed approximately equal with Austria in the graph teaching science for approximately 90 hours per year compared to less than 50 hours per year.

Within the NSW KLA of Science and Technology, it is suggested that some topics might be taught for longer periods than others. In a study of pre-service and post-initial education teachers, Skamp found that topics such as Living Things, The Earth and its Surroundings, Natural Phenomena and The Investigating Process were all delivered to students "a fair amount" or " a lot" (1991, p. 298) by over 50% of this group. He suggests that the findings might be indicative of the situation if applied to practising teachers and consistent with findings previously referred to in this literature review; that is, that the biological sciences seem to be the preferred option of many primary teachers who then spend more time teaching biology-related topics.

The Queensland State Government planned to prioritise science in its government-run primary schools. In 2011, the Queensland Studies Authority (QSA) made updated recommendations on the amount of time to be spent teaching science in its primary schools (QSA, 2011). For the equivalent level of the NSW Stage 3 years, the recommended time was to be approximately one-and-a-half hours per week. The results of a study conducted by Albion and Spence (2013) within a provincial Queensland school system involving 216 primary school teachers demonstrated that more than 50% of the teachers spent less than one hour per week teaching science. A Queensland government report which recognised the importance of Science Technology Engineering and Mathematics (STEM) education to innovation and as being ultimately beneficial for the prosperity of the country, proposed a 10-year plan "to enhance STEM education at all levels" (Albion & Spence, 2013, p. 501) in that state. More recent data on the situation in Queensland primary science education is not currently available.

More recently, a 2014 study by the Australian Science Teachers Association with The Office of the Chief Scientist (ASTA & OCS) found that "time available to teach science each week is minimal at respondent [Australian primary] schools" (2014, p. 7). Given the prevalence of minimal time being spent teaching science in primary

schools is widespread, the time spent teaching the S&T KLA was investigated in my study as one of the factors associated with the low status of science in the schools studied.

2.7 Teacher Self-efficacy

"Teachers' confidence in their ability to perform the actions that lead to student learning is one of the few individual teacher characteristics that reliably predicts teacher practice and student outcomes" (Ross, Cousins, & Gadalla, 1996, p. 3). In this statement, the authors are referring to a characteristic that they call 'teacher efficacy' which they define as "an individual teacher's expectation that he or she will be able to bring about student learning" (Ross et al., 1996, p. 3). Therefore, as teacher practice is influenced by teacher self-efficacy, it is necessary to review the literature on this characteristic as it will have a bearing on the practice of the teachers in my study. Schibeci and Hickey (1996), in defining teacher self-efficacy, refer to a 1989 report by Smith and Neale which summarises the then long-held views about the problem of science content knowledge for primary teachers in relation to their teaching. In part, the quotation reads: "science teaching in the primary grades has been a persistent problem ... teachers in those grades are under pressure to focus on reading and mathematics ... ; in addition they feel untrained and uncomfortable with science" (p. 151). Feeling uncomfortable with science calls into question teachers' self-efficacy and, as Garbett notes, "personal subject content knowledge impacts on the personal confidence of prospective teachers" (2003, p. 469). In referring to teacher efficacy - which Ross et al. (1996) consider to be a subset of teacher self-efficacy - they comment that all research conducted prior to their study approached this characteristic as though it was unchanging for a particular teacher across all teaching scenarios. However, they argue that teacher efficacy can change as the teacher changes from teaching in one subject area to another, say from English to science, or even within a subject such as science because some teachers feel more effective teaching biological topics compared to teaching, for example, physics or chemistry topics (Mansfield & Woods-McConney, 2012).

Bandura is accredited with laying the theoretical framework for the concept of 'self-efficacy' and Bandura is credited by Hopkins with laying the foundations for "later efficacy research that continues to today" (2007, p. 20). Bandura defines self-efficacy as "beliefs in one's capabilities to organise and execute the courses of action required to produce given attainments" (1997, p. 3) and he further postulated that a person's beliefs are better predictors of their future behaviours than are the actual outcomes of whatever course of action that they decide to pursue. Following Bandura's assertions, Henson reasons that, because the course(s) of action that we take are intended to successfully produce a desired or intended result, "self-efficacy beliefs influence our choices, our effort, our persistence when facing adversity and our emotions" (2001, p. 4). Henson, Kogan and Vacha-Haase note that "teacher efficacy has proven to be an important variable in teacher effectiveness" (2001, p. 404) and "consistently related to positive teaching behaviours and student outcomes" (2001, p. 404). Palmer (2011) contends that "teacher self-efficacy is a particularly critical issue at the elementary school level" (p. 578) and that there is "a continuing need to develop the science teaching self-efficacy of practicing elementary teachers" (p. 578). Therefore, it was considered important to examine teachers' self-efficacy in my study because it relates to these positive teaching behaviours. In turn, these behaviours might impact how teachers view themselves as perhaps having an important role in their students' learning journey towards becoming scientifically literate citizens, as well as their obligation towards the students achieving this goal. Teacher self-efficacy is shown in Figure 2.2 as one of the intrinsic factors which can influence the teaching of science.

Leading up to their study with 331 practicing primary teachers in provincial and urban areas in the USA, Riggs and Enochs were informed by Bandura's (1977) well-regarded social cognitive theory of teachers' efficacy. This theory suggests that behaviour is closely linked to outcome expectancy beliefs and self-efficacy beliefs. "Behaviour is enacted when people not only expect certain behaviours to produce desirable outcomes (outcome expectancy), but they also believe in their own ability to perform the behaviours (self-efficacy)" (Riggs & Enochs, 1990, p. 626). Their study found that the majority of these teachers often scored poorly on self-efficacy scales that measure and compare levels at which teachers feel capable of teaching science effectively. This study was conducted using the Science Teaching Efficacy

Belief Measurement A (the STEBI-A) which Riggs and Enochs had developed specifically to gauge participants' science teaching self-efficacy. That is, their self-efficacy was being measured in a specific context. Henson et al. (2001) assert that using the STEBI-A is the most appropriate method of measuring self-efficacy for in-service primary teachers. The STEBI was based on Gibson and Dembo's (1984) development of the Teacher Efficacy Scale (TES) and, thereafter, the STEBI-A became the predominant instrument for measuring teacher self-efficacy (Henson et al., 2001). The STEBI-A was important to my study because it is the most appropriate instrument to measure the self-efficacy of the participants in the research.

In her study on teaching efficacy to student teachers at her Albanian university, Bilali calls into play the definition of teacher efficacy documented by Tschannen-Moran and Woolfolk Hoy (2001) as being "a judgment of his or her capabilities to bring about desired outcomes of students' engagement and learning, even among those students who may be difficult or unmotivated" (2013, p. 179). She notes that a number of studies which have had different foci on aspects relating to teacher efficacy - including Ashton and Webb (1986), Esterly (2003), Raudenbush, Rowan, and Cheong (1992) and Tschannen-Moran and Woolfolk Hoy (1998) - have demonstrated that teachers' efficacy positively correlates with their students' degree of success and academic performance as well as to the tone of the classroom environment. Denham and Michael (1981) reported that students' achievement had a positive correlation with their teacher's positive attitude towards their self-efficacy as a teacher (Barnes, 2000). This stance is corroborated by Bandura (1993) who notes, too, that a teachers' self-efficacy, in part, determines the atmosphere in that teacher's classroom. Woolfolk Hoy (1990) reports that teachers with a strongly developed efficacy perception "support development of students' intrinsic interests and academic self-directedness" (Bandura, 1990, p. 140) and Ashton and Webb (1986) document the aggregate effect of teachers' self-efficacy on student academic achievement. Overall, the literature suggests that high self-efficacy in the teacher predicts high academic achievement in the student(s).

Mansfield and Woods-McConney report on the possible correlation between self-efficacy and teachers' science content knowledge. In their introduction to a study with 24 primary teachers divided into focus groups, they note that "some studies

have found that teachers with high efficacy for science teaching have a strong background in science content" (2012, p. 38) and that, "while efficacy for teaching primary science … [was, at that time,] still not completely understood" (p.38), some studies have shown that "increasing teachers' science content knowledge has a positive impact on efficacy" (2012, p. 38).

Although the notion of 'confidence' involves a complex combination of a number of factors, Blackmore (2013) notes that both 'self-confidence' and 'self-efficacy' play major roles in contributing towards a teacher's confidence. In relation to teaching, she defines self-efficacy as "a measure of individual perception of ability to impact positively on children's learning" (2013, p. 2) in the classroom. It is noted by Palmer (2006) that self-efficacy and self-confidence are "very similar" (p. 337) citing a number of examples from the research literature in which the authors use the terms interchangeably. The distinction between these two terms, therefore, is not made in my research.

Morgan (2012) stated that "where there are low levels of self-efficacy beliefs about the teaching of science, there are low levels of time dedicated to science teaching in primary schools" (p. 76). She additionally states that research which had preceded her study - which was based on a teacher-researcher working on, amongst other outcomes, teachers' confidence to teach science - had shown that there was value in investigating and enhancing primary science teachers' self-efficacy beliefs. Further, she found that a focus on "how to teach science, and ways to teach the specific subject content" (p. 77) was more successful than just focusing on the science content. Morgan considers that various strategies could be considered in research which should contribute towards helping primary "teachers feel better about themselves … as teachers of science, so that more science teaching time occurs, and better science learning outcomes are achieved by students" (2012, p. 73).

2.7.1 Effects of Teachers' Self-efficacy in the Classroom

Researchers have identified the positive effects in the classroom environment of teachers having a high level of teacher self-efficacy. In a review of theoretical

research relating to teacher self-efficacy, Henson (2001) highlighted that other researchers have demonstrated a range of positive effects, in addition to those mentioned above. For example, Gibson and Dembo (1984) noted that teachers with high self-efficacy tend to persevere to assist students who grapple with concepts and tend to make fewer criticisms of those particular students; Meijer and Foster (1988) and Podell and Soodak (1993) stated that teachers with high self-efficacy would be more amenable to integrating a student from a lower socio-economic group into the standard classroom than to referring them for special-needs schooling. Allinder (1994) and Guskey (1988), further observed that teachers with higher self-efficacy tend to experiment with different instructional methods and materials and endeavour to improve their teaching methods. For example, Allinder (1994) studied 437 special education teachers in the USA investigating a number of relationships. One of the relationships investigated was between the use of targeted teaching methods and attitudes - which had been shown in earlier research to be important for student achievement - and "personal and teaching efficacy" (p. 88). One of the findings of her research which is relevant to my study and teacher self-efficacy, is that "teachers who had greater belief in their ability to teach also were likely (a) to try different ways of teaching … and (c) to be confident and enthusiastic about teaching" (p. 9). Therefore, all primary teachers should have the highest possible self-efficacy in order to maximise the learning outcomes of their students (Anderson, 2002).

In 2005, Murphy and Beggs undertook a scoping study on behalf of the Wellcome Trust to ascertain the standing of science and issues of work in primary schools in the United Kingdom. At the top of the list of key findings was that "teachers felt that their overall lack of science background knowledge, confidence and training to teach science effectively was the most significant issue currently facing primary science [teaching]" (2005, p. 86). Murphy, Neil, and Beggs (2007) conducted a later study in the UK on primary teacher confidence involving 300 primary teachers and 100 tertiary institutions involved in delivering teacher education courses. They concluded that although there had been some improvement in primary teacher confidence over the 10 years preceding their study, around half of the participating teachers continued to lack confidence and the ability to teach science. Primary teachers in the UK predominately undertake generalist training for their teaching career. In the majority of cases, this involves teachers studying a Post Graduate Certificate in Education

(PGCE) - typically of only one year's duration - to equip themselves in the pedagogical and subject content knowledge that they need to teach across ten curriculum areas.

Gess-Newsome (1999) noted the relatively small amounts of classroom time devoted to science in elementary schools in the USA. She questions why this might be the case and, based on a number of studies of the problem, identified deficient science content knowledge and subsequent low levels of self-efficacy among teachers as key factors. Fulp (2002) states that, with the USA's National Standards introduction of science content to the full cohort of elementary school (i.e., throughout all grades), their teachers must have a good understanding of the science content. Of 655 elementary school teachers who participated in a national survey, only 4% had an undergraduate degree in either science or in science education. Fewer than 30% of this cohort reported that they considered themselves qualified enough to teach science, given their minimal science background. For those teachers with a minimal science background knowledge, it is suggested that this is accompanied by a corresponding low self-efficacy for teaching science.

These international studies support findings in the Australian context. For example, Jane et al. report that Yates and Goodrum (1990) expressed concern over statistics arising from their study of primary teachers in Perth, Western Australia, which revealed that "28% of teachers lacked the motivation to teach science" (cited by Jane et al., 1991, p.188). Jane et al. considered it important to find strategies "to tackle the problems associated with teachers' lack of interest and confidence in teaching science ... in the primary school" (1991, p.188). Tschannen-Moran, Woolfolk Hoy, and Hoy (1998) make a connection between efficacy and motivation: "the development of a strong sense of efficacy [in a teacher] can pay dividends of higher motivation, greater effort, persistence, and resilience across the span of a teaching career" (p. 238). Blackmore has highlighted that many pre-service primary school teachers felt under-confident to teach science, especially the more complex topic areas related to the physical sciences which they found daunting. She claims that " 'confidence' [is] central to effective science teaching" (2013, p. 2) and that it is this lack of confidence which is a major impediment to the effective delivery of science lessons.

Studies conducted internationally suggest that primary teachers must have sound science content knowledge in order to teach science effectively to their students. Martin et al. (2012) have analysed data collected during the 2011 TIMSS survey relating to teacher education for teachers of Fourth and Eighth Grades. They worked from the pre-supposition that an effective science education depends upon, at least in part, a well-prepared teaching workforce. It was found internationally that 80% of Fourth Grade students were taught by teachers with a bachelor's or postgraduate degree; and that 70% of those students' teachers had at least 10 years of teaching experience. Of the teachers of Fourth Grade students, 62% reported feeling very 'well prepared' and 59% felt 'very confident'. It was concluded from the survey data that, at the Fourth Grade level, the students who were taught by the more experienced and confident teachers demonstrated a higher achievement level compared with the other students. Decreasing levels of Fourth Grade teachers' experience and confidence were reflected internationally in the students' corresponding decreasing levels of science achievement.

Palmer's (2011) study of a short intervention-style, professional development programme with 12 experienced Australian elementary teachers investigated the effects of four "sources of information" (p. 578) on practising elementary teachers' self-efficacy. This, it was hoped, would have a flow-on effect in their classroom teaching. He notes that a low level of teachers' self-efficacy "is an important factor constraining the teaching of science at the elementary level" (p. 577). These aforementioned sources of information were described by Bandura (1997) and Palmer lists them as "mastery experiences, vicarious experiences, verbal persuasion and physiological responses" (p. 578). Each of these sources of information was investigated by Palmer (2011) in relation to their effectiveness for improving in-service elementary teachers' science teaching self-efficacy. Palmer refers to a particular form of mastery experience as 'cognitive mastery' which he contends develops as a consequence of teachers perceiving that they have understood science concepts. He narrows it even further to mean pedagogical mastery in the context of his study. He also uses the term 'enactive mastery' which refers to classroom teaching. These types of mastery are sub-skills of the teachers' overall skill set and Palmer notes that the "mastery of one specialized sub-skill can result in increased self-efficacy for science teaching as a whole. This implies that, by focusing on a

useful set of sub-skills it can be possible to increase teachers' self-efficacy to the point where they are willing to do more science teaching in general" (2011, p. 598). Palmer notes that the main finding of the study "was that within the context of a professional development program, the provision of cognitive and enactive mastery … [and specific types of modeling and feedback] … can result in substantial increases in the science teaching self-efficacy of experienced elementary teachers" and that the flow-on effect of the intervention lasted for a minimum of two years (2011, p. 596).

In their more-recent research conducted with 11 pre-service primary teachers, Danielsson and Warwick (2014) found that, although all of the students would have studied some science at each level through their English school education via the UK's National Curriculum, only three had fulfilled their pre-university A-level requirements and this was in the field of biology. Of these, two had pursued science in their Bachelor degrees prior to commencing the one-year Postgraduate Certificate of Education (PGCE) which is designed to address all subjects taught in the UK's primary curriculum and delivered in universities. It is aimed at producing generalist primary school teachers. Danielsson and Warwick (2014) question the impact and tensions that a pre-service teacher's secondary schooling experiences have on his/her journey while transitioning from a student identity to his/her identity as a teacher - which itself can take many forms from the traditional didactic style to inquiry-based learning. They state that designing primary science education courses that will produce teachers who can effectively deliver a curriculum that aims to produce scientifically literate citizens is somewhat dependent upon the pre-service teacher's prior content knowledge and his/her level of self-confidence.

In the Australian context, Skamp draws attention to research carried out in New South Wales primary schools by Symington and Rosier (1990) which shows that teachers who had recently graduated had lower confidence in teaching the then recently-introduced 'Process and Design' and 'Products and Services' physical science topic areas than theoretically-based topics; and these areas were taught "much less regularly" (Skamp, 1991, p. 293). Skamp further cites Yates and Goodrum (1990) as supporting this finding amongst practising teachers. In this same study, Skamp also identified a close correlation between confidence in content

knowledge and confidence to teach science for teachers of Years 4 to 6. This latter correlation between confidence-types echoes similar findings noted earlier in this chapter. In their 2007 report, Angus et al. communicated that approximately only 18% of primary teachers in Australia felt well equipped for teaching science at that level.

Australia's Southern Cross University (2014), in conjunction with six partner universities, conducted a project entitled 'It's part of my life: Engaging university and community to enhance science and mathematics'. The project started in September 2013 and concluded in late 2016. Among a number of objectives, the project aimed to develop intervention modules to be used across a number of regional universities for the training of pre-service teachers (PST) in an attempt to strengthen and improve their science and mathematics teaching competence and confidence; and engage these PSTs with the science and mathematics problem-solving which underpins everyday life in rural communities in order for it to be incorporated into their teaching practice. At the end of the pilot project in 2016, changes were assessed in the confidence of the PSTs in applying the scientific and mathematical thinking learned through the interventions to their lesson-planning, lesson delivery and subsequent reflective assessment on their taught lessons. An early study on the project (Yeigh, Woolcott, Donnelly, Whannell, & Snow, 2016) reports the effectiveness of the reflective process at the end of a PST's lesson delivery. It investigated PSTs' use and understanding of aspects of their emotional intelligence and "their emotional experiences, defined here as *affect* … in relation to [their] pedagogy" (p. 108). Yeigh et al. highlight that the most important information to come out of this piece of research and which is relevant to my study is that "the analysis of affect, appears to contribute to teacher training in measurable and effective ways … [and] has the capacity to enhance pedagogical confidence in a very practical way" (p. 119). More research is yet to emerge on the project. This is yet another strategy to address the problem of primary teachers' lack of science content knowledge and self-efficacy for teaching science before they begin their teaching careers.

2.8   Primary Teachers Need Sound Science Content Knowledge

"Teaching is essentially a learned profession. A teacher is a member of a scholarly community" (Shulman, 1987, p. 9) and members of such a community should, necessarily, have a knowledge base on which to draw. However, teaching is a complex endeavour for which the teacher relies on many different types of knowledge and skills. In his 1987 paper, Shulman identifies seven categories of teacher knowledge which form the teacher's "knowledge base" (1987, p. 8) including "general pedagogical content", "curriculum knowledge", "pedagogical content knowledge" and "knowledge of learners and their characteristics"(p. 8). Although he suggests no hierarchy for these different types of knowledge, he lists content knowledge first: teachers must first understand the content of the subject area that they aim to teach. "Teacher content knowledge is crucially important to the improvement of teaching and learning" (Ball, Thames, & Phelps, 2008, p. 389). These authors define teacher content knowledge as including the "knowledge of the subject and its organizing structures" (p. 390).

The USA's National Research Council's (NRC) 2010 publication on 'Preparing Teachers' in that country's context, cites Davis, Petish and Smithey's (2006) findings that "teachers with greater content knowledge may ask more demanding questions" (NRC, 2010, p. 141) and have a greater tendency to "engage in sophisticated teaching practices" (NRC, 2010, p. 141) while teachers who have "less secure" (NRC, 2010, p. 141) science content knowledge show much less of a tendency to engage in teaching which challenges students' initial ideas or misconceptions. It is noted that, after reviewing 112 studies on expectations for new science teachers, these researchers identified five main areas of teacher competency which influenced effectiveness in the classroom. The first of these competencies is science content and discipline. In this same 2010 publication, the NRC also cites findings from case studies reported in its own 'Taking Science to School' 2007 report which suggest that "teachers with less content knowledge are less confident and effective at particular skills" (2010, p. 142) such as answering students' questions accurately and "sustaining in-depth discussions" (2010, p. 142) with students.

Gess-Newsome contends that "regardless of explanation, limited science exposure in the elementary grades results in low levels of science achievement" (Gess-Newsome, 1999, para. 2). She identifies four teacher 'attributes' which she considers to be essential for the quality instruction of science: "content knowledge and attitudes" - listed first - followed by "pedagogical knowledge and skill; knowledge of students; and, knowledge of curriculum" (Gess-Newsome, 1999, para. 5). She discusses the basic model for the training of elementary teachers which produces generalist teachers. In such cases, pre-service teachers typically study content and method courses over a number of curriculum areas - reading, writing, science and mathematics. While Gess-Newsome concedes that there are some advantages to using this model, she notes that one major disadvantage is that the teachers ultimately have limited content knowledge in their subject areas.

India's Homi Bhabha Centre for Science Education (HBCSE) (2011) report acknowledges that "a large body of research in science and mathematics education shows the importance of specialized knowledge required for teaching curricular subjects even at the elementary level" (2011, p. 4). To add credence to these international findings, Murphy and Beggs assert that "children should have the knowledge and skills to attain the required targets laid down in national curricula" (2005, p. 86). "There is general agreement that primary teachers [in Australia] have a rather limited understanding of science" (Carr & Symington, 1991, p. 39).

 "Subject matter knowledge ... is a key component of effective teaching ... [and] ... having a deep understanding of the content ... [is] imperative" (Smithey, 2008, p. 10). It is stated in the NSW Government Report 'Great Teaching, Inspired Learning' that "great teachers know the content of the subjects they teach" (March, 2013, p. 6) and that "every student deserves teachers who ... [among other attributes] have a passion for and deep understanding of their teaching content" (March, 2013, p. 6). A teacher who does not have the necessary depth of content knowledge underlying what he/she needs to teach will find it challenging to impart knowledge of that subject matter to his or her students and struggle to maximise students' learning. Garbett acknowledges this and stresses that the lesson-planning abilities of teachers with minimal subject content knowledge can limit lesson content by confining the scope of their lessons. In support of this conjecture, Garbett notes - in addition to

citing a further study in agreement with her assertions - that "the depth of subject content knowledge can affect the ability of the teacher to ask meaningful and appropriate questions" (2003, p. 468).

A further issue which stems from teachers' limited science content knowledge is the seemingly inevitable development and teaching of misconceptions of the science content. Appleton notes that it is "hardly surprising" (2003, p. 4) that primary teachers who are not specialists in science and who have limited science content knowledge could develop misconceptions in the same way that other studies have shown that even scientists who have doctorates in a particular discipline - for example, such as physics - can develop misconceptions around topics within other science disciplines such as biology. Cochran and Jones have found that teachers tend to hold the same misconceptions as their primary students, albeit fewer, and that these misconceptions are formulated using different and more sophisticated terminology. They speculate, based on a number of studies carried out in Australia and overseas, that such misconceptions might be "construed as knowledge without understanding" (1998, p. 709).

Nilsson and van Driel (2011) also refer to studies undertaken in Australia and New Zealand which show that pre-service primary teachers have a tendency to develop science misconceptions which are in keeping with the misconceptions held by the children whom they teach. Unsurprisingly, such misconceptions - or even gaps in content knowledge - can be the result of a lack of depth of science content knowledge. This could particularly be the case for primary teachers who largely rely on their own secondary school and/or limited tertiary science background and/or information gained from other sources in which there may have been gaps and/or misconceptions. With respect to this, Howitt (2007) commented that, in a large number of cases, those pre-service teachers who did rely upon their secondary school science experiences to inform their teaching recalled them as having been designed to meet the needs of the more intellectually able students and as having been quite negative. It has been found that *"misconceptions about sciences occur commonly"* (Subayani, 2016, p. 60) among teachers. Subayani (2016) acknowledges that studies have shown that teachers often develop misconceptions as a result of their own

science background and that these can be passed on to students if teachers' misconceptions are not addressed - particularly during pre-service teacher education.

It is, therefore, important that teachers of primary school students have sound science content knowledge. Part of the solution to assist teachers to develop a sound content knowledge base is their pre-service teacher training: be this a specialist undergraduate degree or a dedicated teacher education degree which includes substantial units of science. The literature relating to pre-service teacher training is reviewed in the following section.

2.8.1 Training Pre-service Primary Teachers

Angus et al. (2004, p. 71) emphasised that "a school's capacity to provide quality teaching depends not only on conventional resources such as staff numbers and facilities, but also on less tangible factors such as expert knowledge". As noted earlier, the majority of New South Wales primary school teachers have a generalist background but these teachers are required to teach across a number of KLAs which include 'Science and Technology'. However, many feel inadequate to teach the science outcomes. As Howitt has stated, "most pre-service elementary teachers see themselves as non-science people trying to become science students at university ... [and] they tend to have poor attitudes and beliefs about science and their capacity to be effective teachers of science" (2007, p. 44). In 1977, Peters observed "that if anything is to be regarded as a specific preparation for teaching, priority must be given to a thorough grounding in something to teach" (1977, p. 151). As Rice comments on the value of the importance of coursework on teacher effectiveness and education outcomes: "teacher coursework in both subject area taught and pedagogy contributes to positive education outcomes" (2003, para. 1). Morgan (2012) reports on the 2007 TIMSS data about Australian teachers' preparedness to teach science. In that year, less than half (= 46%) of teachers of Year 4 students reported that they felt 'very well prepared' to teach "the science topics for TIMSS compared to an average of 54% across all participating nations" (p. 76) and contrasted to 73% of the teachers of Year 8 students - whom she notes are generally taught by science-trained teachers.

These negative perceptions and the apparent lack of expertise in the Science KLA have been supported by a large body of research which Appleton (1995) has summarised concerning the reluctance of many Australian primary school teachers to teach science. Appleton (1995) conducted a study involving 139 pre-service teachers - both primary and preschool - who were in the first year of a three-year degree course at an Australian university and studying a compulsory science education unit. The implications of the findings of this study for both pre- and in-service teachers is that pre-service courses incorporate some compulsory science and technology units to build the students' confidence to teach science and to build their confidence by including more content knowledge to "help students gain further confidence and competence in accessing science/technology discipline knowledge for themselves" (Appleton, 1995, p. 366). He concedes that, because degree courses have institutional and time constraints which may preclude the teaching of such courses, "independent study (as opposed to formal units of study) may be the only viable means for many students to gain further science and technology discipline knowledge" (p. 366). Appleton (1995) further notes that the pedagogies employed in teaching early pre-service teaching units should be such that they enable the students "to access science discipline knowledge" (p. 367).

Appleton follows this up in a later 2003 study and notes that "significant numbers of primary school teachers avoid teaching science, are not knowledgeable about science, and lack confidence to teach it" (p. 1.) and that "the teaching profession seems to attract people into primary teaching who fear science rather than those who love it!" (p. 21). However, in this study which he conducted with 20 beginning teachers, Appleton found that some of them where able to achieve some student learning by the use of sometimes rudimentary strategies "that gets them by in science" (p. 21) and that this often occurred without the support of their school, the system at large or their previous learning in teacher education programmes. These findings are of relevance to my research as some primary teachers find themselves needing to teach science with little background and/or without the supports listed by Appleton.

Hackling et al. (2001) present Fensham's findings of 1998, which corroborate these assertions. Some of Fensham's points on primary teachers were that they are generalist teachers with a poor background of science knowledge and who have few or no colleagues with expertise in science and/or science education. Further, they have no technical assistance and only occasional professional learning opportunities to enhance their teaching of science. Effective pre-service primary teacher training is essential to ensure that graduate teachers have a well-grounded - or better - science content and professional knowledge (Hackling et al., 2001). The employment of specialist science teachers in primary schools is addressed in a later section of this literature review.

In her book entitled 'Primary Teacher Talking: A Study of teaching at Work', Nias (1989) examines the experiences of English and Welsh primary school teachers. She highlights that there is still a tendency for some teachers, even those with many years of experience, to draw on their past experiences as school pupils themselves particularly when they feel unprepared for their teaching task. She quotes one teacher who, 12 years into his career, needed to draw on his own memory of science subjects which he studied at school to give him "some idea of what [he] ought to be doing" (1989, p. 137) because he felt that he had been inadequately trained to teach science.

Danielsson and Warwick have noted that "experience of schooling and of science education, as learners in a school system, is undoubtedly a strong and pervasive influence on all those who are training to teach" (2014, p. 299). In support of this claim, they cite studies published by other researchers such as Mulholland and Wallace (2000, 2002) and Skamp and Mueller (2000). Carlone et al. (2010) also note in their study - which was part of broader research relating to "students' identity development" (p. 947) - with primary school teachers of varying years of teaching experience, that 9 of the 13 participating teachers commented that they drew on their former positive and negative experiences as students and impressions of their former science teachers as 'resources' for their themselves developing as teachers and as "model[s] for the teachers they wanted to become" (p. 961). As a further case in point, Appleton and Kindt (2002) conducted research in Queensland, Australia, with nine participating first-year primary school teachers, each of whom "had achieved

high academic results" (p. 46). While some of the outcomes of this research are more relevant to later sections of this literature review, they note that "a major influence on beginning teachers' science teaching practices is their own experience as students during science lessons at school " (p. 44).

Several past studies set the contemporary situation into an historical context. In their discussion of pre-service training courses for primary teachers, Alexander et al. note that courses in the United Kingdom are quite overcrowded and that this needs to be resolved. They suggest that teachers acquiring a degree of specialisation, as an alternative to studying for a degree as a 'generalist' primary teacher, might be a part of the solution. However, with by far the greater majority of these teachers needing to have a generalist background, they must "continue to attempt to acquire a greater range and diversity of competencies" (1992, p. 51).

It is acknowledged by Harlen that teacher education courses operate under necessary time limitations and, especially in the case of primary teacher pre-service education, teachers are being prepared as generalist teachers who will be required to teach subjects across a broad curriculum. It is further conceded that the time limits and structure of such courses necessarily limit "what can be achieved for the development of certain attributes of effective teaching" (1992, p. 54). Skamp (1991) further contends that, when the science curriculum was introduced into England in 1989 with new attainment targets, there was some apprehension in education circles regarding the possible inadequacy of the content knowledge of some primary teachers and their ability to meet the new targets. Harlen and Holroyd (1997) further support these findings noting that research in Scotland had supported the notion that, for some time, primary teachers' understanding of the science content that they were required to teach had been a cause for concern and that some of the issues that they faced when teaching science were partly associated with their limited science knowledge and a lack of self-efficacy for teaching science.

Reports of more recent education matters in the media on the debate relating to the employment of subject specialist teachers in primary schools in the UK, reflect the community's concerns on this matter. Graham Paton, Education Editor of Britain's newspaper 'The Telegraph', reported in its online version on November 2011 that:

… from 2012, funding will be reallocated to allow more state-funded
training places to be made available for subject specialist [science] primary
school teachers. They will get priority places over students taking general
primary courses and schools will be offered the chance to train their own
primary specialists. (para. 8)

British Education Secretary, Michael Gove, MP, was quoted in this article as saying
that in relation to employing teachers with a specialty in science in private primary
schools, "we want to make sure children in the state sector can benefit from the same
opportunities" (2011, para. 5). Using generalist-trained primary teachers to teach
science in the state primary sector had been perceived as not having enabled students
to attain a high-enough standard. The perception was that generalist teachers were
found to be wanting in their pre-service training.

Noting that the poor science content knowledge of primary teachers is often cited as
a reason for the deficient science teaching of primary school students, Anderson's
(2015) multiple case study research in New Zealand involved observing the teaching
of science to the last two years of that country's primary schooling by three
generalist primary teachers. Her findings suggest that, teachers' "beliefs about
purposes of science education, the nature of science, and science teaching and
learning strongly influence teacher practice and knowledge" (p. 395). Furthermore,
Anderson found that the teachers' beliefs were also observed to "additionally
influence the nature of …[their] subject matter and knowledge" (p. 395) and that
these were a "strong influence" (p. 420) which also impacted on what the teachers
believed about opportunities made available to their students for learning and on the
development of their own science content knowledge. Given these findings,
Anderson suggests that initial education and subsequent teacher professional learning
should have some focus on teachers' beliefs and that, in the New Zealand context,
pre-service teachers experience very little education in the sciences compared with
pre-service teachers in other OECD countries.

Coupled with the apparent low priority given to primary school science teaching is
the academic background of many primary school teachers. In a study conducted

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with Third Year pre-service primary teachers, Symington and Hayes (1989) found that this group generally tended to avoid internalising the necessary science knowledge. The researchers found that some students used a very limited range of strategies to enhance their knowledge. While some referred to books or others asked their lecturer to answer their questions, some other students developed their lesson plans within their own limited understanding rather than extending themselves to better understand the topic. Over 20 years later, it is a reasonable expectation that these students, particularly the younger 'digital natives', might have resorted to the internet to answer their questions. The pre-service teachers in this Symington and Hayes study had little science background and the authors suggest that it would be "worthwhile to focus attention on the strategies and understandings [that primary teachers] may use to increase their familiarity with scientists' understandings of natural phenomena" (1989, p. 285). Masters (2009) noted that a review of his own research findings which was being undertaken at the time, included concerns regarding the restricted aggregate of science content incorporated into education courses for primary teachers in some institutions.

School communities and newly graduated teachers hold an expectation that pre-service teacher training will prepare teachers pedagogically and provide them with adequate content knowledge across the curriculum areas (Kervin & Turbill, 2003). Appleton (2003) found that eight of the nine beginning teachers in this study had to teach with only "limited science content knowledge" (2003, p. 9) and that "where there are substantial gaps in teachers' science content knowledge, and they have low self-confidence about teaching science, one natural reaction for such beginning teachers is to avoid teaching science" (p. 9) to allow them to "survive" (p. 9). DEET's 1989 'Discipline Review of Teacher Education in Mathematics and Science' criticised some institutions for having little compulsory science in their teacher education programmes. Ferry (1993, p. 1) notes that this Discipline Review also raised the issue of teacher confidence and recommended that "a stronger discipline base was needed".

Ardzejewska et al. articulate their doubt "that [generalist primary] teachers approach all subjects with the same level of competence" (2010, para. 2) given the diverse background educations of many primary teachers who, therefore, would have

varying competency levels in different subject areas. Some of these teachers would have come to teaching with quite varied undergraduate degrees and many others with education degrees with a major in primary teaching. Further, in more recent years, the NSW Institute of Teachers (NSWIT) (2007) has mandated that preservice teachers are obliged to attain required standards identified in the 'Nominated Areas of Standards' such as "Literacy, Aboriginal Education, Teaching Students from Non-English Speaking Backgrounds, Special Education, Classroom and Behaviour Management, and Information and Communication Technologies" (2007, p. 1) - leaving little time for the study of science within the S&T KLA. These standards are now embedded in pre-service teacher training courses.

Carr and Symington (1991) refer to the DEET's (1989) 'Discipline Review of Australian teacher education in Mathematics and Science', which reported the calibre of the education of pre-service teachers around Australia. This review made a recommendation that pre-service primary teachers be advised to study a course on explicit and assessed science discipline knowledge. This recommendation was made in light of the growing consternation over the low confidence levels of some primary teachers in their science teaching ability. More specifically, amongst many recommendations made in response to this DEET review were that, in order to improve primary teachers' competency in their science content knowledge, tertiary institutions offering pre-service teacher training should: offer at least 72 hours of face-to-face teaching in the science discipline; offer diagnostic testing and catch-up units if needed; provide one unit of science discipline knowledge; and provide suitable units of electives in science education (Speedy, Annice, & Fensham, 1989). The DEET review also makes it clear that gaps in pre-service teachers' science knowledge should be rectified through bridging courses. After conducting interviews with some primary teacher educators, Skamp reveals that some of these educators are not convinced that it is just a matter of the amount of time and testing undertaken in science study courses. He suggests that what needs to be investigated is "how teacher education can improve the understanding of science by primary teacher education students" (1991, p. 312). Possible solutions for improving primary teachers' understanding of science through primary teacher education are addressed in a later section of this literature review.

Based on research with primary-trained teachers exiting their training courses, Fensham, Navaratnam, Jones, and West were most emphatic about the need to change the amount of time which pre-service teachers spend during their teacher training in learning science content; at that time, "so little time was devoted to [this]" (1991, p. 87). They were astounded at the limited science content knowledge of the participating students and stated that, given that "the respondents ... only showed good quality content knowledge in living things and the environment and in processes of science" (2014, p. 299), "[this situation was] an unsatisfactory state of affairs" (2014, p. 299). These authors also called for the recommendations of the Discipline Review mentioned above to be implemented. Fensham et al. reported that institutions claimed that much of the time spent on science in their pre-service courses was devoted to curriculum/pedagogy and that this was, to the authors, "disappointing in the extreme" (1991, p. 88). It is noted by these authors that, following their study, some of the institutions involved appropriately modified their courses but, at the time, they had no way of gauging how widespread or effective those changes were. Fensham commented that "tertiary studies in science and science education for future primary teachers are generally very limited, and it is a rarity for them to have substantial studies in the sciences themselves" (2008, p. 40). Masters (2009) has noted widespread concerns regarding the minimal time typically spent studying science during Queensland teacher education programmes and refers to Thomson, Wernet, Underwood and Nicholas' (2008) observation that only 44% of teachers of Year 4 students in Queensland considered that they were very well prepared to teach science to those students.

In its May 2013 report on 'Initial Teacher Education' (ITE), the Australian Institute of Teaching and School Leadership (AITSL) reported principals' perceptions of their new career teachers' preparedness for their employment in schools. The principals' perceptions of the new primary teaching graduates ranked as fourth the "understanding [of] the subject matter that they are expected to teach", with only 52% of the principals responding that they felt that these teachers were 'very well prepared' or 'well prepared' in this area. This category followed the higher ranked "collaborating with teaching colleagues", "engaging students in learning activities" and "accessing and using teaching materials and resources effectively" (2013, p. 26). AITSL reports these figures as estimates which were based on the McKenzie,

Rowley, Weldon and Murphy report of 2011 on 'Staff in Australia's Schools (SiAS) 2010: Main Report on the Survey'.

The SiAS 2013 survey - to which 5213 primary school teachers responded - further reported that only 49.9% of primary teachers had general science in their teacher training (McKenzie, Weldon, Rowley, Murphy, & McMillan, 2014, p. 8). With the introduction in 2013 of the Australian Professional Standards for Teachers (APSTs), which details levels of knowledge and skills for four identified teacher career stages, the requirements provided by these APSTs for the accreditation of teacher education programs and for the ongoing accreditation of teachers themselves throughout their careers do address content knowledge. At every stage, including the 'Graduate' stage for newly graduated teachers, Standard 2 within the teaching domain of Professional Knowledge is entitled 'Know the content and how to teach it'. Questions in the 2013 SiAS survey were aligned with the APSTs and participating primary teachers indicated that, on the standard addressing subject content knowledge appropriate to the school curriculum, 69% of the participating 5213 primary teachers found their ITE courses 'very helpful/helpful' while around 30% did not (ACER, 2014). In the same survey, 765 principals indicated their perception that only 40% of their recent graduate teachers were 'very well prepared/well prepared' with respect to their content knowledge. No further comparable empirical data are currently available in the literature.

Figure 2.7 (Grindrod et al., 1991) shows how positive were the feelings of 346 pre-service primary teachers about science: 34% had neutral feelings whilst 51% carried negative feelings; an overwhelming majority had negative or neutral feelings. This research with students at Victoria College, Australia was conducted - in part - to give the researchers an understanding of why the pre-service teachers chose, or avoided, teaching science during their practicum during each year of their teacher-training course. It was also found during this particular research that the greater number of students observed or taught six or fewer science lessons in each year of their training. This is particularly important considering that, in their third year, the pre-service teachers experience around 200 lessons over the practicum's duration. Without accounting for the possible reasons for this "minor emphasis on science in the curriculum" (1991, p. 154), Grinrod et al. propose that such circumstances will

"impact on professional teaching practice, either in the long or short term" (1991, p. 154). Grinrod et al. (1991) also voiced their concern for the need to ensure that the profile of science is lifted in the primary curriculum.

Among suggested opportunities which should be provided by pre-service teacher education courses are "activities which supplement personal knowledge and understanding of the subjects [to be taught] to a level beyond that expected of the children they are to teach" (Grindrod et al., 1991, p. 155). As the focus of Grindrod et al. is on science and mathematics teaching, this highlights the inadequacy of many pre-service teacher education courses around the world in preparing their students to teach science.

In an article entitled 'Call For Maths, Science Expert Teachers To Lift Primary Science', Matthew Knott of *The Sydney Morning Herald* noted the Australian College of Educators' (ACE) proposal to the Australian Federal Government's review into teacher education. In this review, announced in February 2014, the ACE maintains that primary school students should be taught by a smaller number of teachers with subject specialties instead of the standard traditional generalist teacher approach. He quotes the ACE as contending "specialised primary teacher training in ... science needs to be introduced to improve teaching standards" (July 9, 2014). Dinham - the incumbent chair of teacher education at Melbourne University and ACE president at the time - is quoted by Knott in the same article as saying that "many primary teachers lack competence and confidence teaching maths and science" (July 9, 2014) and that poor science results in high school should be addressed by first improving standards in primary schools.

In 2012, Australia was ranked 7th internationally in science (Department of the Prime Minister and Cabinet, 2012, p. 15). In 2013, the University of Melbourne's Graduate School of Education (UMGSE) published a green paper on "Focusing on the learner: Charting a way forward for Australian Education" which acknowledges that the professional skills of teachers have an important role in the shaping of the quality of schools. As noted above, the paper describes a number of recent Australian trends shown by international data collected from TIMSS and PISA. Among these trends,
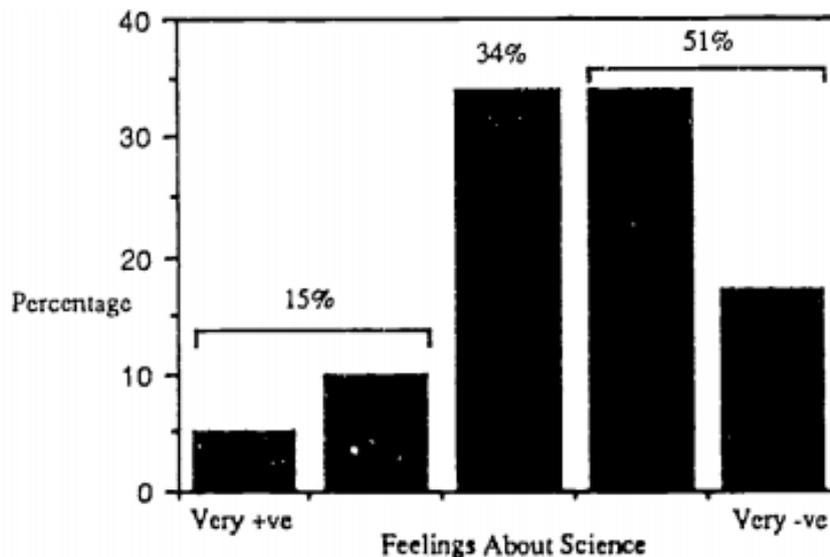
Figure 2.7. Feelings about science brought to a 'Curriculum and Methodology' course by third year pre-service primary teachers at Victoria College. From "A survey of Pre-Service Primary Teachers' Experiences of Science in Schools", by A. Grindrod, A. Klindworth, M-D. Martin & R. Tytler, Research in Science Education, 21, p. 152. Copyright 1991 by R. Tytler.

there has been no change in the science performance of Year 4 students against the performance improvements of other countries over the last 16 years. The UMGSE makes a number of recommendations aimed at addressing this predicament, including the introduction of "primary-level specialist teachers, particularly in maths and science" (2013, p. 14) stating that "it is becoming untenable for generalist primary teachers to cover all aspects of the curriculum with expertise" (2013, p. 14). The paper proposes that such specialist teachers would work alongside their generalist colleagues in team-teaching and/or release approaches.

In response to these concerns, some universities are changing their teacher-training programmes to meet the need for primary teachers to have a deeper science content knowledge. For example, in 2014, Melbourne University (Australia) began a new two-year primary teacher education programme - a graduate course - with a cohort of 60 students. The course provides 50% of these pre-service teachers with the opportunity to spend at least 25% of their course time studying science content and teaching strategies. The Faculty of Science is also involved in aspects of the course. Ferrari reports, in *The Australian*, that the other 30 students similarly specialise in mathematics (2014). At the time of graduation, these generalist teachers will have an extra science or mathematics accreditation. The outcomes of this new approach have yet to be seen.

By way of examining a further alternative, at the Australian Catholic University's (ACU) Sydney campus, Bachelor of Education primary pre-service teachers study three Science and Technology units. Each unit runs over 12 weeks each semester, with one 50-minute lecture and a 90-minute tutorial per week. This unit format has been offered to students since 2006 and Anne Forbes (personal communication, August 21, 2014), Primary Science and Technology Lecturer at ACU at the time, anticipated that they will continue unchanged into the foreseeable future. Information provided by Forbes indicates that, at the time of writing, these units - using the terminology of the NSW K – 6 S&T syllabus - are undertaken as follows:

- Year 1 Semester 1: Content/discipline knowledge relating to: Living World, Material World, Working Scientifically;

- Year 2 Semester 2: Pedagogical focus on the teaching of primary science with examples from Earth and Space and Physical World; and

- Year 4 Semester 1: Pedagogical focus with some integrated content knowledge relating to: Physical World, Material World, Earth and Space and Working Technologically (personal communication, August 21, 2014).

These units amount to, at most, students being exposed to 24, 50-minute science content related lectures, and 24, 90-minute tutorials over the course of a four-year degree. In the same communication, Forbes noted that, in her opinion:

> … an important element of [these units] at ACU is that the content/discipline knowledge is taught by primary science educators - not science researchers/academics from, for example, science/engineering. This enables the content knowledge to be selected, tailored and taught in a way that the pre-service teachers gain relevant knowledge (personal

communication, August 21, 2014).

Forbes has further commented that this mode of presentation "from my understanding of other NSW university's [sic] Primary Education degree programs is that at ACU the discipline knowledge for primary students is taught by education specialists - something that in my view is very important" (personal communication, September 3, 2016). Therefore, pre-service teachers are not unnecessarily exposed to discipline content that is too remote from what they need to teach to primary school students.

At The University of Sydney, NSW, Australia, the Bachelor of Education primary teaching program requires students to attend one semester of science each year during the four-year degree. In the first two years, lectures are science content based and taught jointly by the Education and Social Work and Science faculties. In contrast, the second two years are pedagogy-based (Preston, personal communication, September 5, 2014).

Palmer, Dixon, and Archer (2015) conducted a study with 104 first-year pre-service teachers studying at an Australian university in order "to investigate whether science teaching self-efficacy is enhanced in a science content course that is developed specifically for pre-service teachers" (p. 29). Their conclusions and recommendations reinforced the need for teaching science content knowledge to pre-service teachers and supported the idea that a science content course - in this case, using the more traditional mode of transmission delivery but supported by interactive tutorials - could enhance self-efficacy "as long as the content and techniques are chosen to be relevant to primary teaching techniques" (p. 37).

The literature above establishes the need for primary teachers to have a sound content knowledge base, to enable them to better teach students. It also shows that teacher-training courses can be designed to give pre-service teachers an opportunity to build on their science content knowledge where needed. As Mansfield and Woods-McConney (2012) have noted, some studies support an emerging link (discussed in the previous and following sections) between teachers' science content knowledge

and its positive impact on teachers' efficacy. Therefore, effectively designed pre-service courses for primary teachers which adequately address content knowledge could also assist in having an impact on teachers' efficacy.

2.9 Enhancing Primary Teachers' Science Content Knowledge

Because the literature reviewed above suggests that a primary teacher with sound science content knowledge benefits not only him- or her-self - by generally having a higher self-efficacy - but also brings many benefits to his or her students via improved classroom practice - it is important to review methods to enhance this knowledge. Murphy and Beggs contend that "teachers who had carried out professional learning in science were significantly more confident to teach science" (2005, p. 14) and that many teachers feel that their science content knowledge and confidence to teach science need further development. Following are examples relating to teachers' content knowledge and some implications of each for professional learning experiences. Anderson (2015) writes about teacher beliefs and science content knowledge in the New Zealand context. In that country, as in Australia, there has been concern around the poor science background of many primary teachers. Notwithstanding this, in response to surveys carried out and published in 2012, Anderson reports that the New Zealand Education Review Office highlighted that some teachers do have sound content knowledge. She further notes that there is available evidence indicating that teachers in some primary school environments are, in fact, "able to develop the knowledge they need to successfully engage their students and foster learning in science" (2015, p. 396). Gillies and Nichols reinforce the need for teachers to have sound content knowledge by stating that "knowledge of science content ... [among other things, is] ... critically important if teachers are to be effective" (2015, p. 172). Anderson states that "understanding the nature of teachers' beliefs and how they influence their knowledge and practices … [can be useful] in informing future professional development initiatives" (p. 396).

The term 'professional learning' is frequently used interchangeably with 'professional development' in some of the literature and in current professional practice. In their document on professional learning in the research literature - commissioned by the Australian Institute for Teaching and School Leadership

(AITSL) in October 2011 - Mayer and Lloyd attempt to clarify these two terms. They note that "even though often used interchangeably within the teaching profession, the literature usually differentiates between what is meant by each of these two terms" (2011, p. 4) and that, through the literature, various authors debate their meaning and use. They further note that across Australian education jurisdictions, the term 'professional development' has largely run out of momentum and its use has diminished. They contend that this is because of a certain set of perceptions about the term's meaning and "the presumed 'baggage' associated with poorly conceived, fragmented, one-shot and de-contextualised 'in-service' workshops" (2011, p. 4). Throughout this research, then, the term 'professional learning', or PL, is used for two reasons. Firstly, many teachers and school communities currently use the term 'professional learning' to encompass both formal and less-formal learning activities in which they engage. Secondly, for teachers completing surveys and interviews, the use of one familiar term throughout avoids confusion.

Discussion of science education in the Scottish government's HMIe 2005 document on Scottish education notes that, over recent times, there has been a significant growth in the body of scientific knowledge and the investigative skills associated with it; and it acknowledges that many teachers over the age of 40 years may not have encountered developments in this content knowledge in the time since they completed their initial science training. The authors note that, while some primary teachers in Scotland had availed themselves of a variety of opportunities for professional learning to update their science content knowledge, many teachers were unable to take advantage of such opportunities. They advise that strategies must be put in place to ensure that all teachers are able to avail themselves of high-quality professional learning opportunities. Fulp notes that many of the teachers surveyed in the USA for a 2002 report, were not confident that they were "well qualified to teach specific science disciplines and [that] almost three-fourths perceive a substantial need for professional development to deepen their own science content knowledge" (2002, p. 19). In common with the British teachers, these teachers highlighted a need for help in increasing and enhancing their science content knowledge, especially using instructional technologies, as many of them had little time to engage in PL courses specific to science.

A longitudinal study of 5 years duration was conducted in the USA by Davis (2008) with six early career primary teachers. The research "included three interviews each year, files tracking use of an online learning environment, daily descriptive logs, written reflections, and correspondence" (p. 2). Some of the findings on their ideas about effective science teaching relate to various elements of pre-service teacher education. Davis states that preservice teachers need to "be prepared for the forces that will work against their innovation" (p. 2008, p. 7) and "know of resources and other forms of support to which they can turn. Induction support, professional learning, structural changes and preservice teacher education can all play unique but complementary roles in helping teachers develop and maintain knowledge" (2008, p. 7).

The HBCSE's 2011 working paper for the Government of India's Ministry of Human Resources and Development highlights the need to strengthen the links between teaching and content knowledge to increase elementary school teachers' sense of autonomy in the classroom. A number of strategies for achieving this goal are suggested, such as introducing teachers to the research literature on science education and developing professional learning programmes which give teachers the opportunity to acquire specialist content knowledge.

In the Californian context, many undergraduate courses taken at universities by prospective teachers do not necessarily teach the content required by the National Standards. This is even less so for courses taken at community colleges. "The fact that experienced teachers seem to gain confidence in their reading and math [sic] teaching, but not science, suggests that much stronger preparation and in-service support is necessary" (CCST, 2010, p. 3). This contention around more effective preparation and in-service professional development is supported by an example from New Zealand.

Aiming to develop targeted science concepts among New Zealand's primary school students, the Ministry of Education produced a series of 64 books -issued between 2001 and 2004 - designed to assist primary school teachers in achieving this aim. The series was titled 'Building Science Concepts' and the books were designed to match the New Zealand curriculum. They contain concept overviews and diagnostic and classroom activities, some of which could be adapted to suit the needs of students

and gradually build their understanding of the science concepts. Of particular interest to my research, is the statement on the New Zealand Ministry of Education's 'Building Science Concepts' website page advising teachers that they could "use the science notes in the book to refresh your science understanding of the topic" (2017, para. 1). Anderson revealed that a study found, however, "that many teachers were not using the series and some did not know about it [and] so more professional development may be needed to familiarise teachers with the booklets and the ways they can be used" (2006, p. 153). Anderson highlights the use of these booklets in both initial teacher training and by in-service teachers. Harlen argues that the ability relating to "how-to-find-your-way-about knowledge" (1993, p. 39) is much needed by the resourceful teacher. This skill "consists of a knowledge of resources and their accessibility" (1993, p. 39) and she contends that having this ability makes a teacher more self-reliant in his or her own learning.

Lowe and Appleton (2014) investigated the issues that confronted Queensland primary school teachers during the implementation of the Australian National Science Curriculum, which relies upon a pedagogical shift for many teachers from a transmission- to an inquiry-based style of teaching. Lowe and Appleton (2014) describe how the Queensland State Government, in an effort to assist its teachers, developed a resource called 'Curriculum to Classroom' (C2C) to "assist teachers in identifying specific content understandings and help them make appropriate pedagogical choices" (p. 845). The 'Primary Connections' (PC) resources - "a series of innovative and literacy support materials … to help build teacher confidence and competence to teach science in primary schools" (p. 846) were made available to the Independent School teachers in the study. In both cases, the resources were accepted unquestioningly at face value. Teachers in the two participating schools came to view curriculum implementation as corresponding to the "selecting and teaching [of] suitable activities from the resources provided" (p. 858). The researchers acknowledged that the teachers endeavoured to do the best that they could in the contexts of their school environments, but were frustrated by the lack of science resources provided to them - even resources that would allow them to follow the C2C and PC activities. There was also frustration with the lack of professional development and "in-class support" (p. 862) on offer to the teachers. Of direct relevance to my research is that the potential for pedagogical reform was missed and

the teachers engaged in the "selection and delivery of activities from endorsed resources that apparently represented the new curriculum" (p. 860). This is in contrast to Harlen's (1993) notion that being able to identify and use appropriate resources is an important skill for teachers. Being able to do this enables teaches to make effective use of resources to assist with enhancing science content knowledge and delivering the curriculum effectively rather than using a 'recipe' or 'cherry-picking' approach. The use of the resources in these latter ways did little to enhance the science content knowledge of the participating teachers in the 2014 Lowe and Appleton research.

In an audit of in-service training undertaken as part of the National Primary Science Survey in England and published in 2008, Hopkin and Sharp identified several critical results. Among these were the following four which relate to the teaching of science in primary schools. Firstly, amongst the 303 primary teachers from 206 schools who took part in the survey, there had been a generally low uptake of in-service courses. This was particularly the case in regional Science Learning Centres. Secondly, there was a lack of "coherency and consistency" (2008, p. 4) in the in-service courses that were provided and in the rate of uptake of courses - particularly those which addressed science content knowledge. Thirdly, the number of co-ordinators attending these in-service courses was disproportionately higher compared to the number of teachers at the classroom level attending; and, finally, there was also a disproportionately high uptake by those who had been teaching for over ten years in comparison with teachers with fewer years of teaching in the classroom.

Shahali, Halim, Treagust, Won and Chandrasegaran (2015) conducted a study in Malaysia with 392 teachers from 52 randomly selected primary schools in which the understanding of science process skills (SPS) - an important component of inquiry-based learning - was investigated. They noted that "recent studies from various countries have found that teachers were competent in executing the practical component of SPS but lacked the conceptual knowledge underlying the skills" (p. 259) and these teachers valued the use of the skills more highly than knowing and "understanding the meaning of the skills in order to appropriately and effectively teach them to students" (p. 259). The concern is that such teachers will ultimately produce students who can follow the steps of processes but who have no real

conceptual knowledge of what they are doing. Shahali et al. (2015) note that this study has serious ramifications for teacher education in Malaysia, if that country's primary teachers are to successfully teach science inquiry to their students. The same ramifications could apply to teacher education in Australia.

Research since the 1990s has consistently demonstrated there is some degree of deficit in generalist primary teachers' science content knowledge. This will vary from teacher to teacher. Teachers' curiosity can partly drive their need to enhance their science content knowledge.

2.10 'Curiosity' Construct

The goal of enhancing content knowledge is also partly dependent on a teacher's level of curiosity around that particular content area. The construct of 'curiosity' can simply be defined using Berlyne's notion that it is "the desire for more information and knowledge" (Edmonson, Boyer & Artis, 2012, p. 42). Edmonson et al. further note that curiosity is "a key-characteristic of SDL [self-directed learning] which has been demonstrated to stimulate exploratory behaviours" (p. 45) in learners (SDL is be addressed more thoroughly in a later section). Litman, Hutchins and Russon also add that, according to Berlyne (1954), not only does curiosity stimulate exploratory behaviour but also "knowledge acquisition" (2005, p. 650). They refer to this type of curiosity as 'epistemic curiosity' and describe its role - deduced from the work of a number of authors - as motivating exploration that is "aimed at resolving discrepancies [or 'gaps'] in one's knowledge" (p. 559).

In their study with 265 university undergraduate students, Litman et al. (2005) investigated knowledge gaps and individual differences which might combine to stimulate curiosity and exploratory behaviours. As part of their method - and with attributions to the works of many authors - they employed a three-part scale to question responses as levels of knowing. These were 'tip-of-the-tongue' ('TOT') - a 'feeling-of-knowing'; 'don't know' - a 'feeling-of-not-knowing'; and 'I know' - 'feelings-of-certainty' (p. 560). The 'TOT' feeling-of-knowing state was associated with the smallest knowledge gap but stimulated the greatest curiosity and the most exploratory behaviours for the answers. The largest knowledge gap was associated

with the 'don't know' level of 'feeling-of-knowing' and was accompanied by a corresponding decrease in curiosity and exploratory behaviour. Finally, there was no perceptible knowledge gap for the 'I know' responses and this motivated the least curiosity and exploration by the participants.

Another finding of Litman et al. (2005) was in relation to curiosity and personality traits - "trait epistemic curiosity" (p. 561) - and the emotions that accompanied the knowledge gaps and exploratory behaviours. In summary, the 'TOT' feeling was associated with "relatively unpleasant feelings of tension and uncertainty" (p. 579) whereas the 'don't know' state elicited feelings of "interest and enjoyment" (p. 579). No particular emotional state was reported for the 'I know' state. Therefore, in addition to other factors which might affect the enhancement of science content knowledge by particular primary teachers, it is also contingent on their base-level - or, as Litman et al. (2005) point out, their perception - of knowledge of some aspect of content and to some extent upon the individual's personality.

A teacher's curiosity, therefore, plays a role in his/her self-directed learning. So, too, does the teacher's awareness of his/her own level of content knowledge. Together they play a part in the teacher's search for content knowledge: how much searching is engaged in, the depth of their search and how frequently they might do this.

2.11 Addressing Teachers' Science Content Deficits in Primary Schools

The above literature review suggests that, in Australia and particularly in NSW, the teaching of science - which is a National priority - is allocated minimal teaching time and is taught by teachers who, in many cases, do not have a strong scientific knowledge base. How this situation could be improved is considered below.

In 1998, the [American] National Science Teachers Association (NSTA) recommended that "the preparation of elementary school science teachers include coursework in science education as well as content in life, earth/space, physical, and environmental science" (Fulp, 2002, p. 4). Other researchers, as previously noted, have echoed this sentiment. In its 2010 report entitled 'The Preparation of

Elementary School Teachers to Teach Science in California: Challenges and Opportunities Impacting Teaching and Learning Science', the CCST made a number of recommendations about using a multi-faceted approach - to alleviate the poor results of students in the National Assessment of Education Progress and other tests. Firstly, existing programmes and infrastructure which had shown promise should be discussed in a symposium and made effective use of. Secondly, teacher credentialing and policies should be structured "to protect and enhance K - 6 science teaching" (2010, p. 4). Thirdly, science education programmes should be supported and nurtured to increase the confidence and preparation of K - 6 teachers. Finally, the Centre for the Future of Teaching and Learning in California should take advantage of current data becoming available about the "components of effective elementary science teacher [education programmes]" (CCST, 2010, p.4). The above-mentioned symposium was designed to encourage stakeholder tertiary institutions, research laboratories, corporate partners, etc. - i.e., the broader 'community' - to identify opportunities to assist primary teachers in the development of both their pedagogical skills and their science content knowledge.

In his 2011 speech delivered to the United Kingdom's National College for School Leadership, Michael Gove nearly admitted that having generalist teachers teaching science in primary schools is no longer desirable. He noted that, while most state primary teachers had been trained as generalist teachers, "the best state primary schools in the country insist on discrete subject teaching" and that "one of the things many parents value about private primaries is that they often have specialist teaching [in science]" (2011). While he conceded that having specialist teachers in small rural schools would present difficulties, he forecast the need to prioritise the training of specialist primary science teachers for employment in the state sector.

Appleton (2003, p. 20) suggests that, if we are going to have generalist teachers teaching science in primary schools in Australia, then there must be a "major investment in professional learning over a sustained period of many years". In their 2001 report, Hackling et al. found that 40% of primary teachers identified a lack of resources as a major factor which limited their science teaching.

2.11.1 Teacher Training Courses

In research reviewed in a later section, the provision of targeted courses during and after teacher training has been shown to improve teachers' science content knowledge, attitudes towards teaching science and self-efficacy. From a study of 417 pre-service teachers in Turkey - 262 of whom were primary teaching majors - Kirik (2013) made some notable observations from their results. Firstly, pre-service teachers' teaching self-efficacy is linked to their conceptual understanding of science. Secondly, science teaching attitudes are a major predictor of science teaching efficacy belief - based on data gathered using the STEBI-B for pre-service teachers, the Science Concept Test and other instruments. Finally, Kirik distilled from the body of research data previously collected that there was a low but positive correlation between science-teaching attitudes and the number of methodology courses in science that the pre-service teachers had undertaken. These types of findings could assist teacher educators aiming to improve the attitudes and science-teaching efficacy of pre-service teachers. Turkmen (2007) made similar findings.

Carr and Symington have noted that "there is no universally accepted view amongst teacher educators in Victoria [Australia] about the steps that need to be taken to improve [primary teachers'] subject matter competence in science" (1991, p. 39). In this research, they identified teaching approaches that can assist students by using the students' prior knowledge and understanding to construct new ideas. They suggest that such an approach could be incorporated into pre-service training to meet the needs of those pre-service teachers who have a limited understanding of science.

Grindrod et al. (1991) also studied the introduction to Third Year students of a specifically-designed curriculum and methodology course on applying, in the context of a school, an inquiry-based approach with a three-fold aim to improve the students' science discipline knowledge, knowledge of curriculum and methodology, and attitudes towards their science teaching. It was found that the students who experienced this more hands-on approach and how to manage it in the classroom felt much more prepared to teach science. Their confidence increased and a more positive attitude towards teaching science developed. The authors expressed the

wish that such an approach be incorporated into more primary teacher training courses.

Jane et al. (1991) reported another course that was introduced at the same institution used in Grindrod et al.'s (1991) third-year course study. This first-year course - 'Professional Readiness Study - Understanding Science' - was introduced in an attempt to increase confidence and interest among students who had limited science backgrounds and who had not chosen science as a general study area. This was especially through providing experiences in the physical sciences (i.e., an area with which many students are relatively unfamiliar). The course employed a diverse variety of strategies and there was an overall positive response to the course. For a number of the students, there was a gain in confidence in teaching science in the future as their understanding of the science content increased.

A number of recommendations was made to the Queensland Government's Department of Education and Training by the 2009 'Masters' Review'. One of these recommendations was the introduction of mandatory, standardised science testing across year-groups in that state, including Years 4 and 6, which could assist in the identification of those students who were not satisfying benchmarks for their year cohort so that their progress could be monitored. In 2009, the Queensland Government Department of Education and Training acknowledged the "views expressed by stakeholders on the suitability of introducing mandatory testing in an environment where many teachers admit to a lack of confidence and expertise in teaching science" (2009, p. 4). The Government stated in its response that it would endeavour to assist in the development of the necessary skills and science content knowledge needed by teachers so that they can teach more effectively (2009, p. 4).

Riegle-Crumb et al. (2015) conducted a quantitative study of 238 pre-service elementary teachers in order to investigate whether teaching these students using inquiry-based science-content courses would assist in promoting "a change in attitudes towards science among preservice elementary teachers" (p. 826). Their findings suggest that, although they did not assess precisely which aspects of the course the preservice teachers found most favourable, this approach produced a positive change in teachers' attitudes towards teaching science, increased confidence

in their science skills and reduced anxiety towards science teaching. Tessier (2010) used a comparable study approach to pre-service teacher education with 133 pre-service teachers participating in an inquiry-based methodology course in the USA. His findings support those above of Riegle-Crumb et al. (2015). Loughland and Nguyen (2016) have identified from the literature, that many primary teachers in Australia have negative attitudes towards the teaching of science and that the courses in pre-service teacher education that they attended did not teach them enough science content to be confident teachers of science in the classroom.

2.11.2 Professional Learning and Targeted Programmes/Resources

For teachers whose science content knowledge is relatively weak and/or who have low self-efficacy beliefs, part of the solution to the problem could potentially be their participation in various modes of professional learning for enhancing their content knowledge and professional practices (Smith, 2015). Skamp (1991) noted that, for post-initial education teachers, PL courses only made minor contributions - between 5% and 14% - towards their science knowledge base. Schibeci and Hickey reported that an initiative involving a course designed to support primary teachers by enhancing their science teaching self-efficacy through professional learning also enhanced their science content knowledge. They note some questions which are under-researched, such as "what are major obstacles to [primary teachers'] learning of science concepts?" (1996, p. 1). In their discussion, Schibeci and Hickey claim that the PL course studied provided strong support for "an increased focus on the content involved in primary teachers' professional learning" (1996, p. 158) and that working on this study raised important "practical issues relating to the identification of the most effective ways to develop primary teachers' [science] content [knowledge]" (1996, p. 159).

Smith (2015) notes that professional development for teachers can have a positive impact on teachers' learning and that, in Ireland, the lack of some types of teacher professional development is one cause for concern for both pre-service and in-service teachers. He also refers to research which suggests that it is important for professional development programmes to involve teachers' science content knowledge and the ways in which students learn. These types of programmes can

result in positive gains in teachers' content knowledge and the learning outcomes of their students.

In the Australian context, McKinnon and Lamberts (2014) conducted a study in which a group of 21 teachers - a mix of pre- and in-service teachers - took part in a series of one-hour professional development workshops delivered at a science centre. For the purposes of the study, this was viewed as an informal education provider. Data on teachers' self-efficacy were collected through surveys and interviews which were administered directly before and after the workshops, and again 4 and 11 months after the sessions. Following-on from research which showed that the teaching practice of primary school teachers can be influenced by their self-efficacy beliefs, McKinnon and Lamberts investigated the impact of these workshops on teachers' self-efficacy. This study suggested that the workshops had a positive and lasting effect - at least in the medium term - on an aspect of self-efficacy which is referred to as Personal Science Teaching Efficacy (PSTE) and that this effect was still evident in 18 of the participants 11 months following the final workshop. The effect on the teachers' Science Teaching Outcome Expectancy (STOE) was not as pronounced. The PSTE is a reflection of a primary teacher's confidence in his/her science-teaching ability, whereas the STOE is a reflection of the "teacher's beliefs that student learning can be influenced by [being] given effective instruction" (Savran & Çakiroglu, 2003, p. 16). McKinnon and Lamberts concluded that the professional learning delivered by the informal education provider was instrumental in increasing the self-efficacy of the teachers and had a lasting effect on the majority of teachers. The teachers were able to share the activities and resources introduced to them during the workshop with their school colleagues.

In research related to exploring pre-service primary teachers' understanding of the mechanisms of conducting student-centred, inquiry-based learning, Seung, Park and Jung (2014) studied seven pre-service teachers who were participating in a primary teaching science methods course. The interactions between these students and their mentors were investigated during field excursions. Although the research was mainly focused on the mentors' and mentees' interactions and reflections with respect to student-centred learning, Seung et al. reflected on the need for professional development programmes to assist teachers beyond their pre-service courses.

"Considering that learning to teach is a long-term endeavour, the findings of this study also imply the need for a continuous, professional development program to support beginning teachers ... in their early careers" (2014, p. 523). Indeed, and additionally, targeted programmes are needed throughout teachers' careers (Seung et al., 2014).

In New Zealand, Anderson points out that the majority of primary teachers have very little science background and that, in one particular education review, fewer than around 30% of the 100 schools assessed were effective in the delivery of the new science curriculum which had been introduced about five years previously. In connection to this, Anderson notes that "international comparisons show that New Zealand teachers receive relatively little pre-service science education and less ongoing professional development than many of their colleagues in the OECD" (2015, p. 396).

Peer's review of the Australian 'Primary Connections' project - which aims to "establish meaningful connections between science and literacy, to promote effective learning in both domains" (2007, p. 13) - refers to Hackling and Vaughan's (2005) trial research finding on Stage 2 of this project. Of the 97 participants using the 'Primary Connections' programme, "the number of primary teachers with low belief in their capacity to teach science effectively decreased from 22 to 3 after one term ... and to 2 after two terms" (Peers, 2005, p. 16). They also found that, after participating in the programme, more science was generally being taught by the participants, with a 72% increase in the number of these teachers now teaching more than one hour of science per week compared with 33% at the beginning of the trial. Also, the mean confidence scores of the participating teachers showed a significant increase since the beginning of the programme from 3.34 to 4.04 (p < 0.05). In Tytler's (2007) review, former Australian Chief Scientist, Dr. Jim Peacock, describes the successful use of 'Primary Connections' as eliciting remarkable confidence in teachers who had used it and that the "mean achievement scores for students after the 'Primary Connections' trial were almost doubled, with Year 5 students working at or above the national standard for Year 6" (2007, p. v). Because 'Primary Connections' has now been in use for a much longer period of time, it would be of interest to see if

these kinds of data have changed - that is, have been sustained or diminished - over time.

Koul (2010) reports that, in an effort to address the problem of individual primary teacher's lack of confidence in his/her science teaching, the Western Australian (WA) Department of Education instituted the Primary Science Project (PSP) in 2005 in that state's primary schools; this was later expanded to more schools. Having the ultimate aim of improving students' scientific literacy, the PSP aimed to improve the teachers' confidence through a professional learning scheme in which one teacher from each school was trained - via an extensive professional learning regime - as support teacher. This support teacher then worked closely with other staff in the same school. Koul (2010) notes that this PL programme had "a very positive effect" (p. 295) and that there was a noticeable shift away from primary teachers not teaching science towards teaching science, in addition to an overall improvement in the teachers' level of confidence.

One principal aspect of 'Primary Connections' is the availability of professional learning for the teachers to support its use (Lowe and Appleton, 2014). The school involved in their study did not provide its staff with any PL to support the use of 'Primary Connections'. This was a source of frustration for the teachers and accentuates an apparent disconnect between curriculum development and PL needed to effectively implement the curriculum and how to use available resources. Lowe and Appleton noted that teachers "took the materials [such as] ... 'Primary Connections' at face value, unquestioningly accepting the stamp of approval from government authorities" (2014, p. 861). They claim that this approach could be justified in the use of the 'Primary Connections' programme - which underwent extensive development and trialling during and since its initial inception - but some resources did not undergo such trialling. This can be a further source of difficulty for teachers who are not given PL support to either evaluate the suitability of, or implement, resources programmes.

Teachers are increasingly turning to the resources that the internet has to offer for their teacher professional learning (Beach & Willows, 2017). Charalambous and Ioannou (2008) write that "the internet is rapidly becoming an increasingly important

tool for the professional development of teachers" (p. 47), noting that teachers have at their disposal many resources via the internet and the use of ICTs to link them to human resources (e.g., their subject experts and relevant professional groups). Charalambous and Ioannou conducted a study with 158 Cypriot primary school teachers in relation to using the internet for their own professional development and for use as an educational aid. They found that the teachers' "most positive opinion was … towards the internet as a source of information" (p. 52). Another finding relevant to this study is that teachers who were very confident about their own skills in using the internet had much more positive attitudes about using the internet for their own personal development: this is particularly so for "locating information about the topics they are teaching" (2008, p. 52).

Tour (2017) notes that professional organisations must consider the potential of teachers' learning experiences using online platforms for professional learning and give them more trust and opportunity in the professional learning experiences offered to them. Tour warns that, in the future, "an expectation that teachers rely on such informal learning is problematic in some aspects, including the difficulty in assessing the depth and criticality of learning as well as teachers' work life balance" (p. 17). This aspect of teacher professional learning is discussed in a later section on utilising ICT-based resources to enhance science content knowledge.

2.11.3 Employing Specialist Teachers

Some mention has already been made above in relation to the employment of specialist science teachers in primary schools. In an article relating to delivery modes for elementary science instruction, Gess-Newsome (1999) explores potential answers to the question: "How do we best ensure adequate and appropriate science instruction at the elementary level?" (para. 3). She considers it beneficial for a specialist classroom science teacher to be employed to take leadership over the school's science instruction and/or to provide assistance to colleagues. This teacher would have a special interest or training in science and would provide further efficiencies through the division of teaching time, overseeing/selecting science resources, etc. This model provides students with, among other benefits, a desirable level of exposure to a teacher with a high level of science content knowledge.

In the same article, Gess-Newsome also considers a team-teaching scenario in which one teacher within each primary grade takes responsibility for teaching specialised science content and teaches classes, other than his/her own, on a rotational basis. Gess-Newsome refers to this scenario as "departmentalization" (1999, para. 18) which, while admitting that there are some disadvantages to this model which are beyond the scope of this review, would ensure that there are set times for science instruction. This model also increases the likelihood of a better level of science teaching by a teacher who has better science content knowledge than the generalist teacher.

The Queensland Government's response to the 2009 Master's report on the challenges of improving literacy, numeracy and science learning in Queensland primary schools (Queensland Department of Education and Training, 2009) was to make a commitment to place 100 additional specialist science teachers into its government-sector primary schools to enable them to assist primary teachers with their teaching of science to students in the upper primary years. Additionally, 15 secondary school science teachers were provided to prepare and present a professional learning program - the equivalent of one day per teacher - to support and train primary teachers in their teaching of science. Lowe and Appleton conducted a study of the impact of one of these visiting teachers in a targeted Queensland primary school. They reported that the generalist primary teachers who were taking part were not enthusiastic about a secondary science teacher - referred to as a 'Science Spark' - visiting their classrooms to teach or assist with science lessons. They reported feeling intimidated, vulnerable and embarrassed about their lack of science content knowledge and science teaching skills. While the teachers enjoyed the 'Science Spark' teaching their classes for them, they found that they couldn't duplicate the lessons on their own even though some of them had attended the workshops given by the 'Science Spark'; transfer of knowledge had not occurred. After a number of weeks of interaction with and the departure of the 'Science Spark', the school returned to its pre-'Science Spark' status in relation to its science understanding and teaching. The researchers concluded that, if the schools studied typified their sectors, then "indications are not good for the wider implementation of the new science curriculum in Queensland" (Lowe & Appleton, 2014, p. 861).

Ardzejewska et al. (2010) conducted research exploring the employment in primary schools of generalist versus specialist science teachers which involved 401 NSW government primary school principals. Using a sequential quantitative-qualitative research design, 73% of the principles had employed a science subject specialist in their school. A further 6% of the principals had considered the use of a subject specialist. Ardzejewska et al. (2010) provided a case for employing specialist teachers in state primary schools in NSW and noted that this notion has wide support. It was reported by Masters (2009) that a large number of Australian primary schools have specialist science teachers, but he conceded that many of these are probably in independent primary schools which have links with high schools or are K-12 schools. At the current time, however, no data are available to support this claim although, anecdotally, this might be the case. He recommends that "ideally, every primary school teacher would be an expert teacher of literacy, numeracy and science" (2009, p. 73) and that the realisation of this ideal "should remain the ultimate goal". The appointment of a specialist science teacher to take overall responsibility for the implementation - and possibly the teaching - of the science curriculum in his/her school would be another alternative on this spectrum. This specialist teacher would interact with the classroom teacher in differing proportions and approaches as required by the school's learning environment.

2.11.4 Utilising Community Links and Mentoring

As a less costly alternative, Tytler (2007) gives examples of ways in which the needs of students in this century can be met through linking primary school science with outside communities. These examples include, engaging the assistance of local scientific experts to run special programme partnerships with industry and universities and organisations such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO) or school 'clusters' in which a small group of primary schools makes a commitment to share resources (in the broader sense of the word) for mutual support and benefit. Such liaisons would assist the generalist teacher in making up for deficits in his/her science knowledge.

Effective mentoring could also provide one very important part of the solution.

Hudson and Skamp have claimed that "primary science education reform [i.e., improved teaching practices] has not been successful to date" (2002, p. 20). They envisage the role of in-service teachers as being essential in "assisting preservice [and new] teachers to become agents of [this] science education reform" (2002, p. 20). Working with teacher colleagues who might or might not be formally considered to be mentors has the potential to positively influence the acquisition and consolidation of science content knowledge and, broader teacher effectiveness. The positive consequences of such interactions are described by Morgan (2012) in reference to the research carried out by a teacher-researcher during the period when a much larger Australian Research Council (ARC) project was being undertaken (p. 74) in the teacher-researcher's school and many other schools. This school was situated in a high socio-economic, metropolitan suburb and was supportive of teachers engaging in "innovative change practices" (p. 78) and practised a culture of teacher-research. Eight primary school teachers (four from the teacher researcher's school and four from another local school) completed a survey of their sense of well-being and competence as primary science teachers. The teacher-researcher investigated the question of how upper primary "students' achievement in science literacy [is] improved when teachers feel supported by an active and 'generous learning community' " (p. 79). The focus was on both teachers' well-being and self-efficacy beliefs/confidence levels and what they perceived to have been the achievements of their students in science. While the teachers reported their interest in science as relatively high, they also reported low ratings for content knowledge and confidence. The teacher-researcher considered that these levels indicated particular needs of the teachers and sought to investigate ways to address the needs through collaborations with other teachers. The study indicated that teachers benefited greatly from the interactions and dialogues in which they had participated with teachers from the school and other schools as part of focused learning communities during the broader ARC projects. Morgan (2012) reports that the teacher-researcher suggested that the school's primary teacher learning teams should meet:

…formally several times per term and with a focus on science now and then, including specific professional learning activities … [and] … to work with the district/regional hub groups especially in sharing [specific teaching]

experiences and those of implementing the Australian curriculum as it came into the school. (p. 87)

Another alternative lies in the setting-up of 'Communities of (science) Practice (CoPs)'. Smith (2009) describes the model of situated learning wherein engaging with a community of practice can assist learning as proposed by Lave and Wenger (2000). He quotes Wegner's definition of CoPs as being "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly" (2009, para. 5). There has been some success in improving primary teachers' confidence and content knowledge through the establishment of CoPs which utilise community links and mentoring strategies. In a CoP, some unintended learning can usually, and often does, occur. The primary school with its teachers, students and volunteer science 'experts' can be one such example of a CoP.

The Australian 'MyScience' primary science education initiative is an example in which participating teachers and their pupils - initially in NSW urban schools - become part of a broader CoP involving, ideally, local industry, business and university personnel. This model, which has been developed from a pilot programme in 2006, uses a team approach in which teachers and students work collaboratively on their science curriculum with mentor science experts. The programme was initiated in urban primary schools and attempted to provide settings to simulate those found in the rural Victorian school communities which took part in the Victorian 'School Innovation in Science' (SIS) project during 2000 to 2002 - a successfully set-up community-based project (Forbes & McGloughlan, 2010).

On the 'MyScience' website, it is stated that the 'MyScience' programme "aims to stimulate interest and enhance capacities of primary science teachers and students in conducting authentic scientific investigations" (Forbes & McGloughlan, 2010, p. 24). Most of the students' learning follows a science inquiry process into open-ended investigations. Some of the structures which are embedded in the 'MyScience' programme are designed to support the teachers' professional learning and pedagogy - designated as 'Elements 1 and 2' - which offer participating teachers opportunities to develop their science content knowledge and understanding (Forbes & Skamp,

2014). Analyses of the programme at various times since 2008 have demonstrated that teachers' content knowledge and their sense of self-efficacy have increased as a result of participating in 'MyScience'. The main source of data was interviews, which were supplemented by data from "field notes, conversations and email exchanges between the participants and one of the researchers" (p. 5). The following two statements were collected by Forbes and McCloughlan (2010) from participating teachers in 2008 and exemplify their attitudes. Firstly, " it's made me more confident in teaching the practical aspects [of science]" (p. 28); and, secondly, "my attitude has definitely changed. I am now a little more confident of teaching Science. Before I would say 'no way', I would teach anything but Science, but these days it's getting a little bit better" (p. 28).

A teacher who participated in the 2013 programme added:

> You really need (the mentors) because, that specialist interest or area of
> expertise was what enriched the program and gave it depth and allowed the
> children to focus on their area of interest ... a generalist (primary)
> teacher ... would find that quite difficult unless they had done some more
> science after high school ... I would hate to see the programme without
> [mentors] because I think that was of very high appeal to the children and
> for me". (Forbes and Skamp, 2014, p. 17)

The 'MyScience' project differs from other initiatives used in Australian primary schools in that it offers "a collaborative framework for learning science which appreciates the value of the socio-cultural nature of student learning" (Forbes & McCloughlan, 2010, p. 29). It embeds a practice of teamwork between "primary teachers, primary students and volunteer mentor scientists working collaboratively as the students conduct authentic scientific investigations to answer their own questions" (2010, p. 24). Other programmes identified by Forbes and McGloughlan (2010) are: the aforementioned 'Primary Connections' (which provides units of work for individual teachers to deliver to the students, professional learning opportunities

and support materials for teachers); CSIRO's Scientists and Mathematicians in Schools (SMiS) (which seeks to establish partnerships between interested teachers and working scientists); the Australian School Innovation in Science and Technology and Mathematics (ASISTM) program (which focused on community-based projects and ran between 2005 and 2008); and the School Innovation in Science (SIS) program (which focused on teaching and learning in the context of particular schools and their goals, and was run between 2000 and 2002) (Forbes & McCloughlan, 2010).

Working with science experts as mentors is not always a viable option. For teachers who work in provincial areas, physical isolation can also manifest itself as professional isolation (Smith, 2015) in which teachers might have little or no contact with colleagues. This can further result in teachers from these areas being unable to participate in formal professional learning activities. Having conducted research in the West of Ireland, Smith makes a statement to the effect that the physical isolation of teachers, because of the large distances between provincial towns and schools, is as important in the Australian context as it is in the Irish context and that "the isolation of teachers from their professional colleagues has been one of the more enduring challenges for teachers in small rural schools" (2015, p. 233). Based on research in 15 small provincial and isolated primary schools, Smith discusses the "critical" (2015, p. 232) importance of the setting up of CoPs or, as he puts it, "collaborative professional development programmes" (2015, p. 232) for teachers who are professionally isolated in provincial communities. Smith (2015) contends that such practices empower teachers, once a rapport and a level of trust has been established, to support each other in their own learning and in the implementation of improved classroom practices.

2.11.5 Utilising ICT-based Resources to Enhance Science Content Knowledge

Many primary school teachers seem to be "achieving well within the constraints in which they have to work" (Appleton, 2003, p. 21) - 'constraints' referring to their deficit in science knowledge. The literature is reviewed on how primary teachers can supplement their basic science content knowledge. As Moseley et al. note, many "research studies report the beneficial effects of the computer on pupil's literacy"

(1999, "Potential Benefits or 'Hotspots' for support with ICT" section, para. 1) and other skills. For primary teachers who need support with science content knowledge to enrich their teaching of science, the use of ICT-based science resources could be of benefit to both themselves and, ultimately, to their students.

In general, "people search for information for personal … or work purposes, but also in order to learn" (Puustinen & Rouet, 2009, p. 1016). When learners need to find relevant information they might either engage in 'help seeking' behaviours which were traditionally considered as an interaction with humans - or in 'information searching' (Puustinen & Rouet, 2009) - such as referring to books in libraries by themselves or, more recently, using searches on electronic devices. Puustinen and Rouet (2009) contend that the boundary between help seeking and information searching has become blurred since the evolution and availability of ICT-based resources, because humans - at least at the time of their writing - were ultimately responsible for the setting-up of ICT-based resources and search systems. They propose that these two pursuits are now on a spectrum of inquiry behaviours (2009). Additionally they note that "expert document searching requires self-awareness of one's information needs as well as the ability to assess when enough information has been acquired; … it is a self regulated learning activity" (p. 1016). Therefore, in order for teachers to initiate deliberate and targeted searches for science content through the use of ICT-based researches, they must be aware of their need to enhance their science content knowledge and what it is that they are searching for.

The searching for information via ICT can be referred to as a 'self regulated activity' but can also be labelled as Self-Directed Learning (SDL). This concept of teachers' SDL is "derived from adult learning theories that accommodate for the idea that teachers formulate their own learning needs and consequently direct the learning" (Louws, Meirink, van Veen, & van Driel, 2017, p. 172). Edmonson et al. (2012) attribute their definition of SDL to Knowles' (1975) work and define it as "a process in which learners take the initiative in planning, implementing, and evaluating their own learning needs and outcomes, with or without the help of others" (p. 40). Bonk, Lee, Kou, Xu, and Sheu similarly state that "self-directed learners take initiative related to their own learning with or without an instructor present" (2014, p. 350) when accessing new learning technologies or resources.

At this point, it becomes important to address the use of two terms which have been introduced in this review - 'self-initiated' and 'self-directed' learning. In their writings on modes of learning, Mocker and Spear (1982) briefly describe the large number of terms used for what is understood to be the same learning process. Some of the terms that they identify include, for example, "autodidactic learning", "self-directed learning", "self-teaching", "self-initiated learning" and "autonomous learning" (p. 11). They describe that, at that time, the "problem with terminology persists" (p. 11) in relation to labelling the process. They acknowledge that the trend was moving towards the use of 'self-directed learning' as more research was conducted into what was, at that time, a relatively new field. For the purpose of this thesis, the terms 'self-directed' and 'self-initiated' learning are understood to have the same meaning. That is, that "learners control both the objectives and the means of learning" (Mocker & Spear, 1982, p 25). However, both terms are used in accordance with their usage by the various authors as they are cited throughout this thesis.

Edmonson et al. (2012) conducted a meta-analytic review of papers in relation to adult learning and its relation with five other constructs, two of which are academic performance and curiosity. The papers reviewed had to meet certain criteria to be eligible for inclusion in the review (e.g., reporting Pearson correlation co-efficients between any one of five variables being studied - such as, for example, curiosity or academic performance - and SDL). One of their findings was that adult "students who effectively engage in SDL are more … curious" (p. 45).

In 2012, Bonk et al. conducted a study related to SDL online with 1,429 adults participating through a web-based survey. These adults had subscribed to open courseware through the Massachusetts Institute of Technology (MIT) and, whilst 44% were from the USA, the remainder was from around 12 countries worldwide. Bonk et al. referred to the vast selection of ICT-based resources now available to those seeking to find information through SDL and referred to them in three categories as "open educational resources (OER), open courseware (OCW) and massive open online courses (MOOCS)" (2014, p. 349). The researchers sought to document not only which online resources the participants preferred to use and their

actual informal learning experiences, but also to document what they achieved, their motivations and the hurdles that they faced in this type of SDL. They also acknowledged that, for 21ˢᵗ century learners, there is a multiplicity of online resources from which to choose to initiate and continue SDL motivated by work or other pursuits. One of their major findings which related to my study is that there are so many online resources available that SDL is "not without significant challenges today. Among the key obstacles … [is] the lack of time to utilise the vast resources at [the participants'] fingertips" (2014, p. 362). For teachers who are 'time poor' this alone can present a major challenge.

Tour (2016) outlines different forms of professional learning that have emerged over time and are available to teachers. These include, but are not limited to, seminars and conferences, "ongoing professional learning within schools, … learning communities at schools … [and] online … and blended models of professional development" (p. 179). The use of ICT-based resources to enhance content knowledge is a form of self-initiated professional learning which can assist primary school teachers in enhancing their science content knowledge. Tour (2016) investigated the self-initiated professional learning related to the online learning of three teachers through "what they called personal learning networks (PLNs)" (p. 180). She describes a PLN as "an informal group of like-minded people who share their knowledge and provide resources and the advice to guide learners in the independent learning experiences in different digital spaces" (p. 181). Tour's study of PLNs was a subset of a larger project which investigated the everyday digital literacy practices of five language and literacy teachers in Melbourne, Australia. Her study was based on three of these teachers over a five-month period as they employed self-initiated professional learning through their PLNs. These teachers defined a PLN as "an informal network of teachers that helped them to learn" (p. 183). For example, one of the teachers used 'Twitter' frequently for professional reasons such as research, for work and for professional sharing. None of her personal friends were included in this tweeting, only those in her professional group. The data for the study were collected using photography, open ended-interviews and "online observation of the participants in the digital spaces of e-learning (e.g. 'Twitter', blogs, 'Facebook' and social bookmarking services)" (p. 183). Tour (2016) found that the participants often used their PLNs to exchange information and resources and to collaborate on common

tasks. Tour postulates that "the findings that the participants found self-initiated professional learning important, meaningful and valuable suggested that there is a need to increase teachers awareness about PLN's" (p. 190). This research suggests that there are many possibilities available to primary school teachers to organise and use PLNs - be they setup through 'Twitter', 'Facebook', 'Pinterest' or other social platforms - as opportunities to assist themselves in enhancing their science content knowledge.

Some of the actions suggested by Morgan (2012), which stemmed from her research on teacher well-being and efficacy in an Australian primary school, have already been highlighted in a previous section. However, another of Morgan's actions is more relevant to this section's discussion. The teacher-researcher who worked with Morgan suggested that teachers develop a '21st Century Ning' as a shared chat site "for engaging with science issues, and using it as an ongoing professional learning opportunity" (p. 87). Such shared sites have the potential to allow teachers, both pre- and in-service, to exchange not only science content knowledge information or draw to other teachers' attention where it can be found, but also to share information of importance to colleagues teaching primary science. Expanding on the findings published in 2016 in relation to research about online learning, Tour (2017) further elaborates on her study of teacher usage of PLNs and self-initiated learning in digital spaces. She notes that "teacher's professional learning could benefit if teachers are given opportunities to form their own professional networks and engage in learning that is social in nature, based on co-operation, collaboration and communication" (p. 17). Such learning could not only allow the teachers to improve the use of technologies but also to develop other aspects of their professional practice "such as mentoring and leadership" (p. 17).

Despite the fact that there is now a large body of ICT-based science resources available to support Australian teachers in their lesson planning or the delivery of science lessons, many teachers are still possibly unaware of their existence or do not access these for a variety of reasons. As noted above, a number of such resources exist which have not been specifically designed for this purpose, but which can be utilised to assist teachers in enhancing their content knowledge. According to Bebell, Russell, and O'Dwyer (2004) and Sugar, Crawley, and Fine (2004), although many

teachers avail themselves of these technologies, many more do not. In particular, teachers might not maximise the use of ICT-based science resources to foster knowledge and understanding of science for both themselves and their students. For a number of reasons, this might hold to be particularly true in Australian provincial schools compared with metropolitan schools. In a conference presentation, Blackmore (2013) recommended that it is of "upmost [sic] importance that trainee teachers are encouraged to examine their own efficacy and to 'self-regulate' to maximise their potential" (p. 2). Can this be extrapolated to apply to all primary teachers throughout their careers? As quoted earlier, Veal and McKinster stated that the deepening of expert knowledge in science "promotes the idea of a teacher as a life long learner" (1999, p.11). Therefore, for generalist primary school teachers, making effective use of ICT-based science resources could be a convenient, up-to-date, continuously accessible and cheap means of assisting with enhancing their science content knowledge.

2.12   Chapter Summary

Societal demands influence changes in science teaching in schools (Fensham, 2016) and the Australian Government aspires to make Australia one of the top-ranked countries in the world for performance in reading, science and mathematics by 2025 (Department of the Prime Minister and Cabinet, 2012). Typically, primary school teachers in NSW are generalist teachers and their limited science content knowledge and limited knowledge of science inquiry skills have been a common theme through the literature for many years (Angus, Olney & Ainley, 2007; Morgan, 2012). Sound knowledge of subject matter is an important component of effective teaching (Smithey, 2008) and teachers' low levels of science content knowledge can be among a number of factors which contribute to the low status of science in primary schools (Allen, 2006; Crook & Wilson, 2015; Murpy & Beggs, 2005). The intrinsic and extrinsic factors - shown in Figure 2.2 - which can influence the teaching of science in a school, and which can influence the teachers themselves, have been identified throughout this literature review.

Many primary teachers have a tendency to share society's negative view that science

is a difficult subject (Harlen, 1993), generally don't like the subject (Coburn, 2016) and/or perceive themselves as being inadequate to teach science (Victorian Auditor General, 2012). Teachers' low levels of science-teaching efficacy or confidence (Crook & Wilson, 2015) can negatively affect how much time they spend teaching science (Morgan, 2012). Anderson (2002) states that it is desirable that primary teachers have high levels of self-efficacy to assist in maximising their students' learning. The time spent preparing primary students for the NAPLAN high-stakes testing has also been shown to impinge on the time spent teaching subjects such as science (Dulfer et al., 2012).

Many avenues are available to address the concerns around primary teachers' limited science content knowledge. Initially, this can be through improved pre-service teacher training courses (Kervin & Turbill, 2003; Rice, 2003; McKenzie et al., 2014). In-service primary teachers can improve their own science content knowledge through self-directed learning (Edmonson, Boyer & Artis, 2012) which can be influenced by their levels of curiosity and perceptions of knowledge levels (Litman et al., 2005). They can also seek to engage in various types of professional learning (Schibeci & Hickey, 1996; Smith, 2015) which can also include the use of online platforms (Tour, 2017).

Other solutions to assist those teachers who have a deficit in their science content knowledge include utilising community links and mentors (Tytler, 2007) and employing specialist science teachers in primary schools (Ardzejewska et al., 2010). Primary teachers also have access to ICT-based resources to assist them in enhancing their science content knowledge (Morgan, 2012; Tour, 2016). Tour (2017) states that to the "best [of her] knowledge, there is no [specific] research about self-initiated professional learning online and teachers' professional learning in particular" (p. 12) outside her own. Although Anderson (2015) makes brief mention of two New Zealand primary teachers who, during her study, endeavoured to develop an aspect of their science content knowledge "through reading and searching the internet" (p. 416), there appears to be no specific literature on teachers' use of ICT-based science resources to enhance their science content knowledge. My research makes a contribution to addressing this gap.

Chapter 3: Research Methods

3.1 Introduction

This chapter details the methods employed to conduct a study addressing the research questions as iterated in the Introduction chapter. The primary focus of this research was to investigate NSW primary school Stage 3 teachers' use of the range of ICT-based science resources now available to them for the purpose of educating themselves in science content to enhance their existing knowledge..

The research was carried out in three phases. Phase I involved both principals and teachers across a range of NSW primary schools being surveyed to obtain data on each school's general demographics, its philosophies/policies related to teaching science, any factors affecting the teaching of science in those schools, and how much time was being devoted to teaching science at the Stage 3 level. This is the only stage of the research in which school principals were involved in data collection. Because they were not required to answer any further questions during the research, it was necessary to separate this section from the rest of the survey questions. Some of the data that the principals provided were used to inform the research in relation to the school environments in which the teachers were working. Subsets of these data were also used in the triangulation of data provided by teachers in the surveys and interviews.

In Phase II, one or more teachers of Stage 3 students from a subset of the primary schools - i.e., in a smaller sample of the NSW primary schools which participated in Phase I - were surveyed. This phase aimed to examine teachers' education backgrounds, their confidence in teaching science, and their participation in PL activities. It also specifically examined teachers' uses of ICT-based science resources to enhance and supplement their own science content knowledge.

In Phase III, a sample of participants was interviewed on the same major themes as those in the surveys to gain a deeper understanding of each teacher's school environment and to give more depth to the issues surrounding the enhancing of their science content knowledge. This phase was conceptualised during the data collection of the Phase II surveys - and extensions of ethics approvals were sort accordingly - after it was decided that interviews were needed to add depth and richness to the survey data. Therefore, it became a distinct phase of the research. Some data from this phase contributed to triangulation. These phases are summarised in Table 3.1.

Data collection began during 2013 and continued into mid-2015 when the last of the teachers' logs was submitted and the interviews were completed.

Table 3.1. Instruments used and participant groups in each research phase.

	Participants		
Instruments	Phase I	Phase II	Phase III
Surveys	Principals & teachers	Teachers	
Log-keeping of ICT-based science resource use		Teachers	
Interviews			Teachers

3.2 Research Paradigm

In his 1990 work, Guba (p. 17) refers to the lack of a clear definition of the term 'paradigm' - or 'model' - at that time, and used the term in a very general sense to mean "a basic set of beliefs that guides action ... taken in connection with a disciplined inquiry". Hammersely expresses the opinion that, in reference to modern research methodology, 'paradigm' has evolved to encompass a "set of philosophical assumptions about the phenomena to be studied, about how they can be understood, and even about the proper purpose and product of research" (2012, p. 2). He further comments on the changing nature of research away from the previous situation - in which particular disciplines adopted just one prevalent methodological approach - to the situation in which we now have "a large and complex field in which work of

sharply different kinds is carried out, accompanied by debates in which a disparate collection of theoretical and methodological labels are deployed" (2012, p. 1). Arguably, this shift occurred in the mid-19th century.

A paradigm is characterised by Denzin and Lincoln (2000, p. 22) as "the net that contains the researcher's epistemological, ontological and methodological premises". The four most common paradigms used in the literature are those of 'Postpositivism', 'Constructivism', 'Interpretivism', and 'Critical Theory'. Another paradigm, 'Pragmatism', has gained prominence in the literature especially in research related to "social, educational and health fields" (Glogowska, 2011, p. 253). Other paradigms are used across different disciplines, including 'Positivism', 'Feminism' and 'Postmodernism'. Each of these philosophical stances is characterised by its particular ontological, epistemological and methodological viewpoint as discussed below. Guba further notes that a researcher's chosen paradigm provides a starting point which determines the direction of the inquiry and "how it is to be practiced" (1990, p. 18). Denzin and Lincoln (2000) rephrase this in terms of the paradigm informing the selection of method, participants and instruments to be used throughout a particular piece of research.

As far back is 1979, Reichardt and Cook claimed that there is no reason for researchers to be constrained to either one of the traditional, though largely arbitrary, paradigms when they can have the best from more than one (1979, p. 19). Glogowska argues that the boundaries between the different paradigms, which were once "entrenched" and "polarized" (2011, p. 252), have in more recent times become blurred. Mingers (2001) also offers a similar argument for combining research methods by stating that "rather than advocating a single paradigm, … or even a plurality of paradigms … research results will be richer and more reliable if different research methods, preferably from different [existing] paradigms, are routinely combined together" (p. 240). The philosophical assumptions relating to my research are informed, for the most part, by an interpretivist paradigm with a blend of data-collection from the pragmatist paradigm.

The interpretivist paradigm involves a relativist stance and emerged as a response to traditional empiricism which is based on an objectivist epistemology and uses

empirical experimentalism - or an approximation of it (Guba, 1990). Interpretivism grew from "an insistence that there is a fundamental difference between the nature of the phenomena" (Hammersley, 2012, p. 22) which is researched by the natural scientists as opposed to those phenomena which are studied by, for instance, researchers in the education field or similar related disciplines. Therefore, people derive meaning from or give meaning to both themselves and their surroundings. People's circumstances and the society in which they live and interact influence how they derive this meaning. The meaning itself can, in turn, have an impact on the ways in which people further interact with their surroundings which might include, for example, their interactions within organisations of which they are members as well as the organisations themselves. Hammersley explains that inanimate objects or indeed "most non-human forms of life" (2012, p. 22) are unable to do this.

On the other hand, "pragmatism is concerned with action and change and the interplay between knowledge and action" (Goldkuhl, 2012 p, 136); …"pragmatism means pluralism, but not all pluralism is pragmatic" (p. 141). Johnson, Onwuegbuzie and Turner assert that "the primary philosophy of mixed research is that of pragmatism" (2007, p.113) and that "pragmatism offers an epistemological justification (i.e., via pragmatic epistemic values or standards) and logic (i.e., use the combination of methods and ideas that helps one best frame, address and provided tentative answers to one's research question[s]) for mixing approaches and methods" (p.125). Johnson et al. note that mixed methods research is not new, and was incorporated into the work of, for example, anthropologists during the early 20th century and prior to that. However, it is now recognised as a new research paradigm "that has arisen in response to the currents of quantitative research and qualitative research" (2007, p. 113). Mackenzie and Knipe add to the paradigmic discussion by stating that "pragmatism is not committed to any one system of philosophy or reality" (2006, para. 9). The pragmatist paradigm is usually characterised by the use, primarily, of quantitative and/or qualitative methods which may also include the data collection tools from the other paradigms (e.g., interviews, tests, experiments, observations and surveys) (Mackenzie & Knipe, 2006) to name a few. In a pragmatic approach, the methods are chosen to suit the research questions and purpose.

As stated by Hammersley, interpretivists argue that researchers are not able to understand why people carry out their actions, or "why particular institutions exist and operate in characteristic ways" (2012, p. 22), unless they are able to understand the ways in which those involved interpret their own world. The researcher must understand the particular nature of participants' perceptions, attitudes and beliefs. Research methods focused on the improvement of personal development and/or of professional practice can be encompassed within some interpretations of Interpretivism (Hammersely, 2012). Some writers argue that educational research should be of educational value and Hammersely notes that "educational research must itself be educative in character, that it should be concerned with realising educational ideals or achieving educational outcomes, rather than simply producing educationally-relevant knowledge" (2012, p. 23).

As a point of contrast between pragmatism and interpretivism, which are oriented differently with respect to their epistemologies, Godgkhul (2012) contends that pragmatism has an empirical focus on actions and change - emphasizing constructive knowledge - and that the research is focused on change, while interpretivism has a focus on beliefs and the research is focused on understanding. Both paradigms, therefore, could inform my research to different degrees, in that it aimed to understand the position of the participants within their work context (interpretivism), as well as to focus on enhancing their science content knowledge and suggesting ways in which this can be achieved (pragmatism). Notwithstanding this, interpretivism was the dominant paradigm in my study.

My research involved the way in which teachers were coping with a particular situation in their professional employment, namely, how they were using ICT-based science resources and/or professional learning to enhance their science content knowledge. It also attempted to illuminate how the participating teachers perceived and interpreted this particular situation, including their attitudes towards it and their interests and attitudes towards improving themselves, as well as whether or not they felt that their science content knowledge was inadequate. In keeping with this paradigm, it is important to note that, throughout this research, the researcher did not impose her own prior assumptions on the data - an important feature of conducting research under the interpretivist paradigm.

This research was informed by an ontology which is concerned with the philosophical nature of being or reality (Guba, 1993): what exists in society - or system - and that which can be learned about it. According to this ontology, reality is influenced by the research's context and is, therefore, subjective. It results from the individual's perceptions of his or her own experiences and social environment. This viewpoint contends that the socially constructed reality is a consequence of the many interactions between the researcher and the participants (Ponterotto, 2005), but that such interactions are "central to capturing and describing the 'lived experience'... of the participant" (Ponterotto, 2005, p. 131). Therefore, with a number of participants (who each has his/her own perspective) and one or more researchers (who, in turn, each has his or her own perspective) - as was the case in this study - there would be multiple realities. Each of the individuals establishes his or her own reality from his or her life experiences. In a study such as this, the researcher is aware of the importance of the perceptions and values held by the research participants. The revelation of these aspects of the participants gives the researcher the potential to explore and interpret the collected data. As pointed out by Mulholland and Wallace, the realities established by the presentation of the participant's lived experiences is finally arrived at after a 'reflective hermeneutic' cycle of writing, thinking and discussion (2003, p. 881). In this study, this involved a series of surveys for the broader group - some of whom also kept logs for a short time - followed by interviews with a subset of the participants to assist with establishing the realities of those participants.

Interpretivists maintain that there is no objective knowledge. This arises out of their assumption that it is the subjective interpretations of a study's findings that give rise to the meaning and knowledge gained. Interpretivists would further argue that knowledge is determined by a researcher's perspective on reality and, therefore, truth (Schwandt, 1994). As a consequence of this approach, a specific perspective forms the basis of the truth. Encapsulating and describing the participants' life experiences is an integral part of the interpretivist's research and these interactions with the researcher, which capture these experiences, form the basis of what interpretivists consider to be a socially constructed reality. Anderson refers to the research findings of Merriam in 2001 and Stake in 2006, and notes that the major focus of the

qualitative aspect of the interpretivist's approach "is to understand a phenomenon from the participants' perspective and the context in which it occurs" (2015, p. 402). This epistemology, that is, the relationship between the participants of the research and the person conducting the research - referred to as "the knower" and the "would-be knower", respectively by Ponterotto (2005, p. 131) - has informed my research and the epistemological knowledge acquired was derived from the interactions within this relationship.

Mackenzie and Knipe (2006) contrast this by commenting that pragmatic researchers investigate the 'what' and the 'how' as the focus on the research problem and note Mertons' (2005) assertion that "early pragmatists rejected the scientific notion that social inquiry was able to access the truth about the real world solely by virtue of a single scientific method" (para. 9). While the interpretivist paradigm predominantly uses methods of data collection such as interviews and observations, Mackenzie and Knipe note that "it may in fact be possible for any and all paradigms to employ mixed methods rather than being restricted to any one method, which may potentially diminish and unnecessarily limit the depth and richness of a research project" (2005, para. 14). By way of illustrating the blending of paradigms, Goldkuhl draws attention to one research school which utilises a blend of interpretivism and pragmatism (p. 142) - the sociological school of symbolic interactionism - and notes that the interpretivists and pragmatist paradigms have some common ontological assumptions underlying them. These can be summarised by the phrase "meaningful action based in evolutionary social interaction" (p. 142). On the other hand, there are some characteristics which typify differences between the epistemological orientations. For example, "the key character of the interpretive knowledge is understanding, while for pragmatism, constructive knowledge is emphasised" (p.142). Goldkuhl cites as an example of how "elements from pragmatism and interpretivism can be mixed" (2012, p. 143), by describing a research project which was based on an action and design-research inquiry into the distribution of welfare payments though a number of government bodies.

Mackenzie and Knipe agree with this stance on blending paradigms in saying that:

> many researchers … now use qualitative and qualitative methods as

complementary. … while some paradigms may appear to lead a researcher to favour quantitative or qualitative approaches, in effect, no one paradigm actually prescribes or prohibits the use of either methodological approach. (para. 22)

Johnson et al. agree with this assertion in stating that a pragmatist "would claim that research paradigms can remain separate, but they can also be mixed into another research paradigm" (2006, p. 125).

3.3 Methodology for the Research

Noorderhaven elucidates the distinction between 'methodology' and 'method'. He defines "a research 'methodology' as a system of ontological and epistemological assumptions on which research is to be based" (2004, p. 91) and "a research method is a particular strategy for collecting and analysing data" (2004, p. 91). 'Methodology' is defined by Schwandt as

… a theory of how inquiry should proceed. It involves analysis of assumptions, principles and procedures in a particular approach to inquiry (that, in turn, governs the use of particular methods). Methodologies explicate and define (a) the kinds of problems that are worth investigating, (b) what comprises a researchable problem, testable hypothesis and so on. (2001, p. 161)

Schwandt also itemised how 'methodology' addresses ways in which the problem should be "framed" (2001, p. 161) so that it is able to be investigated using appropriately chosen data collecting procedures; how matters relating to generalising the results should be considered; and how the arguments surrounding the analysis of the data are logically proposed.

The methodological question is: "How should the inquirer go about finding out knowledge?" (Guba, 1990, p. 18). According to the Faculty of Humanities Study

Skills section of the University of Manchester's website the term research 'methodology' implies "more than simply the methods you intend to use to collect data. It is often necessary to include a consideration of the concepts and theories which underlie the methods" (2016, n.p.). According to Mackenzie and Knipe, a survey of definitions of the term 'research methodology' which are most commonly used "suggest that methodology is the overall approach to research linked to the paradigm or theoretical framework while the 'method' refers to systematic modes, procedures or tools used for collection and analysis of data " (2006, para. 2). They further note that other researchers argue that the research is provided with a frame of reference by the methodology, and that the theoretical perspective of the paradigm in which the researcher is working influences this. The paradigm within which the researcher works casts a critical influence on the methodology. Ponterotto agrees that "the researcher's paradigmic, ontological and epistemological positions [can influence the research methodology]". He defines 'methodology' as the "process and procedures of the research" (2005, p. 132).

Methodology pertains to the research theory and the subsequent way in which the research is designed. It provides the explanation behind the research questions and why they are important. A methodology delineates the starting point and the direction of the research and justifies the approach that the researcher follows. The reasoning behind the selection of the particular methods of data collection used is also justified by the methodology. Some methodologies can also have inbuilt implications on the completion of the research.

The mixed research methodology employed in my research is mainly in keeping with the interpretivist assumption that knowledge and the meaning gained from studies are based on subjective interpretations, and that there is no objective knowledge. Knowledge is always relative (Livesey, 2006). In addition to this, interpretivists argue that one's perspective on reality determines knowledge and, therefore, truth (Schwandt, 1994). It is, therefore, important to capture and describe the life experiences of participants in relation to the research focus. According to Davison, "the methodology that is best suited to the problem under consideration, as well as the objectives of the researcher, should be the one chosen" (2005, p. 3-3). Therefore,

a mixed research methodology was the methodology which best suited the intentions of my particular research project.

Quantitative and qualitative techniques can be employed to differing degrees in the same study. A mixed methodology is sometimes an appropriate and attractive alternative to purely quantitative or qualitative methodologies because it involves a broad range and depth of data types. According to Kiessling and Harvey, this combination of quantitative and qualitative approaches maintains "methodological rigours as well as measures for reliability and validity" (2005, p. 22), and argue in favour of mixed method research, where appropriate, because as it adds the "fabric required" (2005, p. 22). Traynor (2007) notes that the qualitative dimension enables the researcher to add richer illustrations of what can be quite complex situations and that - through the use of interviews, for example - it also allows the participants to give voice to the issues investigated. Later, Glogowska (2011) adds to the justification by noting that, among other benefits, using mixed methods research allows the researcher to construct a more "comprehensive picture: where using a combination of quantitative and qualitative methods can allow a phenomenon to be described and explained broadly and comprehensively" (p. 153). It also allows for greater validity by permitting the checking of findings of different methods against each other, and for one method to enhance and/or facilitate the use of another. It gives the research depth and the researcher the flexibility needed in some areas of the research.

Onwuegbuzie and Teddlie, proponents of mixed research, ground their work according to the "fundamental principle of mixed research" (2002, p. 352). They define this principle as "the use of quantitative and qualitative analytical techniques, either concurrently or sequentially, at some stage beginning with the data collection process, from which interpretations are made in either parallel, an integrated, or an iterative manner" (2002, p. 352). When used in a single study, the mixed research design procedure involves collecting and analysing blended qualitative and quantitative data in an attempt to understand the problem that is being researched (Creswell, 2008). Creswell emphasised that this combined approach "provides a better understanding of the research problem and questions than either method by

itself" (2008, p. 552) and cites previous research in claiming that it is a "legitimate inquiry approach" (2008, p. 552).

3.4 Design of the Research

The research was carried out in three distinct phases. In Phase I, principals and teachers were surveyed to establish each school's demographics and some aspects relating to its culture. Each teacher was again surveyed in Phase II to establish his/her level of confidence, educational background and use of science resources - particularly those which were ICT-based - to enhance their science content knowledge. Log-keeping of ICT-based resource-use was incorporated into this phase. Interviews with a subset of the participating teachers were conducted in Phase III to elicit more detailed information about the areas surveyed in Phases I and II and, additionally, to allow triangulation of some of the data. The participation of principals and teachers was shown previously in Table 3.1 while the numbers of teachers in each phase is shown in Table 3.2.

Table 3.2. Numbers of teachers participating in each research phase.

| Sector | Number of teachers in each Phase | | | |
| | Phase I | Phase II | | Phase III |
	Surveys	Surveys	Logs	Surveys
Metropolitan	29	29	6	5
Provincial	18	18	5	5
Total	47	47	11	10

3.4.1 Data Sources

Schools were selected using disproportionate stratified random sampling. In this method of sampling, the researcher divides the total population into discrete subgroups or strata. From these subgroups, the researcher is able to randomly select the participants to be studied. There was no overlap between the members of the strata populations. This method was used to allow the researcher to "observe existing relationships between two or more subgroups" (Castillo, 2009, p. 1) and to "sample even the smallest ... subgroups in the population" (Castillo, 2009, p. 1). For this study, the total population was all primary schools in NSW, including the primary sections of some larger Kindergarten to Year 12 schools. The group was firstly

divided into 'metropolitan' and 'provincial' on the basis of the Australian Government's 'My School' website's classification. To provide a balance between the three education sectors, these two groups were further subdivided into three approximately-equal groups of schools: NSW Government DEC Public; Catholic Systemic; and Independent primary schools. This was intended to provide six mutually exclusive study groups which each contained approximately equal numbers of schools. This sampling technique is labelled 'disproportionate' because the sampling fractions do not represent the proportions of the schools in each of the provincial/metropolitan and State/Catholic Systemic/Independent sector strata. Because, this study did not differentiate the teachers and the schools where they taught on the basis of them being from a particular educational sector - that is, proportionate representation was not necessary - this sampling technique was selected as the best choice for this research.

As noted earlier, targeted schools were selected before submissions were made to the relevant education bodies for permission to conduct research. This occurred because most of these bodies required their targeted schools to be named as part of the application process. Using the 'My School' site as a guide, the boundary between provincial and metropolitan school areas in NSW was ascertained. It is necessary to note here that the categories of 'remote' and 'very remote' as used on the 'My School' site were combined under the umbrella term of 'provincial' to distinguish them from schools in metropolitan centres. Within each of these two categories, a similar number of schools from each of the three sectors were chosen and contacted. A cross-linked coding identification process was employed between all phases to enable the researcher to re-contact participants from some of the Phase I schools for participation in Phase II - the surveys and log keeping - and the Phase III interviews. To ensure the anonymity of the participants, all data were de-identified after the completion of the data collection and analysis.

3.4.2 Research Instruments

Before the research instruments were designed, it was necessary to define the term 'science'. For the purpose of the K - 6 syllabus, The Board of Studies NSW (BOS NSW) Syllabus and Support Document defines 'science' as:

… being concerned with finding out about the world in a systematic way...

[It is] ... not just a body of knowledge but is also a process of investigation

... [whereas] ... technology is concerned with the purposeful and creative use

of resources in an effort to meet perceived needs or goals. (1993, p. 1)

In designing the research instruments, the distinction between the KLA name of 'Science and Technology' and 'science' content - the main focus of this research - had to be kept in mind. Even though the KLA is called 'Science and Technology', the use of the full title in certain questions was a condition of ethics approval for one education sector's governing body. Where questions related to the teaching of the KLA, or to resource-selection and use, or to some PL courses, then the full name was used to avoid confusion for the participating teachers. However, where the questions were focused on the actual science component of the KLA, the terms 'science knowledge' or 'science content' were used. The questions in the surveys and interviews were worded as carefully as possible in this way to avoid misinterpretation of the question's intent.

One focus of the piloting process had been to minimise the possibility of such misinterpretations occurring. The survey responses, however, do seem to indicate that the teachers were aware of the fact that the questions were only in relation to the teaching of the science component. In this way, the chances of misinterpretations becoming a limiting factor in the data collection were minimised as much as possible. Many resources accessed by teachers and PL courses attended, - including those originating in NSW - for example, still simply use the term 'science' and teachers frequently make the distinction between the KLA name and the 'science' discipline subset.

As mentioned previously, the research was undertaken in three distinct phases using a number of instruments. Collecting data via different instruments added depth and allowed triangulation of data. As all methods of data collection have in-built errors, the use of triangulation across these sources assisted in achieving more reliable and

meaningful findings. Both quantitative and qualitative methods were used in this research, and conclusions were drawn from each of these methods. Correspondingly, these conclusions were reinforced by the conclusions from the data sets obtained through the other methods to assist in establishing the overall validity of the study's findings. This particular process of triangulation is referred to by Guion (2002) as 'methodological triangulation' while it is often referred to by post-positivists as 'critical multiplism' (Guba & Lincoln, 1998).

3.4.2.1 Strengths and Limitations of the Types of Data Collection Methods Employed

In this research, the surveys were partly designed using some questions written by the researcher to explore areas where no instrument was available; and in some sections, the questions were based on previously designed and validated questionnaires as discussed further below. These surveys were used to provide data to address the five research questions. All participants were also requested to keep a log of their use of ICT-based science resources to supplement their own science content knowledge over a four-week period. As noted above, a smaller cohort participated in subsequent interviews. The strengths and limitations of employing each of these methods of data collection are discussed below.

As used in this research, surveys have a number of strengths that are important to consider. Firstly, they can be administered in a relatively short time (Creswell, 2008); and, as is the case for this study, surveys do not have to be administered in the presence of the researcher. Both of these attributes ultimately saved time for either the participating teachers and/or the researcher. Furthermore, and relevant to this research, employing surveys which did not take too long to complete was a positive step because they were being completed by teachers who had limited time. Many teachers would not be inclined to complete long, painstaking surveys. Surveys can be completed at a time which is convenient for the participants, and this feature was of particular importance in my research because busy teachers have very full days at work but might find time to complete surveys at their leisure when at home.

Further strengths of surveys include their usual cost-effectiveness as a means of data collection. The 'Survey Monkey Gold' software used for some of the data collection in this study was purchased because of its reasonable price, easy accessibility for teachers, and saving the researcher time and potential travel and/or postage costs for distributing and collecting the surveys. Surveys are also useful for targeting a large number of participants who are widely spread geographically (Creswell, 2008) as was the case in this instance with teachers working in schools distributed across NSW. Thus, the need for the researcher to travel to schools over long distances was eliminated, while this technology allowed the inclusion of these participants.

Adding to their strengths, surveys can be formatted in such as way that they can be sent and returned either as hard-copies or electronically as required by the circumstances. Some of the participants preferred to complete the Phase 1 surveys for this research online and return them to the researcher by email, while others preferred to download, print, complete them by hand and return them either by email or post. It was hoped by the researcher that this level of flexibility would be of assistance to the participants. Because, as mentioned above, surveys can be self-administered, this aspect was likely to encourage participants to complete them. Self-administration is likely to eliminate any biases which might exist if the researcher were to administer the survey in person (Creswell, 2008). Because the researcher was not present with any of the respondents for the completion of the surveys, these two advantages are likely to hold true.

Furthermore, surveys can eliminate subjectivity problems if closed questions are used. For example, either the teachers have a degree in science or they do not, and there is a fixed number of computers available in a school. Wherever possible, the questions were phrased so that they wouldn't influence the participants' responses. In relation to this point, and for this particular research, surveys can be structured in such a way that the answers to many of the questions do not need to be interpreted by the researcher. It is also possible that survey answers can be categorised to fall within ranges determined by the researcher. For example, a school has a population number within a given range or teachers have teaching experience within certain ranges of

years, etc. Much of these data can be quantified for analysis (Creswell, 2008). Wherever applicable, the data collected in this study were analysed quantitatively.

In contrast to the above, surveys can have a range of limitations. There can be difficulty in framing unambiguous questions to elicit the best responses and to avoid misinterpretation. This is a common problem which can sometimes be challenging for survey writers (King, Murray, Salomon, & Tandon, 2004). It was evident from the types of responses given to some questions that, in this case, there might have been some slight ambiguity in some of the survey questions: that is, a number of the respondents read more into the question than was needed. There is a further possibility that some questions would have had highly subjective answers which could be difficult to interpret and, therefore, the biases of the researcher might skew their interpretation (Creswell, 2008). Where this might have been the case, these answers were included in the results and it was acknowledged in the discussion that they could have been misinterpreted.

A large number of respondents is often required in order to allow the extrapolation of responses to the broader population represented by those surveyed (Sheehan, 2006). As there was a relatively small number of respondents in this study, this aspect was commented upon and it was noted that it was not possible to generalise the results to the broader Stage 3 teaching community. In relation to the latter limitation, this possibility, and the resulting complications, of low response rates (Sheehan, 2006; Welsh & Barlau, 2013) is addressed in more detail in Chapter 5. Respondents were able to leave unanswered, survey questions that were not applicable to them - particularly in Phase II. Such questions were, therefore, not included in the mandatory fields. Where answers were analysed quantitatively, this was based only on the number of teachers who had responded. Walsham points out that "interpretive does not equal qualitative" (2006, p. 323) and that quantitative data gained from surveys are "perfectly valid inputs for an interpretive study" (2006, p. 323).

The collation and analysing of data collected from surveys can be inherently time-consuming. In this study, the use of 'Survey Monkey Gold' software aided the analysis of some of the questions for presentation in graphical or diagrammatic form.

Other answers could be exported into an 'Excel' spreadsheet for analysis. Some answers, however, were still time-consuming to interpret.

Finally, there is the possibility that some important aspects of a research question could be answered inadequately or overlooked if the questions are not framed appropriately. Survey questions which are not open-ended "do not control for the many variables that might explain the relationship between the independent and dependent variables" (Creswell, 2008, p. 414). This eventuality was accounted for by using a large proportion of questions that were taken directly from, or were adapted from, pre-validated surveys. Many of the other questions which were not open-ended - for example, identifying ICT-based science resources or for how many years the teachers had been teaching - largely had quantifiable answers. Questions which did not fit either of these two descriptors were analysed with this in mind. The research also required some of the participants to record the amount of time which they had spent using the ICT-based science resources they had identified, and how often these resources were used to assist in the enhancing of their science content knowledge. Some aspects of these limitations are discussed further in the 'Limitations of the Research' section of the Chapter 6.

Participating teachers were also requested to keep a log or diary of their use of ICT-based science resources over a period of time. As is the case in relation to surveys, logs or diaries also have strengths and limitations which are commented upon below. As in this research, logs or diaries have merit in that they can be completed after each successive usage of ICT-based science resources. The interactive logs in my research were designed to be populated using a cut-and-paste method immediately after each usage if teachers chose to do this rather than have a printed log into which entries were handwritten. Other information surrounding the use, such as the teacher identifying each site as a 1, 2 or 3, was easy to record. This avoided the researcher and participants waiting for an interview some time later to report all of the details. Additionally, because not all teachers were interviewed, the logs allowed the collection of a maximum number of responses.

Logs and diaries can be emailed to the researcher for progressive monitoring if required. This point is similar to the advantages of using electronic surveys as

discussed above. However, as it became evident that it would be difficult to encourage teachers to complete and return the logs completed over the desired period of time, it was thought prudent not to require staged filling-in of the logs. Keeping a log can, as is the case in this study, draw the user's pattern of the monitored behaviour to his or her attention (University of Sheffield (US), 2016). In the case of this study, a participant might then reflect on his/her ICT-based science resource usage for enhancing content knowledge. Although this could ultimately be a beneficial process for the participant, there is a danger that this would become a limitation of the use of completing a log by changing the participant's behaviour (Iida, Shrout, Laurenceau, & Bolger, 2012).

There is also a number of limitations to using a diary or log. These include the participant not entering each use of ICT-based science resources and/or losing motivation as time progresses. This was probably the case for some of the teachers who were initially very enthusiastic about completing the logs but who, eventually, submitted either partially-completed logs or nothing at all. Furthermore, as completion of logs was at the participant's discretion and good will, the participant might return a completed log covering a reduced period of time. This, indeed, was a distinct possibility, and another reason why some logs were not returned. The original time period for the log completion was six months. The reasons for shortening the period to one month, and why logs kept over a shorter period were analysed are discussed later in this chapter.

Further limitations of these methods of recording behaviours - and relevant to my study - were that a participant might include ICT-based resources that were not related to the purpose of the research. Therefore, such usage was excluded from the analysis. Some participants might need more guidance in relation to how to complete their log than others (US, 2016) and, therefore, it was made clear to the teachers that they could contact the researcher for assistance at any time. Additionally, a participant might not be entirely honest regarding his or her usage, leading to data distortion. There was no way of overcoming the effect of this action among a small sample of respondents.

As the data entries are very specific, the researcher cannot gain any insight into the reasons why a participant used a particular resource - i.e., the causal effect (Iida, Shrout, Laurenceau & Bolger, 2012) - or what a participant did or did not gain from that use. However, the ranking of each site's usefulness by each teacher potentially counteracted this latter possibility. Similarly to the analysis of open response answers, it can be time-consuming for the researcher to interpret and analyse (Creswell, 2008). As responses needed to be analysed individually, this time-consuming process could not be avoided. Further, if the participant is not particularly careful with the data entry, then it might be difficult for the researcher to interpret such an entry (Crosbie, 2006). Again, this was a possibility in my research. The ramifications of a number of the above points for both the strengths and limitations of using logs are dependent upon the commitment and dedication of the participants. Without an appropriate level of commitment, the data may be incomplete and/or inaccurate and/or untruthful and therefore, unreliable and invalid (Crosbie, 2006; Iida, Shrout, Laurenceau & Bolger, 2012).

Walsham (2006) notes that interviews are a very important part of data collection for an interpretive study and that surveys can supplement the data collected. Interviews were used in Phase III of this research. Creswell (2008) notes that interviewing is as popular among qualitative researchers as is observing. Questions can be carefully framed and the participant is left to make a response without being forced into response possibilities. Cohen and Crabtree refer to this type of interview in which the researcher uses a set of prepared questions or "interview guide" (2006, 'Characteristics of Semi-structured Interviews' Section, para. 2) on the topics to be covered during the conversation as a "semi-structured interview" (2006, 'When to use Semi-structured Interviews' Section, para. 2). Cohen and Crabtree state that this style of interview "is best used when [a researcher] won't get more than one chance to interview someone" (2006, 'When to Use Semi-structured Interviews' Section, para. 1) as was the case in some instances in my research because teachers are a relatively mobile work-force moving between schools.

Interviews were also included in this research to gain additional data to permit triangulation with data collected using surveys. It is also important, therefore, to consider the advantages and limitations of incorporating interviews into research.

Firstly, answers given to interview questions "can provide reliable, comparable qualitative data" (Cohen & Crabtree, 2006, 'Benefits' section, para. 3) and this was probably the case for my research as the interviewees had no prior relationship with the researcher. Secondly, preparation for the interview can be done in advance by the researcher so that the questions are directly on the topics to be discussed. Therefore, the interviewer is fully prepared (Cohen & Crabtree, 2006) and is assured that he/she covers all of the requirements of the data collection. This was the case for the interview questions used in this research which were developed in relation to the research questions, over a period of time and with the assistance of the researcher's doctoral supervisor.

Another advantage is that the participant is free to answer the questions without interference from the researcher or by being influenced by the researcher's perspectives. The interviewer can, however, steer the participant in a particular direction if necessary by asking pertinent questions (Cohen & Crabtree 2006; Creswell, 2008) but which do not introduce a particular bias. The interviewer needs to be mindful of this possibility during the interview process. Furthermore, the questions can be posed in such a way as to provide information that has not been available through other methods of data collection (Creswell, 2008). Participants were able to make contributions during the interviews and to elaborate on points that had been broached in the surveys. Finally, the interviewee has the opportunity to include unexpected information that had not been asked about directly but which might add significant depth and detail to the topic under investigation. The interviews for this research certainly had the potential for extra information and ideas to be put forward. The interviewees were asked at the end of the interview if they would like to make any additional comments that were relevant to the research.

Similar to the other modes of data collection discussed above, interviews also have limitations. For instance, if the participant is not particularly skilled in expressing him- or her-self clearly, then the answers might not necessarily convey everything that the participant might want to express (Creswell, 2008). As most teachers are relatively adept at expressing themselves and the interviewees were given as much time as they required to answer questions, this possibility was considered to have been quite minimal for this research. Participants can also deliberately be untruthful

or skew findings through the answers they give. That is, they can give the interviewer the answer that the participant thinks the interviewer might want (Creswell, 2008). While this possibility couldn't be ruled out in my study, it is likely that nothing would be gained by the participants deliberately giving false information and, therefore, nothing could be done to gauge the extent to which this might have occurred. Hence, the need for triangulation with other data collected.

In order to be able to set the interviewee at ease so that he/she feels comfortable to express him- or her-self openly, the interviewer must have a minimum level of expertise in interviewing skills. The interviewer must also have the skills to keep the interviewee's responses in line with the interview topic (Cohen & Crabtree, 2006; Creswell, 2008). As the researcher conducting this study came from a long background of teaching and interacting with people of all ages and had prior experience both as an interviewer and as an interviewee, this possible limitation was considered to be minimal. Piloting of the interview questions was carried out which further enhanced my interviewing experience and provided further training for the Phase III interviews. The piloting process also enabled the identification of ambiguous wording in the questions.

A further limitation, relates to the interviewer needing to interpret the interview answers so that they are not subject to misinterpretation (Creswell, 2008). In this study, interviewees were offered the opportunity to read their interview transcripts, if they so wished, to assist with minimising misinterpretation. An interviewee beginning an interview without having first seen the questions can be a further limitation. It is, therefore, possible that he/she does not include some relevant information in the responses to the questions because he/she didn't think quickly enough during the interview. However, teachers were not rushed to give answers and had the opportunity to backtrack over areas that they felt needed more elaboration during the interview. Interviewees were also instructed that they could contact the researcher after the interview if there was something important that they wanted to add, or change, in their responses. Finally, aspiring researchers are warned by Creswell (2008) of the pitfalls of recording responses to interview questions. Equipment can break-down unexpectedly. To avoid this occurrence, two recording devices were used simultaneously for the interviews in this study although only one

copy was kept after the interviews were transcribed,

3.4.2.2 Phase I Instruments

Phase I surveys - one for principals and one for teachers - were designed by the researcher to gather information in order to answer the research question:

Qn. *1. What is the current status of the teaching of science in Stage 3 in NSW primary schools?*

Both Phase I and II surveys - See Appendix 3 - were piloted with 12 volunteer teachers to ensure that the wording was unambiguous and to minimise misinterpretation by the participants. Consultations regarding the wording were held between the researcher and supervisors, and the researcher and pilots. Any awkward or ambiguous wording was altered where necessary. However, as noted earlier, such precautions could not guarantee that misinterpretations would not still occur. Many of the questions on the Phase 1 surveys, such as the school's classification as metropolitan or provincial, and the number of students at the school, could not be misinterpreted.

In this phase, the principal - or an executive staff member - of each participating school was asked to identify the size of the school according to its number of students, to give an overview of the school's policy related to teaching the S&T KLA, to identify the subject areas which are given highest priority in the school and the reason(s) for this. They were also questioned about whether or not the school employed any specialist teachers to teach the S&T KLA, and how much time was spent devoted to this at the Stage 3 level at their school. Further, in Phase I, teachers of Stage 3 students from each participating school were asked to identify as many factors as possible, both intrinsic and extrinsic, which affect science teaching in their school - including the school's policy and culture. They were also asked to estimate how much time, on average, they spent each week teaching science to their Stage 3 classes.

Where a teacher identified that his or her science content knowledge was inadequate and needed to be supplemented, the teacher was asked whether they used resources to achieve this supplementation, or opted to avoid teaching science as much as possible. This theme was re-addressed in the interviews of Phase III. Any teacher who used resources - such as textbooks, purpose-made software, ICT-based resources of any kind, PL courses, engaging a mentor or team teaching - was asked to identify the resources. The survey asked for resources to be identified by name and that PL courses attended also be identified by name, institution - or individual conducting the course - and the course's duration. Participants were further asked to briefly explain/describe the nature of any mentoring processes and team teaching undertaken.

The survey also included questions related to the number of computers available for the participant's use at his or her school. Questions were designed to address the issues related to factors affecting the teacher's accessibility to computers for his or her own use. The teacher was also asked to identify any preference, if there was one, for searching for science content at home rather than at school and why this was the preferred option.

3.4.2.3   Phase II Instruments

Phase II - involving more detailed surveys and log-keeping - was piloted to ensure that the survey questions were clear and unambiguous. The sources of the questions are discussed in a later section of this chapter. The participants in the pilot test were asked to provide written feedback - on the actual surveys which were both in a hard-copy format at that time - on the wording of the questions and the ease with which the responses could be made, as well as the time taken to complete the survey. Once this initial piloting phase had been completed at the end of June 2013, the survey was formatted electronically using the 'Survey Monkey - Gold' software. Another small pilot survey based on the feedback from eight teachers was employed to ensure that the software was working properly and reliably before the survey went 'live' and the link sent to participants via email. All pilot responses collected by the 'Survey Monkey - Gold' software during the piloting process were cleared from the

software's data-collection table before the survey was sent to participants. This avoided the inclusion of any of the pilot responses in the final data. The electronic survey was ready for distribution by early September 2013 after some technical issues had been addressed.

Phase II was designed to answer four research questions. Each question is stated below with a brief explanation of the research instrument used to address that particular question. For the participants' ease, the instruments were combined into a single survey with discrete sections.

Qn. 2. What is the level of teachers' self-efficacy with respect to teaching science?

The efficacy beliefs of the participating teachers in this research were measured in relation to their science teaching. Riggs and Enochs (1990) have noted previous research which links an individual's outlook to his or her life-experiences and the development of specific beliefs in relation to this. This outlook, or expectancy, also includes teachers' "specific beliefs concerning their own coping abilities" (Riggs & Enochs, 1990, p. 626) including their particular fears/negative beliefs. In this research, the primary teachers' efficacy beliefs were measured using the 'Science Teaching Efficacy Belief Instrument' (STEBI). This instrument, administered to in-service primary teachers - and referred to as the STEBI-A to differentiate it from the version for pre-service primary teachers known as the STEBI-B - was designed for the specific purpose of measuring the efficacy beliefs of those teachers. Riggs and Enochs note that the STEBI-A specifically measures "teachers' efficacy beliefs in science teaching ... [and] maintains consistency with Bandura's (1981) definition of self-efficacy belief as a situation specific rather than global construct" (1990, p. 627). Riggs and Enochs also established, through rigorous testing, that the "STEBI is a valid and reliable tool for studying elementary teachers' beliefs towards science teaching" (1990, p. 633). In this research, the STEBI-A was administered in its entirety and without alteration.

Qn. 3. Do teachers participate in Professional Learning activities to supplement their science content knowledge?

Qn. 4. What ICT-based and other science resources are available to and/or used by both metropolitan and provincial NSW Stage 3 teachers to supplement their science content knowledge?

Qn. 5. How often do teachers explore available ICT-based science resources to enhance their science content knowledge?

The part of the survey addressing the above research questions consisted of both close-ended and open-ended questions to measure the participants' individual levels of education in the areas of science/mathematics and/or computer information technologies; ascertain the types of PL undertaken during the 18-month period prior to completing the survey; and to gain insight into each school's technology and PL culture. The reporting period of 18 months was chosen as the surveys were completed in the middle of the academic year and it can be difficult for teachers to recall PL attended or engaged-in beyond the preceding academic year - particularly informal types of PL activities.

A number of the questions used in this section of the survey were based on two educationally recognised surveys. The first survey was the United States Department of Education's (2007) 'Spring 2007 Teacher Background Questionnaire'. This was developed by a survey research organisation for use as a self-administered questionnaire by teachers who were an integral part of the study's wider cohort's school experiences in a nation-wide survey - 'The Early Childhood Longitudinal Study'. There were no contextual 'translational' issues in relation to the language used in this survey as all questions selected were phrased in such a way so as to minimise misinterpretation of their intent by either American or Australian teachers. However, the word 'elementary' used in the USA was substituted with 'primary' for use in Australia in reference to the first stage of schooling. The second survey used was the Organisation for Economic Co-operation and Development's (OECD) 'Teaching and Learning International Survey' (TALIS) Teacher Questionnaire (2007) - Main Study Version. This survey was developed as part of the 'Indicators of Education Systems Project' by a panel of international education experts in the TALIS Instrument Development Group. The 2007 report notes that questionnaires from this survey were reviewed throughout the period of their development with education authorities and teacher representative bodies of the participating countries

- and other interested bodies of the OECD - and had been administered in 24 countries. This on-going cyclical project has provided information about teachers, teaching and learning. One component of the project was to produce data on teachers which contributed to an international database for the evaluation of teachers, and to inform professional development practices to support effective teaching practices, attitudes and beliefs. The questions from this section of the survey were particularly useful for the purpose of my research and were adapted for inclusion in my Phase II survey. See Appendix 3 for the Phase I and II survey instruments.

The survey was further designed to ascertain which ICT-based science resources the participants were aware of and/or had used prior to the commencement of the research period. Throughout the duration of this phase, the participants were required to keep a log of each ICT-based resource that they used to enhance their science content knowledge (including its URL if applicable), the date(s) of usage, what type of information was offered, the resource's author(s) or institution responsible for the resource and how long they spent working each time they used a resource. Participants also were requested to provide a subjective ranking of the usefulness of each resource for informing the participant about the science topic being researched - 3 = very useful, 2 = moderately useful, and 1 = of little use. ICT-based resources could have included web-based sites, lesson creation/information software, platforms such as 'Twitter' or 'Facebook', video conferences and any other resources available to them. The link to the interactive-PDF table into which the URLs - and other information - could be pasted, was provided in the final section of the Phase II electronic survey. The final time period over which the logs were to be kept was decided upon after taking the following considerations into account. Firstly, the original difficulties in garnering participants from the outset of the research needed to be considered. Secondly, it became apparent during communications with the pilot teachers and some future participants, that it would be extremely difficult for participating teachers to complete and return the logs of ICT-based usage over the originally planned six-month period. This was because of the time constraints placed on them by teaching an over-crowded curriculum and fulfilling roles other than teaching in their schools. This was all in addition to life's commitments outside the work environment such as family responsibilities. It was judged to be prudent, therefore, to opt for having the logs completed by each teacher over a shorter time

period. Consequently, the original instruction suggesting the period over which the logs were to be completed was modified to a suggested minimum period of one-month. Six metropolitan and five provincial teachers had each submitted the logs by the end of Term I, 2015. Seven of these teachers provided logs which were partially completed to varying degrees.

3.4.2.4 Phase III Interviews

Interviews were conducted to triangulate, increase confidence in and validate the survey data collected from the Phase I and II principal and teacher surveys. The interviews - which took place between March 26 and May 8, 2015 - were conducted by telephone, as this was the most convenient mode for the researcher and for both the metropolitan and provincial teachers, especially given their wide geographic dispersal. The majority of the teachers preferred to be interviewed during the evening or the weekends because of their busy schedule at school. The interview protocol was informed by and modelled on a protocol design suggested by Creswell (2008, p. 234). These interviews were digitally recorded, using two recording devices for security, transcribed and coded. It was made clear at the outset of the interviews that the questions related only to their teaching of the science component of the S&T KLA.

As mentioned previously, to avoid any misunderstandings or misinterpretations of the participants' responses during the interview coding process, all interviewees were offered the opportunity to read their interview transcripts for accuracy. When the offer was taken up, the transcripts were sent via email. Interviewees were offered the opportunity to make any adjustments that they felt necessary before the responses underwent an interpretive analysis. The formal part of the interview was begun after some time was spent establishing a rapport with the interviewees. This section of the interviews took approximately 17 - 25 minutes and was concluded after the interviewee had been given enough time to mention and elaborate on any issues relating to the questions that they deemed important. The interviews were used to give the participants the opportunity to add more depth and insight to the responses given in the Phases I and II surveys. To meet this need, the questions: established

each teacher's educational background with respect to his or her science training at tertiary level; were concerned with trying to determine teacher's current-confidence levels related to their science teaching at the time; and established whether or not the teachers attended professional learning related to the science component of the S&T KLA. If they did so, the teachers were asked to identify the nature of any PL and other details relating to it. Many of the interviewees expanded their responses to explain the reasons why they did or did not attend professional learning. The questions were also designed to ascertain whether or not teachers were using ICT-based science resources to deepen their science content knowledge, the type(s) of resources that they were using, including examples and, finally, if teachers were conducting their information searching at home or at school, and the reasons(s) for this.

Prior to the conclusion of each interview, participants were asked if they would like to make any comments relating to the teaching of science at the primary school level. The majority took this opportunity to elaborate on the circumstances surrounding the teaching of science in their school. The interview protocol and questions - all of which were open-ended - are found in Appendix 4. For the purpose of reporting interview quotes, the participants were given identifying codes such as M1 and P1 to denote metropolitan participant number 1 and provincial participant number 1 *et sic porro*.

3.4.3 Recruitment of Participants

Wherever possible, primary schools encompassing only Kindergarten to Year 6 (K - 6) were selected because staff in schools encompassing Kindergarten to Year 12 could possibly have at their disposal the science resources - in all senses of the word - of the secondary section of their school. Of the total sample group, only four schools encompassed Kindergarten to Year 12 classes, and all of these were independent and from metropolitan areas. In these four schools, the primary sections operated independently of the high school and did not use secondary science teachers or resources. If a school did not respond to, or declined, the invitation to participate in the research, then another school from within the same category was invited to

participate. As shown in Tables 4.1 and 4.2 in the Results chapter, the number of schools participating from each sector was not equal, particularly in the provincial school division. The number of participating schools was more uniform across the sectors in the metropolitan division. However, this was not an issue as the schools and their teachers were not categorised according to their membership of any particular education sector in NSW but were categorised as either metropolitan or provincial.

In October 2012, hard copy packages, addressed personally to each principal, were mailed to 240 NSW schools. Each of these packages contained:

- a letter of introduction individually addressed to the principal by name;
- relevant research information sheets and consent forms for the principal - to give written consent for him- or her-self and the teacher(s) of the school to participate - and participating teacher(s) of Stage 3 students;
- the researcher's contact details;
- Curtin University ethics approval and, where necessary, the details of the appropriate governing body's ethics approval (ethics is discussed in a later section of this chapter); and,
- a stamped, self-addressed envelope to encourage principals to return the completed forms.

The original goal for Phase I was to have around 200 schools participate. One hundred and twenty two (122) metropolitan schools were initially invited to participate in the research and 118 from provincial areas. Therefore, a total of 240 NSW schools were initially approached via this hard-copy mailout. The immediate response rate was 3.9% (i.e., 9) and, of those, all but one declined participation. After the initial hard-copy mailout, all further correspondence and distribution of introductory letters, information sheets, consent forms and surveys for principals and participating staff were sent digitally.

All schools were subsequently re-approached via email - sending the same package in electronic format - with a further uptake by only four schools - representing 1.7% of the number initially approached - and through telephone calls direct to the

principal. Directly speaking to principals was a much more productive method of recruitment and led to a further 15 schools participating in the research. Although a large number of principals expressed their interest in both the aims of the research and in participating, this did not always result in the school's ultimate participation. Similarly, a principal's enthusiasm for participating did not guarantee that his/her teaching staff would ultimately follow through with their participation. This was the case for many schools. It is stressed here that no teacher participated in the research at the direction of the principal: all participation was voluntary. As the 2012 academic year was drawing to a close, and because teachers and schools are very busy places at the end of the year, it was considered prudent to suspend further attempts for recruitment until the beginning of the 2013 academic year. More approaches were made several weeks into the 2013 academic year after the 'busy-ness' of the return to school had settled down.

During Semester I of 2013, a different approach was used to contact school principals. In March and April, all of the NSW DEC principals of provincial schools involved in the original mailout, with the addition of another 30 schools, were again contacted via email. Unfortunately, this elicited no response at all. Principals of an additional 20 metropolitan primary schools across the three sectors were approached by telephone. The success rate of this approach was higher with a further nine schools agreeing to participate in the research.

Two academics from different NSW universities were also contacted as they each had a known interest in science education issues, and might have been able to provide advice on further possible avenues of recruitment. Some advice was offered on other potential methods for recruiting schools. Following this advice, some of the NSW DEC K - 6 Science Consultants were directly requested for assistance via telephone and by email - when the timing of telephone calls became difficult because of the consultants' and the researcher's availabilities - but this did not lead to any further school recruitment.

In order to recruit further schools to participate, advertisements were placed in electronic communications sent to members of the Science Teachers' Association of New South Wales (STANSW) and to teachers participating in the Commonwealth

Science and Industrial Research Organisation's 'Scientists and Mathematicians in Schools' (CSIRO SMiS) Programme. Once again, no positive responses were obtained. More success at recruitment was achieved through contacting, via email, the presidents of all 42 NSW DEC's Primary Principals' Associations across New South Wales. Many of the presidents forwarded the email to their principal-colleagues for their consideration. This strategy resulted in 11 more schools and one teacher from each school being recruited from both metropolitan and provincial areas. Many hours on the telephone speaking directly to school principals further yielded more participant schools. Some schools were recruited via the researcher's personal contacts that were followed up through telephone calls and emails. At this point, all possible avenues of recruitment seemed to have been exhausted. The desired, large number of schools for Phase I was not achievable because of the rate of non-acceptance to participate.

The original goal for Phase II was to have approximately 100 participating teachers of Stage 3 who would be selected from within the larger group of schools surveyed in Phase I. Again, this was not achievable and any teachers from the Phase I group of schools offering to participate were accepted. In some cases, therefore, more than one teacher from a Phase I school participated. Copies of the Phase I and II letters, consent forms and information sheets for principals and teachers are shown in Appendix 2.

At the conclusion of Phase II, prospective interviewees were randomly selected from within the metropolitan and provincial groups and invited - via email - to participate in the Phase III interviews. Ten interviewees were sought and 19 prospective interviewees were successively invited to ensure that at least a total of ten agreed to be interviewed. Again, equal numbers were preferred and attained from the two main groupings (i.e., metropolitan and provincial) in order to obtain a sample of teachers which was as representative as possible of the broader research participant cohort. Some teachers declined because of a purported lack of interest or personal time constraints, or because they had transferred to other, non-participating schools. Ten participants ultimately took part in the semi-structured interviews with the researcher. As noted below, recruitment of provincial schools and teachers continued into 2014 in order to address the imbalance in the number of metropolitan and

provincial schools and teachers.

The final number of participating schools was 31 and the total number of participating teachers was 47 - the teachers were the same in both phases. The numbers of teachers participating in each phase from metropolitan and provincial regions are summarised in Table 3.2. These numbers are discussed in more detail in the Results chapter.

3.4.4 Timing of the Phases

It was planned that Phase I would be completed by the end of Semester I, 2013 and Phase II by the end of Semester II, 2013. However, as the recruitment process took longer than anticipated and many participants had not returned their Phase I surveys on time, all surveys were accepted whenever they were returned. Phase II surveys were, in all cases, sent after the consent forms had been received, and then the completed Phase I surveys had also been received. By the close of the 2013 NSW school academic year, some Phase II surveys were still outstanding or incomplete and there was an imbalance in the numbers of participating schools from metropolitan and provincial schools. Throughout 2014, more provincial school principals were approached to increase the number of participating schools to address the imbalance in numbers of provincial schools and teachers.

As noted earlier, there was significant difficulty in achieving the return of teachers' logs of ICT-based science resource usage. A cut-off date for the submission of completed logs was extended to allow the teachers more time to complete and return them. All 11 logs completed for the research had been submitted by the conclusion of Term I, 2015. The interview phase - Phase III - began in March 2015 and was completed by the end of May of the same year.

3.5 Data Collection

3.5.1 Dedicated Research Email Address

To comply with privacy issues and to keep all correspondence in one email folder, a

dedicated email account was set-up: galvinsresearch@gmail.com. This address was provided for participants to correspond with the researcher and to return consent forms, surveys and tables on completion. In some cases, however, where participants were employed in the same educational sector as the researcher, some principals and teachers preferred the convenience of corresponding and returning information via the researcher's organisational address. All correspondence with the 'Survey Monkey' company regarding survey formatting, troubleshooting and data analysis assistance was done via email through this dedicated email address. This email address is no longer active.

3.5.2 Surveys

The Phase I surveys for the principal or executive staff member and participating teachers were hard-copy surveys. After initial contact and consent was granted by the participants, these surveys were sent out. Principals were given a choice of receiving the surveys through the post or electronically. The majority of participants elected to receive their surveys electronically and the majority of surveys were returned by this means and printed upon receipt for analysis by the researcher. The use of hard copies for the Phase I surveys better suited the method for analysing the surveys and minimised the participants' perception of having to complete too many electronic surveys (i.e., for variety) as discussed in the Literature Review.

Each survey, upon its receipt, was given a colour code which identified it as coming from either a metropolitan or provincial school, and a corresponding number was used to identify and cross-match principals from the same school. Principal and teacher surveys were also denoted with 'P' or 'T' to allow quick identification during the analysis process. These codes were recorded on an Excel spreadsheet - accessible using a password known only to the researcher - against a list of prospective schools so that the researcher could track actual returns against those promised. Once it became apparent that no more surveys would be returned, each survey was de-identified of the school's name. At the conclusion of the research, the Excel spreadsheet was deleted.

In contrast to the Phase I surveys, the Phase II surveys were administered electronically using the 'Survey Monkey - Gold' software. Subsequently, a one-year subscription to this software was purchased and was extended into a second year to allow more surveys to be completed and time to analyse responses. A link to the interactive tables - using 'Dropbox' - in which participating teachers recorded their use of ICT-based science resources was embedded in the survey. Teachers were able to download this table to their desktop to facilitate the recording of their ICT-based usage by using a simple cut-and-paste method.

'Survey Monkey Gold' software - henceforth referred to as 'SM Gold' - was chosen over a number of other survey-software options because, at that particular time, it offered a number of features and tools appropriate for this research. One important feature of the software was that 'SM Gold' imposed no limit to the number of questions that could be included in the survey and offered a variety of question formats which suited the styles/formatting of questions needed for my study. Further, this software allowed as many free responses as required and these responses could be of any length. 'SM Gold' software has embedded in it a branching logic function which allows respondents to skip inapplicable questions - therefore, allowing flexibility within the survey. This feature was vital for my study as not all questions were applicable to every respondent. Of further importance, the researcher was able to upload the questions into the software package without recourse to an outside provider, thus saving time and funds - especially as adjustments were necessary after the piloting process.

Monitoring the gradual progress of an individual teacher's completion of the surveys was possible using 'SM Gold' which also allowed the participants to repeatedly return to the surveys at times convenient to themselves until they were satisfied with their responses prior to final submission. It had been established during the initial mailout process to recruit participants, that mailing directly to principals and teachers presented difficulties when mail was not delivered to the addressees. Mailing paper surveys to the participants and providing stamped, self-addressed envelopes for the return of the surveys was an expensive process. The 'SM Gold' survey could be sent out to participants - and returned to the researcher - via a weblink and offered a customised URL. This was also a major contributing factor for the security of the

survey responses which had the potential to be lost in the mail and read by anyone. Participating teachers were able to return the completed survey and log tables to the researcher electronically as each was completed. The vast majority returned their completed logs by email while a small number of teachers returned hard copies.

The download and analytical features offered by 'SM Gold' suited the required analysis of the responses for this research (Survey Monkey, 2014). For example, there were text analysis functions for analysing responses for frequently used words; some data were summarised and could be presented in graphical form while other data were summarised numerically. The researcher had the option to categorise data sets such as teacher's age and number of years teaching into pre-determined ranges for ease of analysis. Responses could be downloaded in a format compatible for analysis using the Statistical Package for the Social Sciences (SPSS) which was subsequently employed. Moreover, many of the responses could be saved as 'Excel' spreadsheets and/or into a PDF format to assist with further analysis. The package additionally offered quick software support and, overall, was considered to be cost-effective.

Principals and teachers who had not returned their surveys within six weeks of receiving them were contacted either by telephone or email to give them a friendly reminder. Depending upon the circumstances, some were contacted a second time but were not contacted again - even if the surveys had not been retuned or were returned not fully completed. Whilst participants were asked to complete their logs over a suggested period of one month, some chose to complete them over different time periods.

One of the survey questions requested that teachers identify their school. This allowed the researcher to cross-link the codes and list returns and, in some cases, to send a reminder to teachers who had not completed their surveys by the due date. After the data collection period was completed, the IP address, school's name, etc., for each respondent were removed from the SM Gold Excel spreadsheet of responses. Correspondingly, all data sources were de-identified.

3.6   Analysis of Data

3.6.1   Phase I - Surveys

Data collected from the principals' and teachers' surveys in this phase were predominantly qualitative. These data were related to a number of aspects characterising the school: its classification as either metropolitan/provincial and Catholic/Independent/State Government - although this latter distinction was not required for any of the analysis; factors affecting the teaching of science in each school setting; and matters relating to the school's policy on science teaching and the school's prioritisation of subject areas. Additional qualitative information included: factors affecting the teaching of science in each school setting; the self-reported efficacy of the teachers in relation to teaching science; each teacher's professional learning; and their access to computers in the workplace. The quantitative data collected related to, for example, the number of students in the school and the number of specialist science teachers, if any, working at the school. These data were sought in case some correlations existed between these and other parameters which might have become apparent after all data were collected and analysed.

3.6.2   Phase II - Survey and Log-keeping

3.6.2.1   General Questions

The data gathered from all questions - with the exception of those which comprised the STEBI-A - were collated and, where appropriate, cross-referenced with corresponding data from the Phase I survey responses for each participating teacher. Where necessary, any discrepancies - for example, what some teachers might consider comprises 'professional learning' - are commented upon in the Discussion chapter. The open-ended questions provided participants with an opportunity to express their opinions or to provide data without any predetermined constraints. This type of information adds to the overall richness of the data. Creswell (2008) discusses the benefits of open-ended questions and notes that an "open-ended response to a question allows a participant to create the options for responding" (p.

225) so that "the participants can best place their experiences unconstrained by any perspectives of the research or past research findings" (p. 225).

Open-ended responses were analysed by following a format recommended by the 'Survey Monkey' software analysis support team (personal communication, 28 July, 2014) - even though the Phase I responses were not collected using the 'Survey Monkey' software. To analyse the data, an overall impression of the general themes was gained by the researcher by first reading the responses. This process made possible the identification and categorisation of responses and distinct themes and sub-themes were allocated numeric codes. After the responses were categorised, they were re-read a number of times, checked and re-categorised and re-coded to ensure that similar responses were appropriately grouped together. These were later aligned with the themes investigated with respect to the research questions. The Phase II data collected from open-ended questions were also analysed in this way with themes identified and grouped appropriately to enable better analysis.

3.6.2.2   Science Teaching Efficacy Belief Instrument (STEBI-A) for In-service Primary Teachers

The STEBI-A, as noted above, was designed by Riggs and Enochs (1990) and is based on the Teacher Efficacy Scale developed by Gibson and Dembo (1984) and consists of two distinct subscales: the Science Teaching Outcome Expectancy (STOE) and the Personal Science Teaching Efficacy (PSTE) scales (Henson et al., 2001). These scales are largely uncorrelated (Riggs & Enochs, 1990). The STEBI-A is a Likert-style, 5-point scale and consists of a bank of 25 items: 13 gauging PSTE (i.e., Items 2, 3, 5, 6, 8, 12, 17, 18, 19, 21, 22, 23 and 24) and 12 gauging STOE (i.e., Items 1, 4, 7, 9, 10, 11, 13, 14, 15, 16, 20 and 25). The STEBI-A was incorporated into the Phase II survey without any change. For the 5-point Likert scale, the pre-defined responses and assigned scores were Strongly Agree (1), Agree (2), Uncertain (3), Disagree (4) and Strongly Disagree (5) (Riggs & Enochs, 1990).

The initial statistical analysis of the STEBI-A was conducted using the Statistical Package for the Social Sciences (SPSS), Version 22. Using this package, the Cronbach alpha co-efficient was calculated for each subscale to assess internal reliability. Henson et al. (2001) note the importance of including this step in research analysis rather than relying upon the estimates produced by prior studies and support this assertion citing Pedhazur and Schmelkin's (1991) contention that it is "imperative to recognise that the relevant reliability estimate is the one obtained for the sample used in the study under consideration" (Henson et al., 2001, p. 408).

It is important to note that the responses for the items which were negatively worded were reverse scored. This step was both member-checked and crosschecked against Riggs and Enoch's work (1990) to guarantee pre-validation. The negatively worded items were 3, 6, 7, 8, 10, 13, 17, 19, 20, 21, 22, 24 and 25. This reverse scoring was also applied to the calculations of the means, medians and interquartile ranges (IQRs) for the PSTE and STOE items. Therefore, all item analyses - except for the 'persistent minority' analysis which is discussed fully in a later section - employed this technique.

Riggs and Enochs (1990) and Henson et al. (2001) conducted separate studies of the STEBI-A and found it to be a "valid and reliable tool for studying elementary teachers' beliefs towards science teaching and learning" (Riggs & Enochs, 1990, p. 633), but Henson et al. (2001) noted that the PSTE subscale yielded slightly "more reliable scores [with an alpha co-efficient of 0.92] than the ... STOE subscale" (1990, p. 412) and cautioned that, among other factors, reliability can also be affected by sample attributes and the characteristics of a particular study. Riggs and Enochs (1990) do acknowledge that the alpha coefficient for the STOE subscale - 0.77 for the STEBI-A - is consistent with the STOE being quite a difficult construct to both measure and define, which is in agreement with Gibson and Dembo's earlier findings in 1984. Riggs and Enochs conclude that "with regard to reliability, both scales demonstrated their adequacy" (1990, p. 632).

PSTE and STOE items were analysed separately as these subscales are not statistically significantly correlated and therefore independently reflect self-efficacy and outcome expectancy beliefs (Riggs & Enochs, 1990). As there is much debate

regarding the 'correct' methods of analysis of Likert scales, particularly in reference to whether or not they should be treated as producing continuous data (Cohen, Manion & Morrison, 2000; Gilbert, 2008; Gray & Kinnear, 2012), Clason and Dormody maintain that "it is not a question of right and wrong ways to analyze data from Likert-type items. The question is more directed to answering the research questions meaningfully" (1994, p. 34). The data collected with the STEBI-A in my study were treated largely as producing ordinal data; that is, the responses have been ranked (or ordered). The 'distance' between them, however, is not necessarily able to be measured (Allen & Seaman, 2007; Kostoulas, 2013) and so caution is needed interpreting data.

With this point in mind, though, the mean ($\bar{x}$), median scores and IQRs for the individual PSTE and STOE items were calculated to allow one form of analysis. The use of IQRs is important as they indicate whether or not the responses are clustered. That is, a small IQR indicates a degree of consensus whereas a relatively large IQR indicates a spread of responses and relative lack of consensus. Generally, the IQR is not affected by a very small number of quite small or quite large scores. Mean, median scores and IQRs for the metropolitan and provincial group were also calculated and graphed for the PSTE and STOE subscales to reveal any differences between the two groups. To elucidate further meaning from the responses, the total percentage of teachers responding to each item were also examined as calculations of the mean - in particular - and the median scores can occasionally mask some of the intent in the responses as discussed by Allen and Seaman (2007) and Kostoulas (2014). This occurs because, to apply only a mean, there is an assumption that the responses are psychologically equidistant from each other. Therefore, to avoid any statistical distortion, the mean, median and IQR for each item were considered in tandem with the percentage of teachers responding to each item. The responses of the metropolitan and provincial cohorts were analysed by using the weightings for each pre-defined response as noted above. These were assigned in a similar, linear way as suggested by Enochs and Riggs (1990) for analysing their STEBI-B instrument - a version of the STEBI-A instrument designed for pre-service teachers.

The maximum score achievable for responses to the STOE scale was 60. A response approaching this maximum indicates strong disagreement across items relating to

Science Teaching Outcomes Expectancy. The mid-point score between the maximum and minimum scores was 36. Therefore, scores less than 36 indicate an increasingly positive belief as they approached 12 - the minimum score achievable which corresponds with strong agreement across items. Scores greater than 36 were indicative of increasingly negative-beliefs for STOE items as they approached 60. Similarly, for the PSTE items, the most positive beliefs in Personal Science Teaching Efficacy were indicated by scores approaching 13 from 39, with beliefs becoming increasingly negative from 39 and increasing to a maximum score of 65.

The final STEBI-A analysis involved comparing responses of teachers who had a tertiary level major in a science (n = 6) with the responses of those who did not (n = 36) - some teachers did not respond to this question. Given that the cohort with a science background was relatively small, the percentages of teachers' responses given to each alternative for each item can only be used to indicate possible trends within such a group and could not be extrapolated to the broader teaching community. To further assist in making meaningful comparisons, differences between the two groups of 15 percentage points or less were considered to be in reasonably close agreement with each other. As above, the persistent minorities, where they existed, were calculated for analysis and discussion.

3.6.2.3 Logs of ICT-based Usage

Although the editable PDF log table was easy to access and populate with data, it was not completed by all participants. Again, the claim that participants were time-poor was most often given for this and, for others who professed not to use ICT-based resources, there was no point in attempting to complete the table. Although the participants were asked to complete the logs over a minimum of four weeks, some recorded their usage over a longer period, while some did so over a slightly shorter period. In all cases, the data were averaged to produce data representing an average weekly use. Even though the number of participants was relatively small, calculating an average weekly use provided the most appropriate means of comparison of usage within and between groups.

The data for each participant contained in the completed logs were analysed according to the names of the sites used and how often they were accessed, in addition to each site's ranking of usefulness as determined by the teachers. The average amount of time, in minutes, spent on each site per week and the total time, in minutes, spent searching for sites and information over each teacher's nominated time-period were calculated from the log data. Finally, the time at home spent using ICT-based science resource(s) information searching for enhancing each teacher's science content knowledge - rather than at school - was calculated. Each site mentioned by a participant was checked by the researcher and categorised as providing content that was either reliable or not reliable. Further, the data were also categorised as being contributed by either metropolitan or provincial teachers.

3.6.3   Phase III - Interviews

As was the case for the previous research stages, the interview questions for Phase III were piloted for awkward and/or ambiguous wording and later discussed with the piloting teachers. The wording and intent of the questions were also discussed with the researcher's supervisor and other research colleagues - who had much relevant research experience - to establish the Interview Protocol. At the outset of each of the interviews, a brief general conversation helped to establish rapport with the interviewee in accordance with the Interview Protocol (Appendix 4).

In respect to analysing interviews, Weston et al. (2001) note that "coding is not what happens before analysis, but comes to constitute an important part of the analysis" (p. 397). They advise that, from their combined research experience, the interview analysis process should begin with the development of an overall understanding or conception of the phenomenon from readings of the interview data. The process continues through the closer identification of themes which emerge from this data. Thereafter, the original understanding is re-visited and re-evaluated in light of what was learned from the themes. As themes and sub-themes emerge and are identified through this cyclical process, the researcher gradually builds up a table of codes to identify these themes and sub-themes. This process is what they liken to "zooming in and out" (p. 397). Weston et al. (2001) identify the development of a coding system

as a "critical analysis tool in that it leads to an ongoing revolution in understanding the phenomenon" (p. 397).

Therefore, after all interviews had been conducted, the transcripts were examined and persistent themes identified and numerically coded. Subsequent to this, the themes were then further divided and coded into subthemes. The cyclical process was used to identify these themes as they emerged. After this cycle had been completed, the themes were re-ordered and re-numbered to align, as much as possible, with the order of the research questions to further assist in future analysis. The fully-coded themes and sub-themes are shown in Table 4.34.

Where quotes from the interviews were used in this thesis text, they appear in italics and are referenced with the interviewee's code as discussed above, the interview type, the date of the interview and the full interview theme code. For example, "P5, teacher interview, April 12, 2015, 3.2.1" designates a quote from provincial teacher interviewee number 5, interviewed on April 12, 2015 and who said that he or she was not confident enough to teach science - even after many years of primary teaching (Theme 3.2.1).

3.6.4   Sharing Identified ICT-based Science Resources With the Participants

Any ICT-based science resources identified by the teachers as being useful to them to assist with enhancing their science content knowledge were checked for whether or not they were 'reliable' content sources; that is, government or non-government or not-for-profit organisations. The links to the reliable resources, in addition to suggestions for finding other resources - such as through 'Twitter' links - were combined into a leaflet for distribution to the participating schools and their teachers at the conclusion of the research. The leaflet can be found in the Appendix 5.

3.7   External Providers of Professional Learning Opportunities

A systematic, online search was conducted by the researcher to find professional learning opportunities that were on offer and appropriate for Stage 3 teachers for the

science component of the NSW S&T KLA. The search included the NSW DEC and BOSTES NSW sites, and four private providers who advertised their courses quite extensively. Where lists of PL were provided on sites, they were examined for numbers and types of courses. In three cases, representatives of the private companies were contacted by telephone and followed-up with emails to obtain feedback relating to the courses offered and participation rates. The research participants were asked in both the surveys and the interviews about their engagement in professional learning activities. These included 'formal' PL activities/courses which were organised by external providers.

3.8 Research Ethics Considerations

In order to achieve and maintain a high standard of human research ethics, Howitt (2010) advises addressing a pre-determined number of ethical protocols in a systematic way. These might include giving information, gaining permission, maintaining privacy and confidentiality, giving due consideration and acknowledging participation. Each of these protocols was addressed within the framework of this research. The research was conducted in accordance with the Australian Health Ethics Committee guidelines - under the National Health and Medical Research Council) Act (1992) (NHMRC, 2015) - for research involving humans.

Initial ethics approval was granted by Curtin University on 7 June, 2012 - reference Protocol Approval SMEC-30-12 - for a period of one year. Permission from the NSW DEC was initially applied for in April 2012 and granted in June of that year - SERAP Approval Number 2012175 - for a period of one year. Both ethics approvals were subsequently renewed at the appropriate times in 2013 and 2014 for additional 12-month periods. As permission to conduct teacher interviews was not a part of the original NSW DEC ethics submission, additional NSW DEC approval to conduct such interviews was sought and granted in March 2015. This variation of approval also expired in mid-2015.

As schools from the NSW Catholic Diocesan and NSW DEC sectors were to be approached in the recruitment process, prior permission to approach schools

overseen by these bodies needed to be obtained in order to conduct research with their staff. It was not necessary to seek any permission for the independent schools participating as they are not answerable to any overseeing organisation for this purpose. Approval was also sought from the Catholic Education Offices of the dioceses of Wagga Wagga, Parramatta, Broken Bay and Sydney. Ethics approval was gained from the Lismore Catholic Education Office in June 2013, in an effort to extend the opportunity to recruit more schools. Eight schools from this diocese were approached but none chose to participate. This process of seeking multiple ethics permissions across the NSW Catholic Education entities was time-consuming and, in one case, quite protracted, as the particular governing body requested both a telephone interview and an in-person panel interview with several of its education officers before final permission was granted. By mid-2015, after which time it was no longer necessary to collect more data, the ethics approvals were allowed to lapse.

As previously noted, the principal or governing body of each selected school was contacted to gain written permission for that school and selected staff members to be incorporated into the study. Using an information sheet (shown in Appendix 2), written in plain language, all participants were made aware of aspects of the research such as its aim(s), and the intended use of the findings. Anonymity and confidentiality were guaranteed to those involved, and it was made clear that participants could withdraw their participation from the research - regardless of the reason - whenever they thought it appropriate and without any consequences to themselves. Meetings or telephone calls were sometimes requested by governing bodies, principals and/or teachers to discuss the finer points of the study and to give participants the opportunity to clarify points when needed. For example, one school principal asked the researcher to meet with the participating Stage 3 staff members to discuss aspects of the research and to 'put a face to the name' of the researcher. Another principal requested an interview to allow her to clarify the school's aims and philosophy to ensure that the school's staff would be suitable participants for the research.

The identities of the participating schools were not made known to anyone outside the research and this information cannot be obtained from the thesis. All data collected were kept separate from any of the participants' identifying material in

order to maintain confidentiality. As explained above, all identifiers were removed from the returned surveys and Excel spreadsheets of responses; Excel spreadsheets of school data were erased; and digital interview recordings were de-identified after administrative tracking of returns had been completed.

The researcher took care during each phase of the research to be considerate of demands on the participants' time in order to avoid any time-related stress being placed on them. Any discussion time for interviews, feedback, etc., occurred at mutually agreeable times. At the outset of each phase, the participants were asked if they minded receiving an email or telephone call to remind them to return surveys and logs. None of the participants objected to this and, as the participants were volunteers, reminders were kept to a minimum of one per participant per survey or log. All data were reported honestly and without alteration.

3.9   Copyright Materials

As some figures from the work of other authors/organisations were considered to make useful inclusions to my thesis, permission was sought from the relevant authors, or copyright holders, to use the figures. This step was a requirement in anticipation of the research being published. A pro-forma letter for this purpose - obtained through the Curtin University Library site - was used, and sent to a total of four authors/organisations. In some cases, a number of telephone calls were made to establish copyright ownership. A copy of the pro-forma letter and the written permissions which were returned via email are found in Appendix 6.

3.10   Chapter Summary

The research method employed in addressing the five stated research questions was detailed in this chapter with reference to the Interpretivist and Pragmatist paradigms - which informed the research - and their related ontological and epistemological frameworks. The methodology and its rationale were described. The mixed-methods design, carried out over three research phases, was explained and justified. The schools and participating teachers were selected by employing a disproportionate

stratified random sampling technique within the two focus groups - metropolitan and provincial primary schools/teachers in NSW. Details of the recruitment process of school principals and teachers were recounted in detail.

The research instruments employed for the Phase I and II surveys, and Phase III interviews to elicit information relating to the five research questions, their origin and derivation were explained. The timing of the phases of the study was almost totally dependent upon the rate of recruitment of the schools and, subsequently, on the co-operation of the participating principals and teachers in returning surveys and logs within the given timeframe. This dependence on participants to complete and return surveys and logs was the primary factor determining the duration of Phases I and II. Data were collected via these research instruments, private logs of ICT-based science resource use and interviews. The methods of analysis appropriate to each of these instruments - or part thereof - and of the interviews were detailed. The range of ethical considerations relating to the implementation of the research methods used in this study was also addressed in this chapter.

Chapter 4: Results

4.1 Introduction

The results of my research into the use of ICT-based science resources by Stage 3 teachers in NSW schools to enhance their science content knowledge are presented in this chapter. They are derived from the surveys conducted in Phases I and II, the logs of usage of ICT-based science resources submitted by teachers, and the interview results of Phase III. In some cases, school principals' representatives - for example, an executive staff member such as the assistant principal or a relieving principal - completed the principals' surveys. For the purpose of reporting, all respondents to the Phase I principals' survey are referred to as 'principals'. In some instances, reported results percentages quoted do not add exactly to 100 because of rounding.

Some of the following percentages for the total cohorts of principals and teachers have been calculated to allow ease of comparison of data between and within (i) the metropolitan/provincial groups of principals and teachers; and, (ii) the principal/teacher grouping for the Pearson product-moment correlation co-efficient figure. For example, in Figure 4.4, 56% of the total number of teachers participating nominated 'literacy and numeracy' as priority subjects at their schools whilst 32% of the total cohort chose English and mathematics. The coloured blocks representing metropolitan and provincial teachers denote the proportion of the total cohort within each of these groups. It is important to note, however, that this is a small sample and the percentages only represent a small number of participants. Percentages are given in some of the tables and in some of the accompanying text in order to give an indication of the proportionate sizes of, for example, the numbers of teachers within the grouping being analysed. The examination of percentages to highlight trends can be useful even within relatively small cohorts.

4.2 Sample Schools' Demographic Profiles

The data collected from the Phase I surveys were used to build a profile of the participating schools' demographics as detailed in the introduction of the Research Methods chapter. The schools' demographic data contribute towards the broader picture of the contexts in which the teachers in this study were working. These data are presented in the following sections.

4.2.1 Participating Schools

4.2.1.1 Metropolitan or Provincial?

The final combinations of participating schools and Stage 3 teachers for Phases I and II are shown in Tables 4.1 and 4.2. In summary, the total number of schools participating in the Phase I and II surveys was 31 with a total of 47 participating teachers. Of these, 11 completed logs of their usage of ICT-based science resources and a further ten - with some overlap between these two latter groups - agreed to participate in interviews.

Table 4.1. The number of participating metropolitan schools and Stage 3 teachers according to sector.

Number	State	Catholic	Independent	Total
No. of schools	7	5	4	16
No. of participating teachers	9	14	6	29

Table 4.2. The number of participating provincial schools and Stage 3 teachers according to sector.

Number	State	Catholic	Independent	Total
No. of schools	13	1	1	15
No. of participating teachers	16	1	1	18

Feedback regarding the low level of uptake for this research was obtained by telephone or via email from some of the 27 principals contacted after the original mailout. Comments (with each comment being from a different principal) included:

– "Principals are notorious for not responding to unsolicited emails";

– "The office staff often vet the mail at many schools so their principals doesn't even get to see it - even if it's personally addressed to them";

– "Our teachers are just too busy/overloaded to participate in research";

– "Our school isn't focusing on science this year";

– "Teachers aren't interested in research";

– "We are receiving too many requests to participate in research"; and finally,

– "Filling out surveys doesn't get lessons planned" .

4.2.1.2   School Sizes

For the purposes of this research, participating schools are referred to as either 'metropolitan' or 'provincial' according to the Australian Curriculum, Assessment and Reporting Authority's (ACARA) 'My School' (2013) website's classification. Participating schools were quite varied with respect to the sizes of their student populations. Table 4.3 (metropolitan schools) and Table 4.4 (provincial schools) show the numbers of students enrolled at the participating schools and the number of participating teachers from each school-size grouping. Schools with an enrollment of 200 - 500 contributed the largest representation amongst the metropolitan group. Schools with an enrollment of less than 100 students comprised the largest representation of the provincial group.

Within each of the metropolitan and provincial groups, teachers were employed in schools of different sizes. Within the metropolitan sector, 10 schools (= 63%) had fewer than 500 students, and 6 schools (= 27%) were larger with over 500 students. In contrast, the provincial sector had a slightly larger number of 13 schools (= 87%) with fewer than 500 students and 2 schools (= 13%) with over 500 students.

As the average student enrolment size of provincial primary schools often tends to be smaller than those of their metropolitan counterparts, the numbers of teachers engaged in teaching Stage 3 students in the participating provincial schools was correspondingly fewer. At the time of the research, some of the provincial teachers were teaching both Years 5 and 6 students in 'composite' classes (i.e., classes

comprising combined multiple-year groups) and reported during telephone conversations during the recruitment period that they were too busy to participate in the research because they were delivering lessons to two different class groups - this was often in addition to assisting with the general running of their small school. This imbalance was reflected in the numbers of participating teachers representing each group.

Table 4.3. Numbers of participating metropolitan schools, teachers and corresponding numbers of enrolled students.

Number	Number of enrolled students					
	< 100	100 - 200	200 – 500	500 -800	800+	Total
No. of schools	1	1	8	4	2	16
No. of participating teachers	1	0	19	7	2	29

Table 4.4. Numbers of participating provincial schools, teachers and corresponding numbers of enrolled students.

Number	Number of enrolled students					
	< 100	100 - 200	200 – 500	500 - 800	800+	Total
No. of schools	6	2	5	1	1	15
No. of participating teachers	7	2	5	3	1	18

4.2.1.3 Schools Employing Specialist Science Teachers

It should be noted here that, because primary school sections within the four participating Kindergarten to Year 12 schools operated separately from, and independent of, their secondary sections, the Stage 3 teachers were not supported by their secondary colleagues. Nor was science equipment provided to the school's primary section. For the purposes of this research, this was the preferred situation as it negated the possibility and concern that the Stage 3 teachers might have been relying on the secondary school teachers to support their planning and resourcing of science lessons.

A summary of the extent of the sample schools' employment of specialist science teachers is shown in Table 4.5. One of the metropolitan schools employed a science teacher on a full-time basis plus another in a part-time capacity - on a full-time

equivalent (FTE) basis of 0.1. A second school's specialist teacher instructed each Stage 3 class once per fortnight in a fully-equipped laboratory setting, while a specialist teacher in the third school was employed for the FTE of 0.6 and the fourth employed three part-time science teachers to cover all classes as required by the school's needs. However, only one of the specialist teachers from these schools actually took part in the research and, where appropriate, this was taken into account in the data analysis.

Table 4.5 Frequency of employment of specialist science teachers in the sample schools.

Sector	Number of schools employing specialist teachers	Percentage of total school participating.
Provincial	0	0
Metropolitan	4	13

4.2.2 Participating Teachers

4.2.2.1 Ages of the Participants

The age groups - in terms of years of age - of all of the participants are shown in Table 4.6. One teacher omitted the answer to this question. The average age of the metropolitan teachers was 46 years and 2 months, while the average age of the provincial teachers was slightly lower at 40 years and 7 months. The group born between 1960 and 1969 had a much higher representation in the metropolitan group. Notwithstanding this, however, and given the overall sample size, the two groups could be considered to be comparatively similar in age.

Table 4.6. Age groups of participating metropolitan and provincial teachers.

Year of birth	Numbers of teachers		
	Metropolitan No. (% of group)	Provincial No. (% of group)	Total No. (% of group)
1950 – 1959	5 (17)	4 (22)	9 (19)
1960 – 1969	12 (41)	5 (28)	17 (36)
1970 – 1979	5 (17)	5 (28)	10 (22)
1980 - 1989	7 (24)	4 (22)	11 (23)

4.2.2.2 Teaching Experience of the Participants

As seen in Table 4.7 and Figure 4.1, 37 of the teachers in this research had been teaching in primary schools for over six years and, of these, 24 teachers had been teaching Stage 3 students for over 6 years. The study group, therefore, can be considered to be one with substantial experience in teaching Stage 3 students.

Table 4.7. Teacher experience in primary schools.

Range of years	Years teaching primary school		Years teaching Stage 3	
	No.	(% of group)	No.	(% of group)
<1	1	(2)	6	(13)
1 -2	4	(9)	7	(15)
3 -5	5	(11)	10	(21)
6 - 10	11	(23)	17	(36)
11 - 20	10	(21)	7	(15)
20+	16	(34)	0	(0)
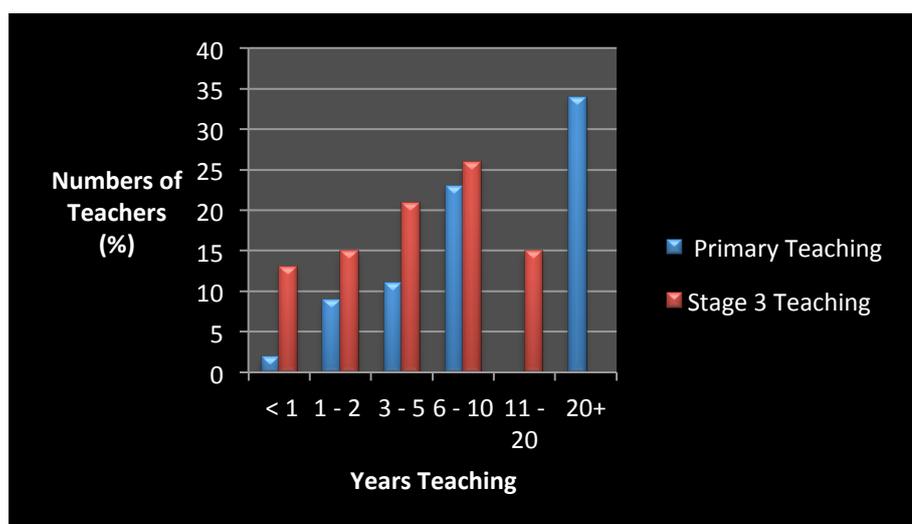
Figure 4.1: Teacher experience in primary schools.

4.2.3 Participants' Educational Backgrounds

4.2.3.1 Secondary Education

Data on the educational backgrounds of the participating teachers during their secondary schooling showed that 11 teachers (= 26% of the 42 respondents) had studied general science to the end of Year 10 in NSW - or the equivalent thereof.

Two of these teachers participated in the Phase III interviews. The other 31 teachers (= 74%) had completed one or more science subjects to NSW HSC level - or the equivalent. The majority of these latter respondents (i.e., 27 teachers) had studied biology, whereas 6 and 4 teachers studied chemistry and physics, respectively, either as a stand-alone subject or in combination with another science.

4.2.3.2 Tertiary Education

Data about the tertiary education backgrounds of these same 42 respondents are shown in Table 4.8 and Figure 4.2. While 27 (= 64%) of the respondents had an undergraduate major emphasis in primary education, four of these teachers had a semester of some primary science-related elements such as pedagogy. A further 4 respondents (= 10%) had studied primary education with a science major, 2 respondents (= 5%) had a specific major in one science discipline but without primary teachers' training, and 9 respondents (= 21%) had majors in areas other than primary education and science.

Table 4.8. Subject areas studied by respondents as a major emphasis at tertiary level.

Subjects studied	Major emphasis
A science major	2
Primary education plus a science major	4
Primary education	27
(Primary education including a semester of primary science related elements)	(4)
Other major	9

Summarising two features of these data, 19% of the total number of schools - none of which was a provincial school - were employing teachers with some form of science-related tertiary background, and 13% of the total teacher cohort had some form of science-related major. These data, combined with those on the number of schools in which specialist science teachers are employed, could indicate that there are schools whose primary teachers might find it difficult to teach science without any form of professional support.
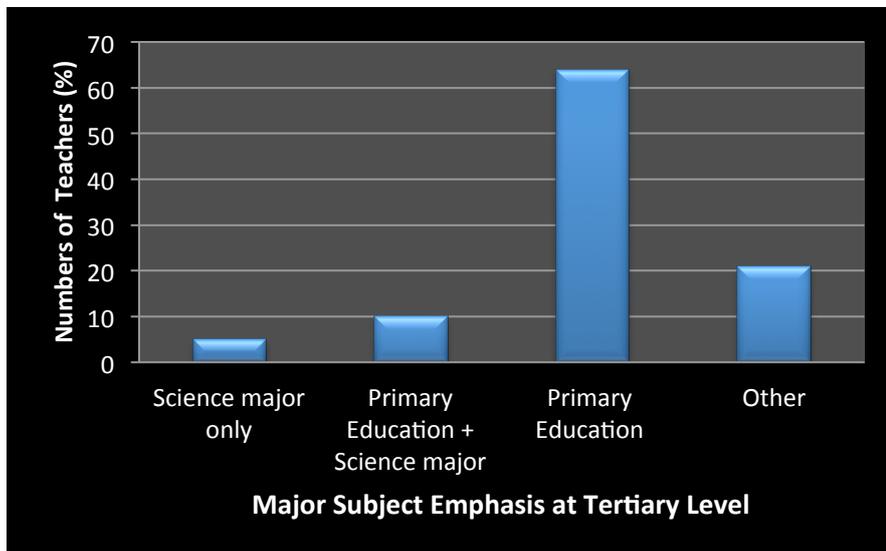
Figure 4.2. Subject areas studied by respondents as a major emphasis at tertiary level.

4.3 Schools' Policies on Teaching Science

4.3.1 Principals - Their School's Policy on Teaching the Science and Technology KLA.

In the Stage I survey, the principals were asked to state their school's policy relating to the teaching of the S&T KLA. The survey question relating to this allowed an open-ended response so that principals were free to answer without restriction. A total of 31 principals responded. The open-ended responses were categorised - and paraphrased where necessary in such a way as to avoid embedding any bias or distortions in the themes - as described in the method chapter.

Summarising these responses into broad categories, eight of the 16 metropolitan schools and four of the 15 provincial principals stated that their school had no specific policy on teaching the S&T KLA. These data include one metropolitan school which had a policy regarding the technology component of the KLA but no policy for its science component. Given the sample size, these figures demonstrated

no appreciable difference between the two school groups, but it is important to note that some principals considered that their school had no form of policy or documented direction in relation to the teaching of science to its students.

Some schools did offer a number of 'policy' statements and, of the remaining 20 schools, the 'policies' were very broadly expressed by the principals. Within this latter group, 17 responses (= 8 metropolitan and 9 provincial) could be represented by the statement "individual teachers are required to teach the current S&T KLA to their students and to follow BOS NSW guidelines and regulations" and four 'policies' as "science is to be taught, on average, for 1 to 2 hours per week". Of the schools with stated policies, some principals contributed one or more 'policy' statements. These were very broadly expressed and are outlined in Table 4.9. Where there was more than one component of the policy, these have been recorded separately. These overlapping statements suggested that: some schools taught the S&T KLA for a prescribed number of hours each week throughout the year; classes were being taught two discrete science units in two short bursts during the year; and enrichment programmes were used to supplement the curriculum, etc. It can be seen from Table 4.9 that the additional responses occurred in equal numbers between metropolitan and provincial schools but with more externally provided enrichment programmes having taken place in the metropolitan (= 3) compared to the provincial (= 1) schools.

Table 4.10 summarises the varied reasons given by principals for not having a specific school policy relating to teaching the S&T KLA. When principals offered more than one reason, these have been recorded separately. Some schools stated that there was "no real reason" for this, while others relied upon either the DEC's and/or the BOS NSW's requirements that science is a mandatory subject or their school's 'scope and sequence' plans - which were developed using the BOS NSW documents in lieu of a specific policy. The existence of a scope and sequence document gave teachers some degree of guidance on what outcomes were to be addressed. One principal gave the lack of staff-interest in teaching science as a reason for not having a policy. Similarly, another principal stated that the school had relied upon its RFF teacher to cover the teaching of science across Stage 3 - and the other Stages. This reason was reflected in another comment made by a teacher from a different school

and was mentioned several times by interviewees such as M3 who noted that *"over the last few years, the RFF has been teaching the science. It gets palmed-off a bit!"* (teacher interview, April 13, 2015, 8.6.1h).

Table 4.9. Summary of participating schools' policies specific to the S&T KLA.

Policy responses	Total number of schools with the same 'policy' component	School by sector: M = Metropolitan; P = Provincial
Individual teachers are required to teach the current KLA to their students and to follow BOS NSW guidelines and regulations	17	9 X P; 8 X M
Using scope and sequence* incorporating parts of the old and new syllabi with an emphasis on outcomes	1	P
Trying to use practical activities	1	P
Have a particular skills and knowledge focus	1	P
Science is to be taught, on average, for a prescribed number of hours per week	4	2 x P, 2 X M
The school has a KLA enrichment programme and/or uses a specialist teacher	4	P 3 x M
Two discrete Science and Technology Units are taught per class per year in two short periods	1	M

*Scope and Sequence: generally refers to the summary of "what is to be taught and the sequence in which it will be taught" (BOS NSW, 2012).

4.3.2 Further Principals' Comments on Policy

Each of the following comments - from separate principals - was made in addition to the specific policy statements:

– "The 5E [instructional] model [i.e., Engagement, Exploration, Explanation, Elaboration and Evaluation] must be used with a strong link to literacy programmes. Compulsory for literacy group to implement one science unit per year";

– "Each year there is an organised incursion with a science theme";

– "Some Science and Technology is integrated into the HSIE programme";

– "Stage leaders ensure topics are programmed and taught and adequate
  time is allocated";

– "The focus of every second term will be science";

– "[The teachers are] currently revisiting the policy as the Australian
  Curriculum is rolled out";

– "As a school for [students] who are academically able, we place great
  emphasis on the teaching of STEM courses"; and

– "We believe that specialist teachers with expert knowledge, skills and
  content knowledge are required to support classroom teachers in the
  delivery of mathematics and science".

The latter two statements are from two metropolitan schools which employed a full-time and a part-time specialist science teacher respectively. These additional comments shed some further light on the principals' stances on S&T KLA policies. It is highly unlikely that having procedures in place - such as organising one science incursion for Stage 3 per year - or integrating "some science" into the HSIE KLA - would ensure that the requirements of the S&T KLA would be fully met.

Table 4.10: Summary of principals' reasons for their schools having no specific policy on teaching the S&T KLA.

Reasons for <u>not</u> having a specific policy	School sector: M = Metropolitan; P = Provincial
No reason - but a good idea! Traditionally the Release from Face-to-face teacher covered the teaching of science but in recent years this has taken on a technology rather than science focus	P
Waiting for the new National Curriculum to be released and for guidelines to be provided by the NSW DEC	P
We have a scope and sequence that is used to ensure that we are covering all topics/themes and outcomes	P
No reason	P
No real reason but there is an expectation that the staff will teach Science and Technology just like all other KLAs.	M
Following the DEC's "policy" which states all requirements we as a school need to follow	M, P
A science scope and sequence had been developed from the BOS NSW syllabus documents therefore no policy needed	2 x M
There has been no requirement to articulate [a policy]	M
No up-to-date science policy as no-one on staff is really interested in teaching it!	M
No policy needed as [science] is a mandatory part of the curriculum.	M

4.3.3 Principals and Teachers - Priority Subjects in The Schools

All participants, both principals and teachers, were asked to nominate - in a free-response format - the subjects given priority in their schools. Figures 4.3 and 4.4 summarise the responses of each of these groups. The percentages are based on the total cohort of principals or teachers. Whilst 'literacy' and 'numeracy' are not recognised as BOS NSW curriculum 'subjects' as such, these are the terms reported by both the principals and teachers and remain unchanged throughout the analysis and discussion.

Twenty six out of the 47 metropolitan and provincial principals nominated the 'subjects' of literacy and numeracy, followed by 15 principals who nominated English and mathematics as having the next highest school priority. Similarly, 24 of the teachers nominated literacy and numeracy as their perceived school's priority 'subjects', and English and mathematics registered second with 14 teachers' nominations. Of the principals' responses, literacy and numeracy/English and mathematics rated a combined 88%, whereas from the teachers' responses, literacy and numeracy/English and mathematics rated a combined 79%. Given the small sample size, this latter figure was just slightly less than the overall percentage for the principals' nominations. Metropolitan and provincial principal groups, were in very close agreement on their schools' priority areas. There did, however, appear to be less agreement between the teachers in the two cohorts. Of the metropolitan school teachers' responses shown in Figure 4.4, one teacher of the nine who quoted literacy and numeracy and one of the four who quoted English and mathematics as having highest priority also included an additional priority subject. Similarly, for the three provincial teachers' totals, one nominated literacy and numeracy and one nominated English and mathematics and also included an extra subject. The extra subjects nominated were either religion or physical education.

As indicated in Figure 4.5, both the combined principals' and teachers' subject nominations were closely correlated. The data presented in this figure were checked by calculating the Pearson product-moment correlation coefficient which measures
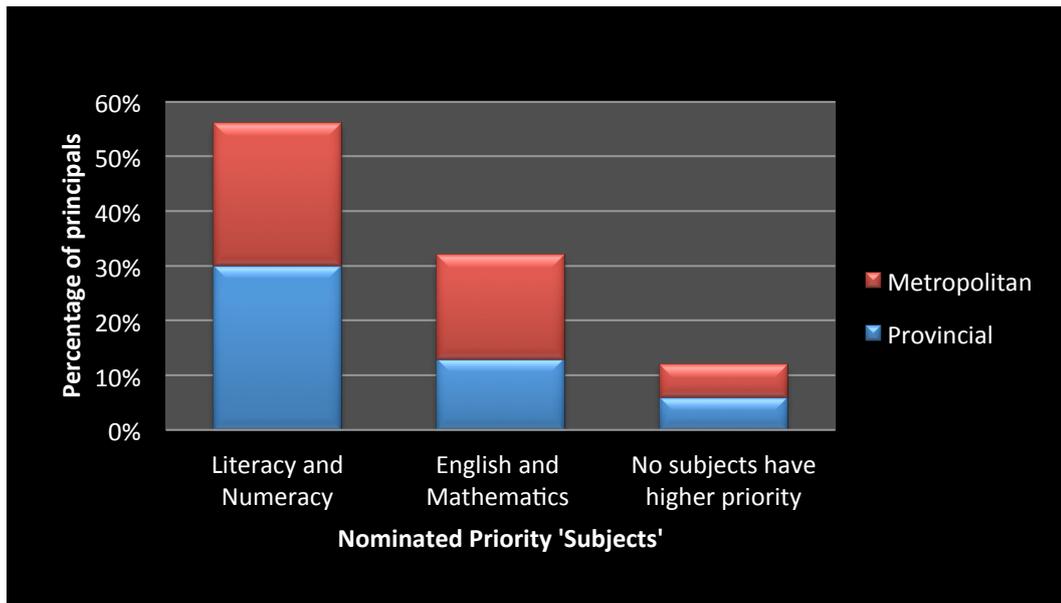
Figure 4.3. Percentage of principals identifying 'subjects' as having priority in their schools.
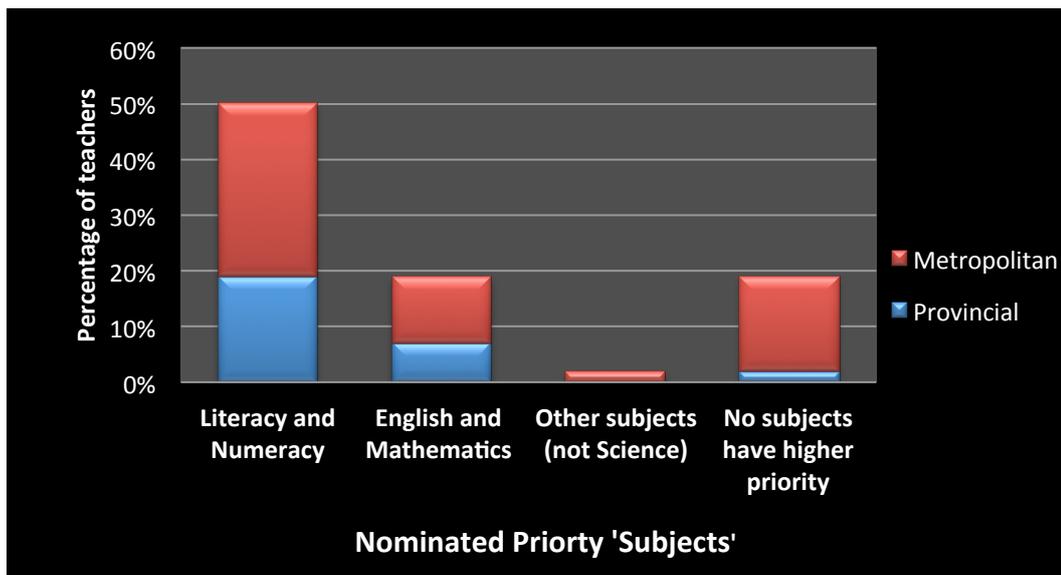
Figure 4.4 . Percentage of teachers identifying 'subjects' as having priority in their schools.

"the strength of the linear association between two variables" as detailed by Leard Statistics (https://statistics.laerd.com/). If there is no association between two variables, the Pearson product-moment correlation coefficient has a 0 value. As values approach +1, they indicate increasingly greater association with each other. The opposite holds true for values as they approach -1. The Pearson product-moment correlation coefficient for the principals' and teachers' responses of +0.997 supported the visually close correlation of the data shown in Figure 4.5 and provided

a strong indication that the school's principals and teachers, at least, had very similar perceptions of their schools' priority 'subjects'.
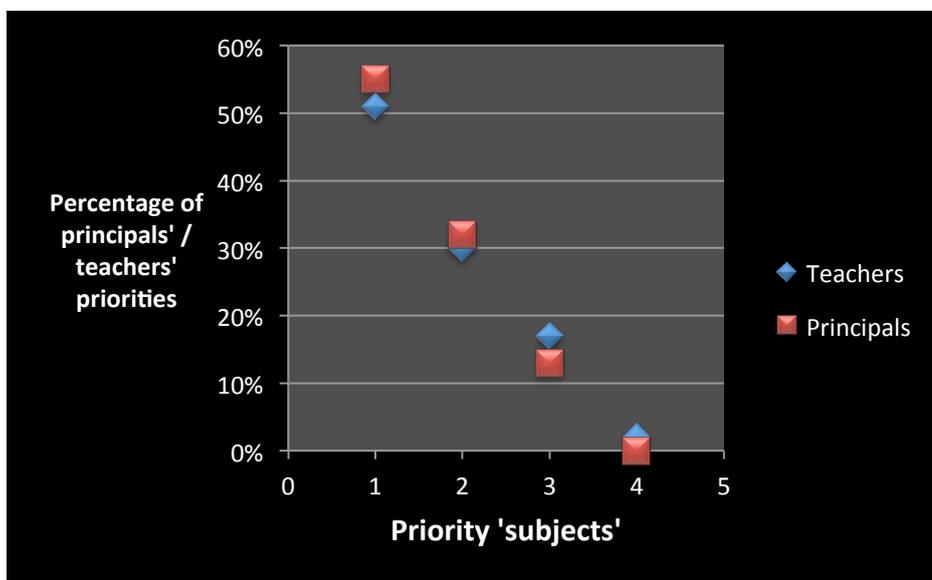
Figure 4.5. Comparison of the percentages of principals and teachers giving priority to different 'subjects'. 1 = literacy and numeracy, 2 = English and mathematics, 3 = No subjects have a higher priority, 4 = Subjects other than literacy, numeracy, English, mathematics and science.

Principals were asked in the survey to identify the reasons for the prioritising of 'subjects' in their school. A comparison of principals of metropolitan and provincial schools of the 'subjects' noted in Figure 4.3 as having priority in their schools, with the reasons for the priority, are graphically represented in Figure 4.6. 'Other reasons' given for the literacy and numeracy nomination in some metropolitan schools included a "strong perceived push" from the school sector's governing and/or parent bodies; "these areas are vital to the students"; and these "are the school's targets". English and mathematics were also prioritised for additional reasons such as a school having extra funding to improve literacy and numeracy within its large ESL population. The 'other reasons' given for literacy and numeracy having top priority in some provincial schools included: some principals' perceptions that English and mathematics should have a greater priority because there was a greater need for those subjects in their schools; and that "preparing for the introduction of the new English syllabus has been time consuming".
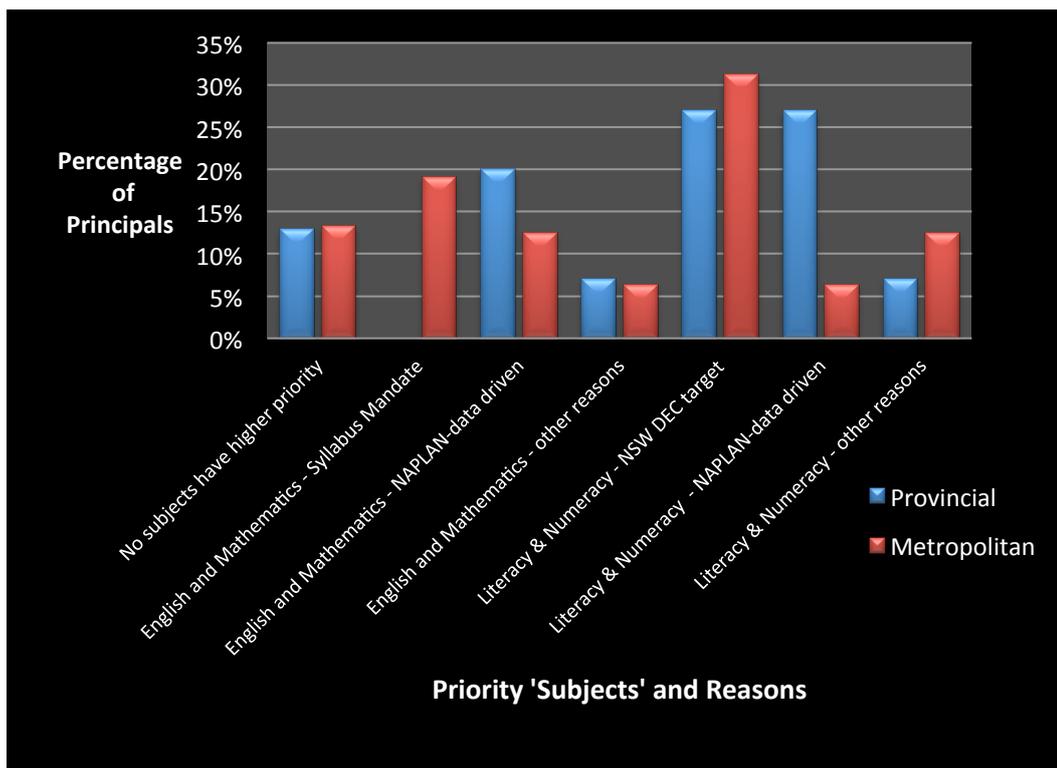
Figure 4.6. Comparison of the percentages of principals of metropolitan and provincial schools giving priority to different 'subjects' in their schools and the reasons for the priority.

4.4 Time Spent Teaching the Science and Technology KLA to Stage 3 Students

The teachers were asked to estimate the average amount of time that they spent teaching the S&T KLA to Stage 3 students each week. The data for the teachers are shown in Table 4.11 and Figure 4.7. The one specialist science teacher who participated spent, on average, 0.5 to 1 hour per week on a regular basis with each Stage 3 class in the same school.

Table 4.11. Average time spent per week by generalist teachers teaching the S&T KLA to Stage 3 students.

Sector	Number of teachers spending time (h/week)				
	<0.5	0.5	0.5 – 1	1 – 2	>2
Metropolitan	0	0	6	18	5
(% of group)	(0)	(0)	(21)	(62)	(17)
Provincial	0	1	5	10	2
(% of group)	(0)	(6)	(28)	(55)	(11)
Total	0	1	11	28	7
(% of total group)	(0)	(3)	(23)	(60)	(15)

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Eight teachers of the metropolitan group felt that they spent less time teaching science than they should. One avoided teaching the subject and a further three said that they just tried to teach the subject with inadequate content knowledge. Another commented that this was because of a lack of teacher training in this area, while another teacher reported that quite a number of teachers did not teach enough science at his/her school because of a lack of content knowledge. One teacher, who had a science degree estimated that a period of greater than 2 hours per week was spent by him/her teaching science to Stage 3 students.

Similarly, five teachers from the provincial schools noted that they felt that they spent less time teaching science than they should, and one noted that he/she avoided teaching the science component of the KLA. One principal commented that "in the past, teachers were not comfortable with teaching science and relied on their relief-from-face-to-face teacher to teach science and this is no longer possible". In this case, at the time of the survey, little science was taught in that school. In summary, the majority of 28 (= 60%) of this group of teachers stated that they spent between one and two hours per week teaching science.
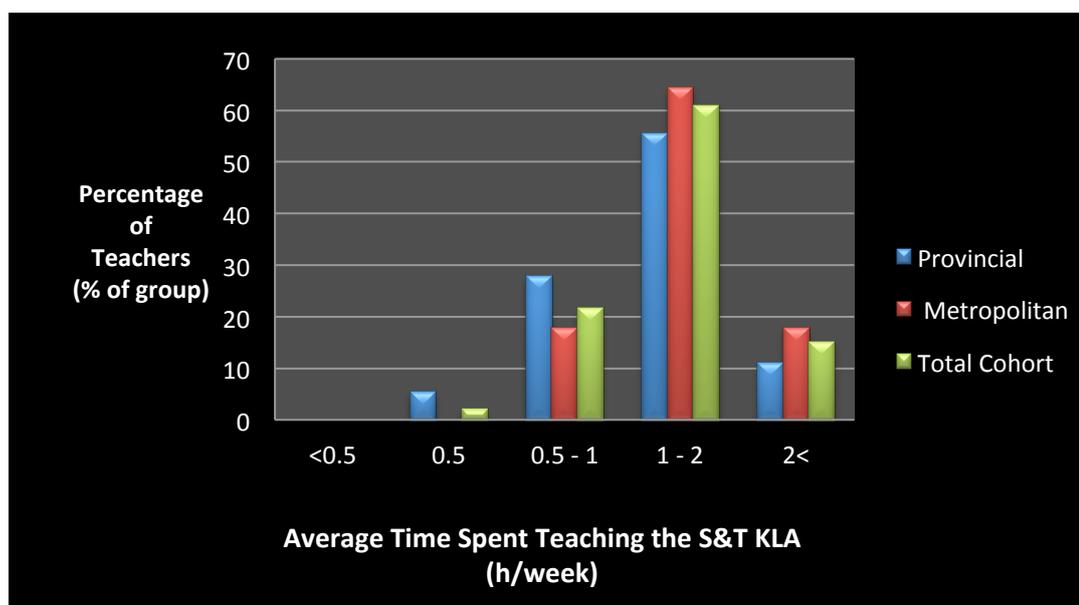
Figure 4.7. A graphical representation of the average time spent per week by generalist teachers teaching the S&T KLA to Stage 3 students.

4.5 Factors Affecting the Teaching of the Science and Technology KLA

In responses to open-ended survey questions, teachers identified factors which they perceived to affect the teaching of this KLA in their schools. The answers were thematically coded as explained in the Research Methods chapter. Most teachers listed more than one factor. For reporting, the factors cited have been divided into those which affect the teaching in a positive and a negative way, respectively, as shown in Tables 4.12 and 4.13. As noted at the beginning of this chapter, percentages are used to highlight the relative sizes of the response groups to each other while keeping in mind the total cohort size. The percentages were calculated as a proportion of all responses, both positive and negative, separately, for the metropolitan and provincial groups. It is of interest to note from Table 4.13, for example, that 18% of the metropolitan teachers identified inadequate time allocated for teaching science/ overcrowded curriculum compared with 37% of the provincial teachers as a negative influence.

Table 4.12. Number and percentage of positive influences mentioned by metropolitan and provincial teachers as factors which affect the teaching of the S&T KLA.

Factor cited	Metropolitan	Provincial
Supportive school policy and/or effective, high quality programmes	9 (11%)	4 (11%)
School has good resources and/or shares resources with other institutions	6 (7%)	1 (3%)
Supportive school executive/community/parent bodies	3 (4%)	0 (0%)
Student motivation	6 (7%)	5 (13%)
Teacher's enthusiasm for science	4 (5%)	0 (0%)
Effective ICT support	2 (2%)	0 (0%)
Teacher's good/adequate science qualifications	4 (5)	0 (0)
Adequate time allocated for teaching science	4 (5)	0 (0)

Table 4.13. Number and percentage of negative influences mentioned by metropolitan and provincial teachers as factors which affect the teaching of the S&T KLA.

Factor cited	Metropolitan	Provincial
Teacher's poor science qualifications	11 (13%)	4 (11%)
Insufficient budget and /or time to maintain resources	14 (17%)	7 (18%)
Inadequate time allocated for teaching science/overcrowded curriculum	15 (18%)	14 (37%)
Team teaching is difficult to organise	1 (1%)	1 (3%)
Lack of and /or availability of teaching space	4 (5%)	1 (3%)
Other staff not interested in teaching science	1 (1%)	0 (0%)
Science is always timetabled in the afternoons	0 (0%)	1 (3%)

4.6 Teachers' Perceptions of Available Science-teaching Resources

In the surveys, the teachers were given the choice of 'good', 'OK' and 'poor' for rating their school's science resources. The majority of both metropolitan and provincial teachers rated their school's resources as being 'OK' - 11 (= 69%) and 11 (= 73%), respectively. This contrasts with four metropolitan teachers and three provincial teachers having rated their resources as 'good' and a further teacher from each of the groups giving a rating of 'poor'. These findings, summarised in Table 4.14, indicate that, on the whole, the majority of the teachers in both metropolitan and provincial areas did not rate their school's science resources as 'poor'. The majority of the teachers thought that their science resources were 'OK.

Table 4.14. Teachers' ratings of their schools' Science and Technology resources.

Location and Number **	Teachers' ratings of S & T resources*		
	Good	OK	Poor
Metropolitan	4 (25%)	11 (69%)	1 (6%)
Provincial	3 (20%)	11 (73%)	1 (7%)

*Teachers at the same schools agreed with each other's ratings of their schools' resources
** Percentage of school grouping

4.7 Additional Comments from the Principals' Survey

Some principals took up the opportunity to respond to an optional question in the Phase I survey which invited them to make any additional comments in relation to the teaching of science in their schools. These comments were analysed for common themes. Because not all principals elected to comment further, the themes are not presented as nominated by either metropolitan or provincial school principals.

Some of the general themes included references to the use of, and reliance on, the 'Primary Connections' resources and the consequent need to keep the resources required to teach the units up-to-date; and, additionally, the two units of science taught each year to Stage 3 where team-taught using the 'Primary Connections' resources. Two principals were quite positive about the teaching of science in their schools, particularly one who was able to say that the school had a science teaching co-ordinator to "organise the team teaching of science" (personal communication, 22 April, 2014). Additionally, three principals commented that they were able to keep their science resources up-to-date, with one principal noting that the school had a specific budget for this. In contrast, another principal was quite definitive in declaring that the science resources in the school were "quite poor", whilst another noted that they didn't have enough science resources. The use of an outside provider employed by the school to deliver science experiences for the school's students provided a solution to that school's lack of time to teach science. Finally, one principal, in contrast, commented that the "onus" for teaching science in that school was on the individual classroom teachers.

Some of the principals expressed hopes for changes to science teaching in their schools as a result of the introduction of the Australian National Curriculum in NSW. The main theme of these comments was a hope for positive change in science teaching that would be precipitated by the approach required by the curriculum. Three principals made comments that the introduction of the Australian National Curriculum in their school might: result in a science teaching "program change"; serve to "refocus teachers on science teaching"; and boost science teaching as it was "really lacking" or a "poorly taught" subject in their schools.

Finally, there were comments from principals that were negative in their connotations. For example, at one end of the range was an expression of apparent apathy expressed by the principals. For example, "a review of science was apparently conducted [in our school] in 2011 but the results of that cannot be located". This comment was made two years after the review was completed. Other comments were made in relation to science being taught by teachers who had no science expertise. Finally, some classes in a couple of the schools were being taught science by the schools' RFF teacher(s) - who were not necessarily qualified to do so - instead of the usual class teacher. This final statement was mentioned again during several of the teacher interviews.

4.8 Teachers' Perceptions of Their Science Content Knowledge and the Resources They Use

Participating teachers were asked whether or not they felt that their science content knowledge needed to be supplemented to enhance their ability to teach the S&T KLA. They were also asked if they used any resources to supplement this knowledge. It is to be noted here, as it has been noted in other sections of this thesis, that the results are based on a small sample of schools and teachers. In the absence of the availability of a larger number of participants, these results should be taken as only representative of the small group from which they were derived. They might, or might not, be representative of the broader school community. However, they are an indication of the broad variance that is present within this small sample group in respect to many of the parameters measured in this study,

Among the 29 metropolitan teachers, 21 answered that they needed to supplement their science content knowledge and, of these, 16 teachers accessed resources to do this and five had not used resources of any kind. However, one of this group noted that the use of supplemental resources depended upon the topic being taught. Eight teachers felt that they did not need any supplementation. For three of these teachers, this was because they had the support of specialist science teachers employed by the school to team-teach and assist with lesson planning. However, all eight teachers continued to use resources to supplement their existing knowledge.

Of the 18 provincial teachers participating, 13 teachers answered that they accessed resources to assist in enhancing science content knowledge. This is a very similar proportion compared to the metropolitan teachers who confirmed that they needed to supplement their science content knowledge but, in this case, all of those teachers used resources of some kind to achieve this. Five teachers said that they did not need to supplement their science content knowledge. Again, these statistics are very similar to the proportion for their metropolitan colleagues. However, two provincial teachers continued to use resources to enhance their existing knowledge and one teacher commented that, because, the RFF teacher often taught the S&T KLA lessons, there was no pressing need for him/her to do so.

The resources listed by the teachers as having been useful have been categorised into 'print', 'online ICT-based', 'human resources - collaboration with others' and 'other' and are tabulated in Tables 4.15 to 4.18. In each of the tables, M and P, respectively, denote the 17 metropolitan and 13 provincial teachers who noted that they used resources. As each teacher was not limited to identifying only one resource, some teachers mentioned multiple printed resources. Table 4.15 is a summary of the print resources mentioned. The 'Primary Connections' printed resources dominated the listings - especially by the metropolitan teachers in comparison to their provincial counterparts.

Table 4.15. Frequency of print resources listed by the participants and used to enhance their science content knowledge.

Resource	M*	P
A variety of books and magazines	15	8
'Primary Connections'. Australian Academy of Science – printed material	17	2
Reference to previously taught units	2	1

*M= metropolitan, P = provincial

Similarly, Table 4.16 itemises the online ICT-based resources that were mentioned by either group. Again, the teachers from both cohorts frequently mentioned the 'Primary Connections' materials. 'Other' ICT-based resources mentioned specifically by name, but only once each, are represented in the final row. These included resources such as 'Scootle', 'Pinterest' and 'Facebook' and a number of CSIRO resources. Twenty-two of these 'other' resources were produced in Australia.

Table 4.16. Online ICT-based science resources listed by the participants as used to enhance their science content knowledge.

Resource	M	P
Use internet searches relating to topics to be taught and a variety of teaching websites	15	5
'Primary Connections'. Australian Academy of Science	17	5
Skwirk Resources (www.skwirk.com.au)	2	1
Twitter – provides links to information sources	1	2
Other ICT-based resources	22	13

Tables 4.17 and 4.18 highlight the use of both 'human resources/ collaboration with others' (ways in which teachers can interact with others to achieve a desired aim), and 'other' resources which received more than one mention by either the metropolitan or provincial participants who found it necessary to enhance their science content knowledge. The entries in Table 4.17 indicate that working collaboratively and sharing ideas with other Stage 3 teachers is, at least, recognised by a number of teachers as a viable way to enhance science content knowledge. These collaborations can also be considered as a form of professional learning and are examined as such in the Discussion chapter. The data in Table 4.17 highlight an interesting aspect of teacher resourcing. The use of the NSW DEC's 'Distance and Rural Technologies (DART) Connections' virtual excursions by provincial schools was mentioned 11 times compared with no mentions by the metropolitan teachers - to whom the virtual excursions are also available. The only restriction on using these resources is that participating schools must have the appropriate hardware and internet connectivity to enable them to connect with the service. This aspect of the use was not mentioned by any of the provincial teachers as being a problem for them. The data for the 'DART Connections' and other video conferencing were included in this table because, even though video conferences are a form of ICT in their own right, it is the interactions between the humans participating in the conferences that is more important. Without those interactions, the ICT itself ceases to be a useful resource. The data in Table 4.18 also show that the teachers considered that they learnt some content knowledge from other sources such as CSIRO science incursions and television documentaries.

Table 4.17. Frequency of human resources/collaboration with others - listed by the participants as used to enhance their science content knowledge.

Resource	M	P
Working collaboratively/sharing ideas with other Stage 3 teachers	6	9
Team teaching to assist another teacher(s) to gain confidence in teaching science	1	3
Swapping classes with another Stage 3 teacher so that one teacher teaches the science course	3	–
Assistance from science professionals/scientists outside of school	2	–
Video conferences with other small schools (occasionally) and outside agencies (e.g., Questacon)	–	2
Video conferences (some booked through NSW DEC - Distance and Rural Technologies ('DART Connections')	–	11
Working with formally arranged mentor	–	1
Collaborate with secondary science teachers or teachers with a science background	1	1
Science in Schools - but discontinued	1	–

Table 4.18. Other resources listed by the participants as used to enhance their science content knowledge.

Resource	M	P
Science in a Box (from Primary Science Matters)	2	
CSIRO incursions	2	
Various topic-related DVDs	3	1
TV Documentaries	2	
Other resources mentioned only once	2	4

4.9 Teachers' Participation in Activities to Enhance Science Content Knowledge

4.9.1 Need for PL to Enhance Science Content Knowledge

When questioned about their PL needs related to the science content of the S&T KLA, 40 of the total cohort of teachers indicated that they had such a need - 36 teachers had a low to moderate need, while a further four had a low need. A comparison of these perceived professional learning needs for metropolitan and provincial teachers is shown in Figure 4.8. Among the total cohort, 39 teachers indicated that they had a need for PL to improve ICT skills to assist their own learning of the science content within the S&T KLA, 19 teachers had a moderate to high need and 20 teachers had a low PL need to achieve this goal.

The Phase I survey asked teachers to identify any professional learning courses - along with the course provider and duration - that they had attended in the given time-frame of two years prior to undertaking the survey. No prompts of any kind
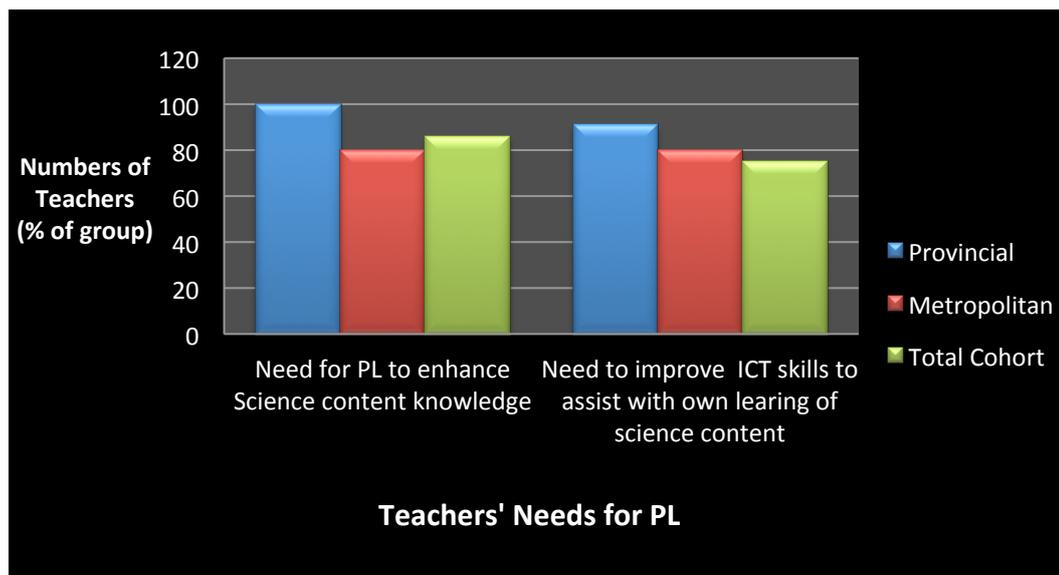
Figure 4.8. A comparison of metropolitan and provincial teachers' perceived needs to participate in PL activities to enhance their science content knowledge and to improve ICT skills to assist their own learning of the science content.

regarding the types of PL activities that they should consider were given in the Phase I survey. However, in contrast, participants in the later Phase II survey were presented with a range of activities which are considered to contribute to professional learning. Some of these were organised activities - such as externally organised courses - whilst others were referred to as 'less-formal PL' - such as informal discussions with colleagues on how to improve one's science teaching and working with Stage 3 colleagues to plan and organise science lessons. This list prompted a slightly more comprehensive response from participants concerning science-related PL activities in which they had engaged.

4.9.2 Phase I Survey Data

Of the 29 metropolitan teachers, five did not attend any professional learning courses in the two years preceding the Phase I survey. In the same period, a further 20 teachers attended courses but none was directly related to science. Five of these 20 teachers attended courses on the new Australian Curriculum. However, the courses' content did not relate directly to the teaching of science content or to enhancing the teachers' science content knowledge. Other courses attended which were not related to science teaching included: numerous courses on the uses of particular computer-based programmes; how to use devices such as tablets and related software; religious

education; differentiating the curriculum (one attendee); and a large number of courses related to the teaching of English and mathematics and improving literacy and numeracy. In summary, 4 of the 29 metropolitan teachers attended science-related courses.

Within the group of 18 provincial teachers, five teachers did not attend any professional learning courses in the given two-year period. One teacher attended three science-related courses only (see Table 4.19) and 12 teachers attended a small number of courses including welfare-related topics, Aboriginal Education and courses relating to the teaching of English and mathematics. The science-related courses attended by the five teachers across both groups are shown in Table 4.19.

Table 4.19. Frequency of professional learning science-based courses - by type and number - attended by metropolitan and provincial teachers.

Course	M	P
Sustainability Course - science related	1	
Scientific Inquiry at the AIS 2013	1	
Kids Design Challenge (KDC) – for Stage 3 teachers to provide PL in Science and Technology and training for running the KDC		1*
Introduction to Primary Connections NSW DEC and Australian Academy of Science (2h overview of units)	2	
Watch your Watts - training day to run programme		1*
Training at the Environmental Education Centre at Observatory Hill, Sydney		1*

*The same teacher attended all three courses in the last two years

4.9.3 Phase II Survey Data

Of the total cohort, 23 teachers confirmed that they had engaged in organised science-related PL activities. This number is in contrast to the five teachers in the Phase I survey who stated that they had attended science-related PL activities. 17 teachers indicated in Phase II that they did not engage in any PL activities and as many as 30 teachers engaged in less-formal PL activities such as informal dialogue on science teaching with their colleagues and/or consulting professional literature. This later group overlapped with those who engaged in organised activities.

The responses of the 23 participants from both metropolitan and provincial groups who had engaged in organised courses/activities are summarised in Table 4.20, while Table 4.21 provides a summary of the less-formal PL in which 35 teachers said they

engaged. The responses of the teachers about the perceived impacts of the courses/activities on their 'development as a teacher' are also included. Participation in one type of organised activity, as shown in these tables, was not mutually exclusive of participation in others. Percentages are included in this group of tables to identify proportions of the total cohort for comparisons. The first column in Tables 4.20 and 4.21 identifies the category of professional learning in which the teachers could engage. For example, category 'a' is 'courses/workshops on science and technology subject matter'. The total number of teachers participating in a category of professional learning is shown in the second column. In the survey question, the teachers were asked to select the level of impact that the professional learning had on them. Columns three to six are populated with the perceived impacts, such as 'large impact' or 'no impact'.

In Tables 4.22 and 4.23, respectively, the data in Tables 4.20 and 4.21 are further partitioned into the same course categories attended by the teachers of the metropolitan and provincial groups. Again, the first column in each table identifies the same category of professional learning in which the teachers could have engaged as per Tables 4.20 and 4.21. The number and percentages of metropolitan and provincial teachers who attended each category of professional learning are reported in the columns. For example, from Table 4.20, a total of 10 teachers (= 22% of the total cohort) attended 'a. courses/workshops on science and technology subject matter'. Three of these teachers considered that the courses had a small impact on their development as a teacher, while one and six teachers, respectively, considered that the courses they attended had a moderate or large impact. The percentages beneath the impact figures represent the proportion of the total cohort. From Table 4.22, of these 10 teachers attending the courses 'a. courses/workshops on science and technology subject matter', 8 were metropolitan teachers (= 28% of all of the metropolitan teachers) and 2 were provincial teachers (= 11% of the total provincial teachers).

Table 4.20. Frequency of participation in categories of formal science-related PL activities and levels of impact of these activities on their "development as a teacher". Note: Percentages are of all participants.

Professional learning activity	Number of teachers				
	Total participation (%)	No impact	Small impact	Moderate impact	Large impact
a. Courses/workshops on Science and Technology subject matter.	10 (22)	0	3	1	6
b. Education conferences or seminars (where teachers and/or researchers present their Science and Technology research results and discuss educational problems related to Science and Technology).	6 (13)	0	4	0	2
c. Qualification program (e.g. a degree program).	2 (4)	1	0	1	0
d. Observation visits to other schools.	6 (13)	0	0	2	4
e. Participation in a network of teachers formed specifically for professional learning in the area of teaching Science and Technology.	6 (13)	1	3	1	1
f. Individual or collaborative research on a Science and Technology KLA topic.	14 (30)	0	4	4	6
g. Mentoring in the Science and Technology KLA, as part of a formal or informal school arrangement.	9 (19)	0	2	5	2
h. Being mentored in the teaching of Science and Technology as part of a formal or school arrangement.	1 (2)	0	0	1	0

Table 4.21. Frequency of participation in categories of less-formal science-related PL activities and levels of impact of these activities on their "development as a teacher". Note: Percentages are of all participants.

Professional learning activity	Number of teachers				
	Total participation (%)	No impact	Small impact	Moderate impact	Large impact
i. Reading professional literature (e.g. Science or Science and Technology journals, evidence-based papers, thesis papers).	18 (39)	2	3	10	3
j. Engaging in informal dialogue with your colleagues on how to improve your Science and Technology teaching.	35 (75)	4	3	17	11

Table 4.22. Frequency of participation in categories of formal science-related PL activities according to metropolitan or provincial membership. Note: Percentages are within each of the two groups.

Professional learning activity	Metropolitan participation		Provincial participation	
	(number)	(%)	(number)	(%)
a. Courses/workshops on Science and Technology subject matter.	8	28	2	11
b. Education conferences or seminars (where teachers and/or researchers present their Science and Technology research results and discuss education problems related to Science and Technology.	6	21	0	0
c. Qualification Programme (e.g. a degree program).	1	4	1	6
d. Observation visits with other schools.	2	7	4	22
e. Participation in a network of teachers formed specifically for the professional learning in the area of teaching Science and Technology.	5	17	1	6
f. Individual or collaborative research on a Science and Technology KLA topic.	10	35	4	22
g. Mentoring in the Science and technology KLA as part of a formal or informal school arrangement.	8	28	1	6
h. Being mentored in the teaching of Science and Technology as a part of a formal or school arrangement.	0	0	1	6

Table 4.23. Frequency of participation in categories of less-formal science-related PL activities according to metropolitan or provincial membership. Note: Percentages are within each group.

Professional learning activity	Metropolitan participation		Provincial participation	
	(number)	(%)	(number)	(%)
i. Reading professional literature (e.g. Science or Science and Technology journals, evidence-based papers, thesis papers).	12	41	6	33
j. Engaging in informal dialogue with your colleagues on how to improve your Science and Technology teaching.	24	83	11	61

4.9.4   Attendance at Organised PL Activities

The PL courses and activity types were categorised into either those organised by an external provider (a, b and c in Table 4.20 and referred to below as Category I activities) or those that had been formally organised at the school level (d to h and referred to as Category II activities). The teachers' participation in the Category I and/or II activities is summarised in Table 4.24. In terms of full days that the teachers spent attending S&T PL activities, 9 teachers spent a total of 30 full days over the relevant period. Both metropolitan and provincial teachers attended the same number of full-day activities, with two metropolitan teachers spending four days, three teachers spending two days and one teacher attending for one day. Within the provincial group, one teacher accounted for 7 of these days, another for 5 days and 1 teacher for 3 days.

Table 4.24. Frequency of participation in PL activities designated as Category I or II.

Courses attended	Number attending
One course only	5
Either a Category I or Category II course	6
One or more Category I and Category II courses	12

4.9.4.1   Do Teachers Want to Participate?

All participants responded to the question asking whether or not they wished they had participated in more PL than they did during the period specified. Of the total teacher cohort, 28 teachers responded in the affirmative, with 15 of the 29 metropolitan and 13 of the 18 provincial teachers responding in this way. Even given that the sample size is quite small, results are noteworthy.

4.9.4.2 Reasons Limiting the Uptake of PL Opportunities

All participating teachers were asked to identify the reasons which best explained why they did not participate in more organised PL for the S&T KLA in the period of interest. This was an open-ended question and the teachers were permitted to identify as many reasons as they felt were applicable. Table 4.25 lists, for each of these reasons, the percentages of participants in each of the metropolitan and provincial group and within the whole cohort.

Table 4.25. *Frequency of reasons for not participating in organised PL activities.*

Reasons for not attending PL	Respondents selecting reasons (%)		
	Metropolitan	Provincial	Total
I did not have the pre-requisites (e.g. qualifications, experience, seniority)	0	15	4
Professional Learning was too expensive - I could not afford it	25	29	27
PL was too expensive - my school could not afford it.	31	43	35
There was a lack of employer support	0	14	4
PL conflicted with my work schedule	50	29	44
I didn't have the time because of my family responsibilities	6	45	9
There was no suitable PL offered	56	71	61

4.9.4.3 Payment for the Activities

Many schools have annual PL allowances to cover costs for staff to attend PL and, where applicable, to provide casual relief for the time period involved. Of the nine participants who engaged in PL activities over a number of days, 2 had to cover the entire costs themselves and a further 6 paid for part of the cost. This suggests that only one of the teachers was fully funded by his/her school.

4.9.4.4 Release Time to Attend PL Activities

A number of PL activities were offered during normal school hours - that is, between 9 am and 3:30 pm - and over half of the PL activities were attended during these hours. The teachers who attended were granted release time from their teaching duties to do so. For these teachers, a casual relief teacher would have been employed - adding to the cost. The remaining activities were offered and attended outside school hours.

4.9.4.5 Compulsory Attendance at PL Activities

It was reported that one metropolitan teacher attended three courses that were made compulsory by the school. Another teacher attended one compulsory day. However, none of the PL attended by the provincial teachers was compulsory.

4.9.5 Impacts of PL Activities Attended

Data collected from the 23 teachers who participated in the categories of formal or 'organised' professional learning indicated that 56% of the Category I activities undertaken were perceived to have had a moderate to large impact on their 'science and technology knowledge' and 67% of the Category II activities had a moderate to small impact in this area. Data collected from the 30 teachers who engaged in less-formal PL indicated that 76% of the activities engaged in were of moderate to high impact on science teaching.

4.10 Computer Access for Teachers to Search for Information to Enhance Their Science Content Knowledge

Teachers were asked to comment on the availability of computers for their own use. Within the metropolitan group of 29 teachers, 14 teachers had a computer or other electronic device (e.g., electronic tablet, notebook, etc.) for their personal use, while 14 other teachers used the computers or other devices in their classroom and/or computer room. These were shared with the students. One teacher only had access to four computers shared with other staff in the staff room. (The number of 'other staff' was not disclosed). Twenty-three of these 29 metropolitan staff commented on the factors which affected their use of computers and other devices and, of these, the 14 teachers who had devices of their own had no access problems. Another five teachers commented that ongoing network issues, internet speeds and maintenance issues at their school limited their access were of concern. Because four teachers relied on access to devices in their classroom or the staffroom, finding time to use the devices presented a difficulty - especially, of course, when students were using them.

Of the 18 provincial teachers, 14 teachers commented on computer availability. One of these respondents had his/her own device for use at school and, therefore, always had computer access. Seven teachers shared between one and five computers in their classroom and ten teachers had access to between 8 and 20 computers either in classrooms, computer rooms or the library. In relation to access issues, the teacher who owned a laptop had no access issues at school. The other teachers had varying degrees of access issues around the sharing of the school computers. One teacher noted that there was no time to use the computers at school whilst three commented that the internet was sometimes unreliable or too slow in the rural regions in which their schools were situated.

4.11 Where the Search for Science Content was Conducted

Teachers were asked for their preferred location for carrying out their search for information to enhance their science content knowledge - at school or in their home - and to quantify how much time was spent in this pursuit each week. The reported preferences are outlined in the following sections.

4.11.1. Preference for Searching for Science Content at School

Nine of the 29 metropolitan teachers had a preference for conducting their information searching at school. Five of these teachers gave no reason for this preference, while two cited that having fewer distractions at school was an incentive to search for information there. One teacher cited that excellent internet access and other resources at his/her school were conducive to searching there, whilst another teacher noted that "research gets done wherever possible". The only specialist teacher participating - who was part of the metropolitan group - did not use the computer for searching for science content because she felt that there was no need but, nevertheless, used computer searching for actual lesson resources. Notwithstanding their preferences, many of these teachers also estimated the amount of time that they spent at home engaged in this pursuit.

Amongst the 18 teachers in the provincial group, 3 had a preference for working at school. The reasons were that the internet at home was not reliable, release from face-to-face time was available at school to do the necessary research, and it was easy to stay back until 6pm. Two of the 16 provincial teachers had no preference for working either at home or at work. One teacher stated that approximately equal time was spent in both places in searching for science content, while the other liked to stay at school to use all available resources. This latter teacher did, however, spend more time searching at home if the resources for a particular topic area were limited at school.

4.11.2 Preference for Searching for Science Content at Home

The teachers' preferences for carrying out searching for science content at home was much greater than engaging in this pursuit at school among both the metropolitan and provincial groups. Table 4.26 shows the amount of time which generalist provincial and metropolitan teachers spent searching for this information at home.

Amongst the 29 metropolitan teachers, 19 teachers had a preference for searching at home. The reasons that the majority of these participants gave can be summarised by saying that they found it too busy when at school with a crowded curriculum and had other things to do and, therefore, working at home with fewer distractions was preferable. Several respondents stated that information-searching at home gave them more time to "achieve greater understanding of the content" and allowed more time "to inform [the teacher] in all aspects of his/her teaching". Two teachers preferred to do their searching at home because they preferred to work outside school hours, while a further two teachers stated that they wanted to make full use of their internet service at home - in the words of one teacher, "using the internet is the up-to-date way to do this". The final two reasons were that it was easier to work at home where the family was, and there was a problem with availability of computers at school. As noted above, the one specialist science teacher only used the computer at home to search for specific lesson resources.

Thirteen of the 18 provincial teachers preferred to work at home for reasons very similar to those of the metropolitan teachers. The predominant reason given by the majority of 11 teachers was that there was more time and fewer distractions/interruptions at home than at school. Therefore, they had more time to search/"surf around"/"get my head around" the information. The remaining two teachers communicated that it was more relaxed and possible to work at their own pace when at home. It was noted by several teachers that, in their rural areas, there were problems with internet download speeds and downloading via satellite. Only one of this group of provincial teachers spent no time at home in this pursuit.

Table 4.26. Amount of time that generalist metropolitan and provincial teachers spent at home searching for information to enhance their science content knowledge. *Not including the specialist science teacher.*

Teacher group	Time spent at home searching for information (h/week)					
	0	<0.5	0.5 - 1	1- 2	2 - 3	>3
Metropolitan Teachers *	0	8	11	4	2	3
(% of metropolitan group)	(0)	(28.6)	(39.3)	(14.3)	(7.1)	(10.7)
Provincial Teachers	1	1	6	8	1	1
(% of provincial group)	(5.5)	(5.5)	(34)	(44)	(5.5)	(5.5)
Total number of teachers	1	9	17	12	3	4
(% of total teachers)	(2.1	(20.0)	(37.0)	(26.1)	(6.3)	(8.6)

4.12 Teacher Confidence - Analysing the Science Teaching Efficacy Belief Instrument - the STEBI-A

In total, 42 participants completed the STEBI-A section of the Phase II survey and their responses are summarised below. For ease of comparison across the data, and given that this sample is relatively small, the percentage of responses to each item is shown together with the actual numbers of responses for the 42 teachers. As discussed in the Research Methods chapter, the scoring of responses to items which were negatively worded was reversed for analysis. The negatively worded items are denoted in Table 4.27 - and, where relevant, in following tables - by the symbol **. The rationale underpinning the analysis of the STEBI-A responses is discussed at length in the Research Methods chapter. Statistical analysis of the responses (n = 42) using the SPSS and pre-validated using the process of member-checking yielded a Cronbach alpha reliability of >0.6 for both the STOE and PSTE subscales. This placed the internal consistency estimate - that is, the degree of interrelatedness of the

items (Cortina, 1993) - of the scales' reliability within the acceptable range (Gliem & Gliem, 2003, p. 87).

4.12.1 Personal Science Teaching Efficacy Belief Scale (PSTE)

The item means for the 42 teachers answering the relevant questions were analysed and are shown in Figure 4.9. The weightings used when scoring items were: 1=Strongly Agree; 2=Agree; 3=Uncertain; 4=Disagree; and, 5=Strongly Disagree.

For each of these PSTE items, there was no difference between the response medians (= 2, Agree) of the metropolitan and provincial groups. There was, however, some variation between the IQRs of the total provincial and metropolitan groups as shown in Figure 4.10 in which the IQRs for each of these groups is graphed against the median score.

Table 4.27. Frequency of teachers' responses to the STEBI-A *.

Item Statement	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
		% of total responses number of responses			
1. When a student does better than usual in science it is often because the teacher exerted a little extra effort	11.90% 5	69.05% 29	9.52% 4	9.52% 4	0.00% 0
2. I am continually finding better ways to teach science	21.43% 9	59.52% 25	7.14% 3	11.90% 5	0.00% 0
3. Even when I try very hard I don't teach science as well as I do most subjects**	2.38% 1	9.52% 4	23.81% 10	50.00% 21	14.29% 6
4. When the science grades of students improve it is most often due to their teacher having found a more effective teaching approach	9.52% 4	69.05% 29	11.90% 5	9.52% 4	0.00% 0
5. I know the steps necessary to teach science concepts effectively	11.90% 5	61.90% 26	19.05% 8	7.14% 3	0.00% 0
6. I am not very effective in monitoring science experiments**	0.00% 0	14.29% 6	16.67% 7	54.76% 23	14.29% 6
7. If students are underachieving in science it is most likely due to ineffective Science teaching**	0.00% 0	45.24% 19	28.57% 12	26.19% 11	0.00% 0
8. I generally teach science ineffectively**	0.00% 0	11.90% 5	7.14% 3	61.90% 26	19.05% 8
9. The inadequacy of a student's Science background can be overcome by good teaching.	11.90% 5	78.57% 33	7.14% 3	2.38% 1	0.00% 0
10. The low science achievement of some students cannot be blamed on their teachers**	4.76% 2	35.71% 15	35.71% 15	23.81% 10	0.00% 0

Table 4.27 Continued

11. When a low achieving student progresses in science it is usually due to extra attention given by the teacher	7.14% 3	66.67% 28	23.81% 10	2.38% 1	0.00% 0
12. I understand Science concepts well enough to be effective in teaching elementary Science	21.43% 9	59.52% 25	14.29% 6	4.76% 2	0.00% 0
13. Increased effort in Science and teaching produces little change in some student's Science achievement**	0.00% 0	23.81% 10	16.67% 7	57.14% 24	2.38% 1
14. The teacher is generally responsible for the achievement of students in Science	7.14% 3	66.67% 28	11.90% 5	14.29% 6	0.00% 0
15. Students' achievement in Science is directly related to their teacher's effectiveness in Science teaching	4.76% 2	61.90% 26	23.81% 10	9.52% 4	0.00% 0
16. If parents comment that their child is showing more interest in Science at school it is probably due to the performance of the student's teacher	9.52% 4	54.76% 23	23.81% 10	11.90% 5	0.00% 0
17. I find it difficult to explain to students why Science experiments work**	0.00% 0	9.52% 4	4.76% 2	64.29% 27	21.43% 9
18. I am typically able to answer students' Science questions	14.29% 6	73.81% 31	11.90% 5	0.00% 0	0.00% 0
19. I wonder if I have the necessary skills to teach science**	0.00% 0	9.52% 4	30.95% 13	47.62% 20	11.90% 5
20. Effectiveness in science teaching has little influence on the achievement of students with low motivation**	0.00% 0	7.14% 3	21.43% 9	69.05% 29	2.38% 1
21. Given a choice I would not invite the principal to evaluate my Science teaching**	2.38% 1	14.29% 6	14.29% 6	59.52% 25	9.52% 4
22. When a student has difficulty understanding a Science concept I am usually at a loss as to how to help the student understand it better**	0.00% 0	4.76% 2	11.90% 5	69.05% 29	14.29% 6
23. When teaching science I usually welcome student questions	47.62% 20	47.62% 20	2.38% 1	2.38% 1	0.00% 0
24. I don't know what to do to turn students on to Science**	0.00% 0	9.52% 4	16.67% 7	57.14% 24	16.67% 7
25. Even teachers with good Science teaching abilities cannot help some students learn Science**	0.00% 0	33.33% 14	16.67% 7	38.10% 16	11.90% 5

*Note: In this and successive tables, the Science Teaching Outcome Expectancy (STOE) scale items are shaded, those of the Personal Science Teaching Efficacy Belief (PSTE) scale are unshaded. ** Denotes negatively worded item statements.*

4.12.2 Science Teaching Outcome Expectancy Scale (STOE)

The STEBI-A response means for the 42 participants to items identified as relating to the STOE scale are shown in Figure 4.11. The analysis was similar to that described for the PSTE items, and responses for the metropolitan, provincial groups and combined (i.e., total) cohort are shown.
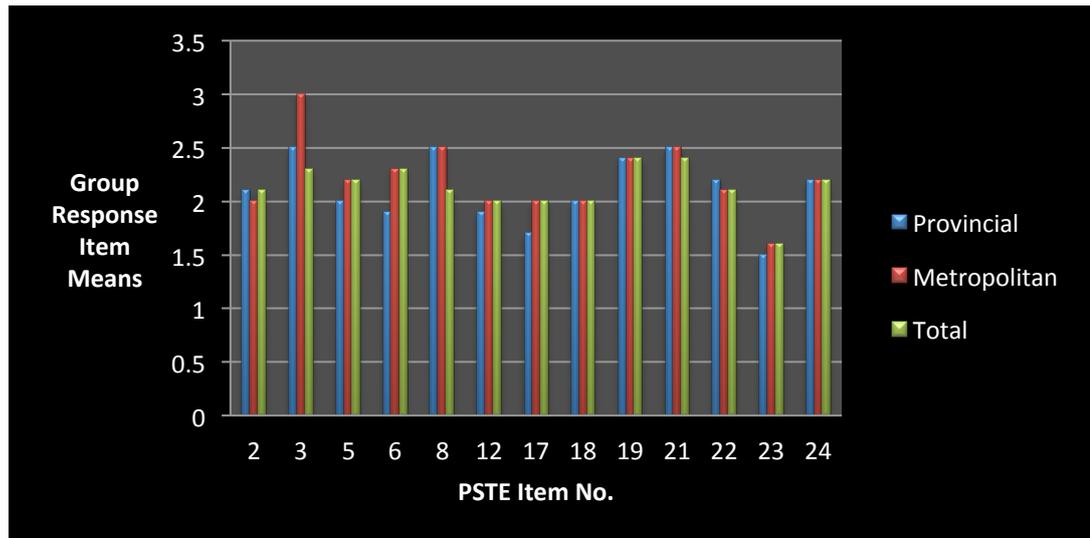
Figure 4.9. Means for the PSTE items in the STEBI- A. (Note: "Total" refers to the results of the whole group.)
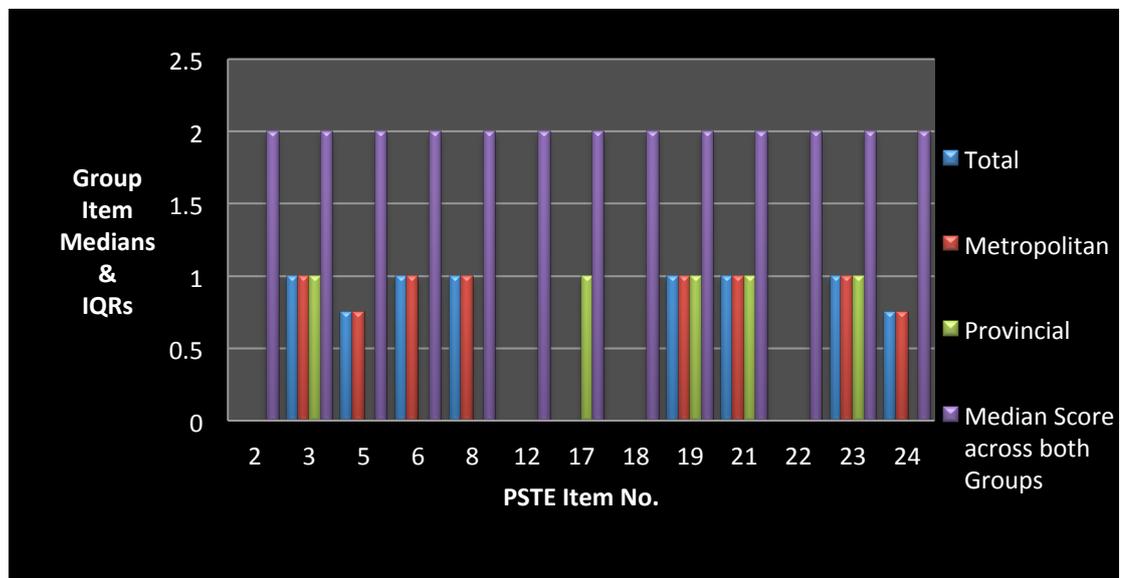
Figure 4.10. Median and IQR values for the total cohort, metropolitan and provincial cohorts for PSTE items for which there is a difference between the medians of the three groups. (Note: "Total" refers to the results of the whole group.

For the STOE items, there was a slight variation in the median scores for several items when the responses for the total group, the metropolitan and the provincial groups were compared. In Figure 4.12, the metropolitan and provincial medians only appear for items with a difference between the three groups.
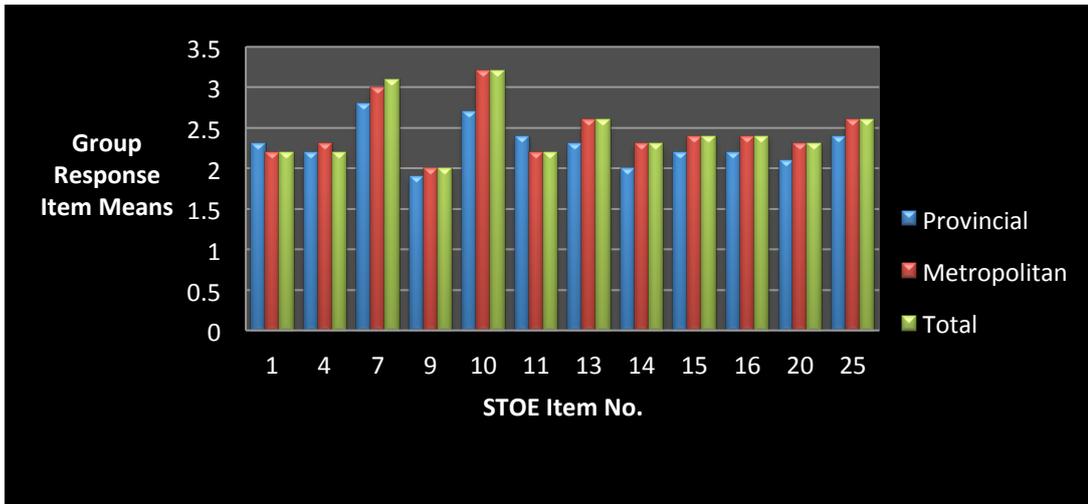
Figure 4.11. Means for the STOE items in the STEBI-A. (Note: "Total" refers to the results of the whole group.)
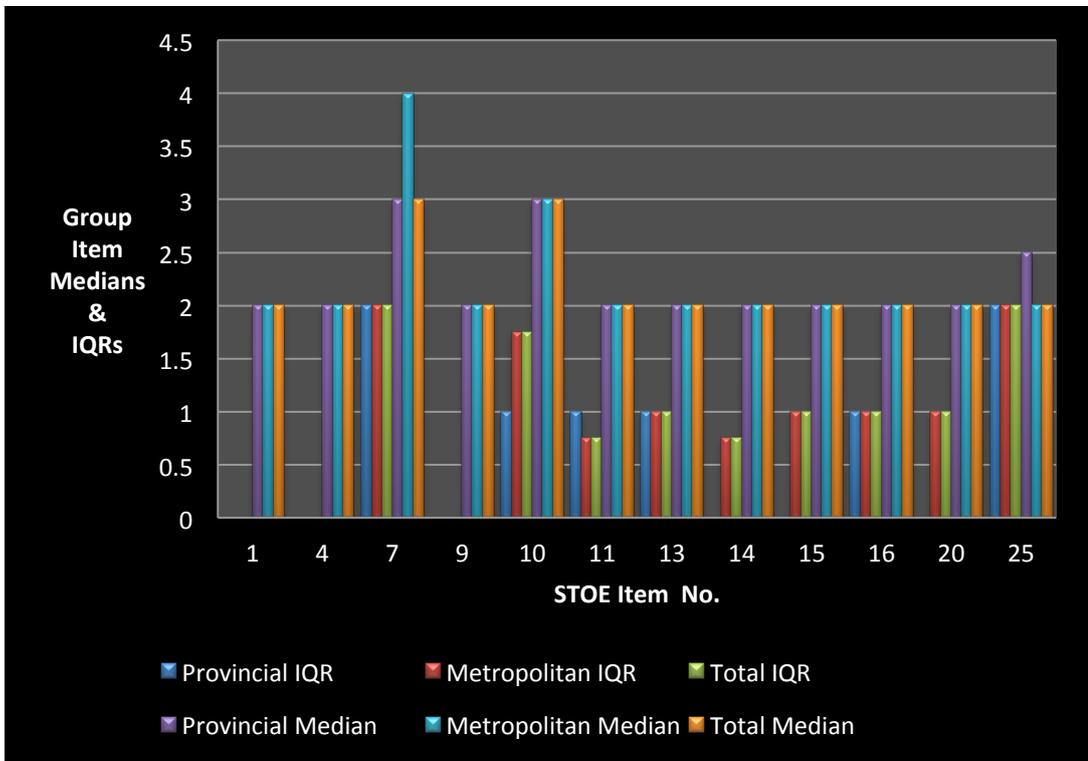
Figure 4.12. Median and IQR values for the total cohort, metropolitan and provincial cohorts for STOE items

4.12.3   Identifying Further Patterns in STEBI-A Responses

Each PSTE and STOE item was further analysed to identify those for which the mean, median score and IQR indicated either a degree of disagreement between the majority of the respondents or that respondents were undecided - as indicated by having an IQR≥1. By way of example, for STOE Item 1 the mean was 2.2, which indicates that, on average, teachers were in agreement with the statement "When a student does better than usual in science it is often because the teacher exerted a little extra effort", but with just a slight tendency towards being 'undecided'. That is, 42 teachers were in agreement with this statement ($\overline{x} = 2.2$). The median - or middle score - was 2 with a relatively small IQR of 1, also indicating the level of agreement within the groups. However, it is important to note that, whilst the majority of 34 teachers (= 81%) were in agreement, there was a 'persistent minority' (PM) of 8 teachers (= 19%) who remained undecided or disagreed/strongly disagreed with the statement. Where applicable, the results for the STEBI-A are reported in this way. The PM was not always the same respondents.

Using the same procedure as with other similar data sets, it was also considered valuable to analyse the number of 'undecided' responses to PSTE and STOE items in order to highlight the degree of uncertainty. These items are noted in Tables 4.28 and 4.29. These tables show (i) the size of the group of the majority of respondents (as a percentage) which were in agreement with each other, and (ii) the size of the minority group who were either in disagreement with the rest of the respondents or undecided. It is important to note here, that the stated percentages refer to agreement or disagreement/undecided with other teachers' responses and NOT to agreement or disagreement/undecided with the actual item statement. This is particularly important for the negatively worded items. A summary of the 'undecided' responses across all STEBI-A items is graphically represented in Figure 4.13.

As noted above, Figure 4.28 shows the relative sizes of the PM, where applicable, for each STOE item to highlight areas of uncertainty between the teachers. The largest PM for a STOE item occurred for the statement "even teachers with good science teaching abilities cannot help some students learn science" (Item 25). An even split with IQRs of 2 indicated a relatively large spread of opinions with 21 teachers

(=50%) agreeing/uncertain and 21 teachers (= 50%) disagreeing with this statement. This casts doubt over how some teachers' perceived their ability to influence the learning of science for some of their students. For this particular item, the complete breakdown of scores was 14 teachers (= 33%) in agreement, 7 teachers (= 17%) uncertain about whether or not they agreed or disagreed with the statement, 16 teachers (= 38%) disagreeing and 5 teachers (= 12%) strongly disagreeing.

With IQR = 1 for Item 13, the PM for this was quite large and indicated that 17 of the 42 teachers (= 40%) were undecided or agreed that an increased effort in science teaching would result in little change in the achievements of some students. A further PM of 15 teachers (= 35%) did not agree with or were undecided that an increase in interest in science on the part of the student is more than likely to be related to the teacher's performance (Item 16; IQR = 1). Similarly, for Item 15, a PM of 14 teachers (= 34%) did not agree with or was undecided upon whether or not student science achievement is directly related to the teacher's performance. The slightly smaller PM of 12 teachers (= 29%) for Item 20 agreed or was undecided about teacher effectiveness having little influence on the science achievements of students lacking motivation. Finally, a PM of 11 teachers (= 26%) was undecided or disagreed that the progress of students who are low achievers is often the result of the additional assistance given by the teacher (Item 11).

Similarly, Figure 4.29 shows the PMs for the relevant PSTE items. Persistent minorities were noted for four PSTE items and are discussed in decreasing order of PM group size. If teachers were given the choice of inviting the principal to evaluate their science teaching (Item 21), a relatively large PM of 12 teachers (= 29%) either agreed that they would not invite the principal to participate in an evaluation or were undecided. Having knowledge of the steps necessary to teach science effectively (Item 5) also had a large PM of 11 teachers (= 26%) and, as noted earlier, had a proportionately large uncertain group of 8 teachers (= 19%). Item 8 regarding the effective teaching of science, Item 17 which focused on teachers having difficulty explaining why experiments work, and Item 23 on teachers welcoming students' questions when science is being taught also showed, respectively, decreasingly smaller numbers of teachers being undecided or disagreeing giving PMs: 8 teachers

(= 19%), 6 teachers (= 14%) and 2 teachers (= 5%). The implications of these and other discrepant findings are considered in the Discussion chapter.

To allow further comparison of metropolitan and provincial teachers, the sum of response scores to the STEBI-A for all STOE and all PSTE items for each teacher and the mean and standard deviation of scores for each scale are given in Table 4.30. The means and standard deviations of $\bar{x} = 30$, $\sigma = 3$ and $\bar{x} = 29$, $\sigma = 5$, respectively, for the metropolitan and provincial teachers suggest that, overall, teachers believed that effective instruction can influence students' learning. The very similar means and small standard deviations indicated a reasonably high degree of agreement. Only two metropolitan and one provincial teacher scored 36, or higher, indicating a larger degree of uncertainty in outcomes expectancy. The implications of these data are taken up in the Discussion chapter.

In order to gauge if there were any major differences in the STOE responses between those teachers who had a science major at the tertiary level and those who did not, those items relating to the STOE were drawn together and shown in Table 4.31. The broader scenarios for the STOE and PSTE scales could also be examined and analysed. As noted in the Research Methods chapter, the minimum achievable score of 12 indicates strong agreement across all items relating to science teaching outcomes expectancy. The mean and standard deviations of all of the STOE scores were calculated and shown in Figure 4.14. These mean and standard deviation scores indicated that, overall, the cohort tended to be located midway between the maximum and minimum scores but with a slightly positive inclination. The same analysis was applied to the scores relating to personal science teaching efficacy - the PSTE scale. The overall mean and standard deviation for the teachers are shown in Figure 4.15. These data indicated that the overall group had a slightly more positive belief in their personal science teaching efficacy than in their science teaching outcome expectancy.

Table 4.28. Responses to the STEBI-A for which the mean, median score and IQRs for a particular STOE item show a persistent minority of respondents in disagreement with the majority of the respondents.*

STOE Item Statement	% Majority of respondents in agreement with other respondents (Majority agreement or disagreement with item statement)	% Minority of respondents in disagreement with other respondents or undecided
1. When a student does better than usual in science it is often because the teacher exerted a little extra effort	81 (In agreement with statement)	19
11. When a low achieving student progresses in science it is usually due to extra attention given by the teacher	74 (In agreement with statement)	26
13. Increased effort in science and teaching produces little change in some student's science achievement**	60 (In disagreement with statement)	40
14. The teacher is generally responsible for the achievement of students in science.	73 (In agreement with statement)	27
15. Students' achievement in science is directly related to their teacher's effectiveness in science teaching	66 (In agreement with statement)	34
16. If parents comment that their child is showing more interest in science at school it is probably due to the performance of the student's teacher	65 (In agreement with statement)	35
20. Effectiveness in science teaching has little influence on the achievement of students with low motivation**	71 (In disagreement with statement)	29
25. Even teachers with good science teaching abilities cannot help some students learn science**	50 (In disagreement with statement)	50

*Note: In Tables 4.28 and successive tables where applicable - ** indicates negatively worded items statements. Whether the majority agrees or disagrees with the actual item statement is shown in brackets after the % majority*

Table 4.29. Responses to the STEBI-A for which the mean, median score and IQRs for a particular PSTE item show a persistent minority of respondents in disagreement with the majority of the respondents.

PSTE Item Statement	% Majority of respondents in agreement with other respondents (Majority agreement or disagreement with item statement)	% Minority of respondents in disagreement with other respondents or undecided
3. Even when I try very hard I don't teach science as well as I do most subjects**	64 (In disagreement with statement)	36
5. I know the steps necessary to teach science concepts effectively	74 (In agreement with the statement)	26
6. I am not very effective in monitoring science experiments**	69 (In disagreement with statement)	31
8. I generally teach science ineffectively**	81 (In disagreement with statement)	19
17. I find it difficult to explain to students why science experiments work**	86 (In disagreement with statement)	14
19. I wonder if I have the necessary skills to teach science**	59 (In disagreement with statement)	41
21.Given a choice I would not invite the principal to evaluate my science teaching**–	69 (In disagreement with statement)	31
23.When teaching science I usually welcome student questions.	95 (In agreement with the statement)	5

Table 4.30. Total STOE and PSTE scores for metropolitan and provincial school teachers.

	Metropolitan			Provincial	
Teacher	STOE scores/60	PTSE scores/65	Teacher	STOE scores/60	PTSE scores/65
1	28	27	1	35	29
2	34	40	2	27	26
3	26	28	3	25	25
4	31	27	4	33	25
5	28	22	5	28	31
6	30	26	6	29	20
7	28	27	7	29	26
8	28	28	8	21	23
9	29	32	9	31	26
10	26	44	10	32	31
11	36	21	11	21	24
12	34	26	12	36	36
13	29	34	13	26	26
14	33	26		$\bar{x} = 29$	$\bar{x} = 27$
15	26	21		$\sigma = 5$	$\sigma = 4$
16	29	37			
17	25	17			
18	26	15			
19	29	30			
20	26	17			
21	31	28			
22	29	17			
23	31	33			
24	28	28			
25	29	29			
26	36	40			
27	39	40			
28	30	35			
29	31	23			
	$\bar{x} = 30$	$\bar{x} = 28$			
	$\sigma = 3$	$\sigma = 7$			
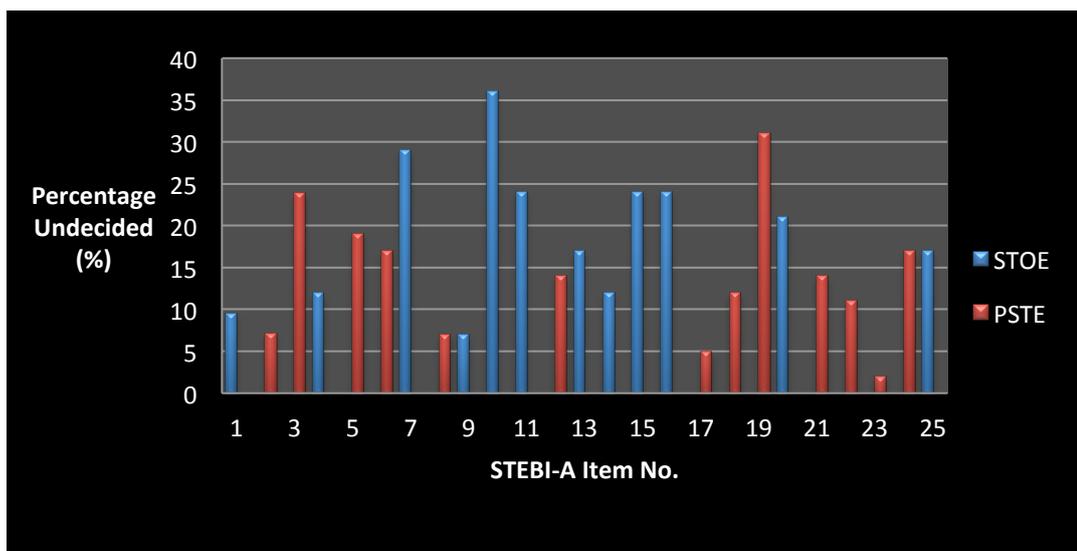
Figure 4.13. Percentage of 'undecided' responses for all STOE and PSTE items.

4.13 Teachers' Use of ICT Science-based Resources for Enhancing Science Content Knowledge

Of the total cohort of participants, 11 submitted logs - 6 metropolitan and 5 provincial teachers - detailing their use of ICT-based science resources over a period of time. In keeping with the survey instructions, only ICT-based resources used to enhance science content knowledge were listed rather than including those used to assist lesson planning. As noted in the Research Methods chapter, although the ideal minimum time indicated for log-keeping was four weeks' duration, the number of weeks over which the teachers kept their logs varied between 1 and 10 weeks. The average time spent online by each of these teachers for the purpose of enhancing their science content knowledge is shown in Table 4.32. The logs kept over a 10-week period by teachers 1 to 3 might yield more meaningful information for identifying patterns in usage. Of the 13 mentioned resources, these teachers used 3 resources with usage frequency ranging from weekly - and spending an average of 40 minutes/week on those sites - to 5 of these resources being used only once over the 10-week period. Although only used once in this time period, some of these five sites were accessed for long periods of time ranging from 1 to 2 hours at each use. Checking by the researcher revealed that 10 of these 13 sites were considered 'reliable': that is, the sites were overseen by government or non-government /non-profit bodies and the information therein could be considered to be correct.

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Table 4.31. Comparison of some STEBI-A item responses of teachers with or without a science major at tertiary level.

Item Statement	Primary or other tertiary major (n=36)		Science tertiary major (n=6)	
	% Majority of respondents in agreement with other respondents (Majority agreement or disagreement with item statement	% Minority of respondents in disagreement with other respondents or undecided	% Majority of respondents in agreement with other respondents (Majority agreement or disagreement with item statement)	% Minority of respondents in disagreement with other respondents or undecided
3. Even when I try very hard I don't teach science as well as I do most subjects**	69 (In disagreement with statement)	31	84 (In disagreement with statement)	16
4. When the science grades of students improve it is most often due to their teacher having found a more effective teaching approach	81 (In agreement with the statement)	19	100 (In agreement with the statement)	0
8. I generally teach Science ineffectively**	84 (In disagreement with statement)	16	100 (In disagreement with statement)	0
11. When a low achieving student progresses in science it is usually due to extra attention given by the teacher	79 (In agreement with the statement)	31	Equal numbers uncertain/disagree	
12. I understand science concepts well enough to be effective in teaching elementary science.	82 (In agreement with the statement)	18	100 (In agreement with the statement	0
15. Students' achievement in science is directly related to their teacher's effectiveness in Science teaching	64 (In agreement with statement)	36	100 (In agreement with statement)	0
18. I am typically able to answer students' science questions	94 (In agreement with the statement)	6	Equal numbers uncertain/disagree	
19. I wonder if I have the necessary skills to teach science**	64 (In disagreement with statement)	36	84 (In disagreement with statement)	16
20. Effectiveness in science teaching has little influence on the achievement of students with low motivation**	73 (In disagreement with statement)	27	Equal numbers agree/uncertain	
22.When a student has difficulty understanding a science concept I am usually at a loss as to how to help the student understand it better**	84 (In disagreement with statement)	16	100 (In disagreement with statement)	0

$\bar{x} = 30$

very positive beliefs	$\sigma = 4$	36 = mid-point of scores	very negative beliefs
12			60
minimum possible score		middle score	maximum possible score
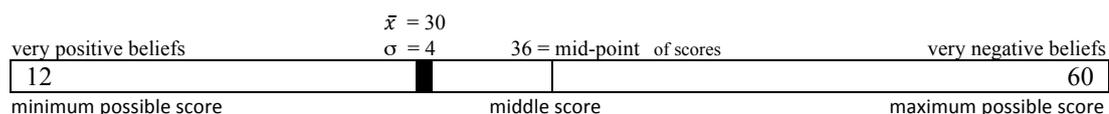
Figure 4.14. Mean (with standard deviation) of all STOE score for the total cohort. .

$\bar{x} = 28$

very positive beliefs	$\sigma = 7$	3 9 = mid-point of scores	very negative beliefs
13			65
minimum possible score		middle score	maximum possible score
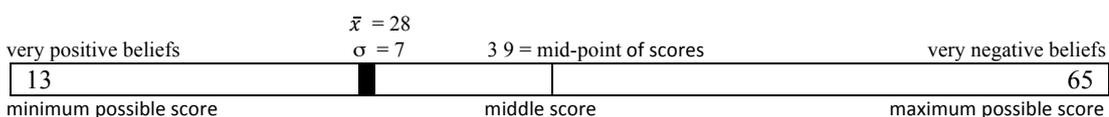
Figure 4.15: Mean (with standard deviation) of all PSTE scores for the total cohort.

The metropolitan teachers 4 to 6 who kept logs ranging over periods of 1 to 4 weeks, used a total of 15 sites - only 5 of which were 'reliable'. The frequency of use of the sites ranged between once per week (3 sites at which they spent an average of 18.3 minutes/week) and once in 4 weeks (4 sites averaging 34.5 minutes for those weeks). These teachers rated 21 of the 28 sites as 'most helpful' for enhancing science content knowledge, six as 'moderately helpful' and one as 'least helpful'.

The provincial teachers also visited, on average, a slightly higher number of sites compared with their metropolitan counterparts - 5.4 sites/teacher. However, of these five teachers, teacher 7 accounted for a total of 15 sites - which were related to learning about electricity - while teacher 9, who was also researching electricity, identified one site. This teacher also spent 97 minutes over four occasions surfing 'YouTube' videos related to content. As was the case with a number of teachers, teacher 10 spent a relatively large amount of time - 100 minutes - in one sitting, exploring one site which was related to environmental issues. Similarly, teacher 11 spent 105 minutes on a NSW Department of Education and Training curriculum support site over 5 occasions. This site provided links to other government sites for the S&T KLA. The only duplication of sites was by teachers 10 and 11 who used the same environmental site, namely, www.coolaustralia.org.

Table A5.1 in Appendix 5 contains a summary of online sites/resources used by teachers searching for science content. For each site identified, this table details the site's identity as given by the teachers; time spent on the site; the number of times the teacher visited the site over the given period; and an indication of whether the online sites/resources were reliable (the latter being determined by the researcher). Where one or more unidentified sites such as "all YouTubes" or "various sites" were mentioned, this is denoted by a '+' after the number of sites. The teachers also ranked the sites on a scale of 3 to 1 - most helpful to least helpful - which also appears in Table A5.1 in Appendix 5. Some of the sites used provide further links to other sites, blogs, etc.

Table 4.32. The average time spent online for the purpose of enhancing science content knowledge.

Teacher	No. of different sites used	Average combined time on sites (minutes/week)	Time sites accessed at home (%)
Metropolitan			
1	4	45	100
2	6	55	66
3	3+	54	0
4	3	55	100
5	5	60	25
6	7	77	100
$\bar{x}$		58	
σ		11	
Provincial			
7	15	60	56
8	5+	20	100
9	2+	45	100
10	2	38	100
11	3	22	80
$\bar{x}$		37	
σ		17	

4.14 Interview Themes

4.14.1 Interviewees

The 10 interviewees - five from each of metropolitan and provincial schools - represented a cross-section from within the larger sample of teachers who participated in Phases I and II. The range of years of teaching experience is shown in

Table 4.33. The overall mean number of years of experience was 23 years. Similar to the broader cohort, this was a relatively experienced group of teachers.

Table 4.33. The numbers of interviewees with different amounts of primary teaching experience.

No. of teachers	Range of teaching experience of interviewees (years)			
	0 – 10	11 – 20	21- 30	30$^+$
	2	3	2	3

4.14.2 Identified Themes

The interview questions, which were aligned with the themes of the research questions, were open-ended and allowed the interviewees to respond freely. The interviewees appeared to be open and honest in their answering of the posed questions. The interviewees generally took their time to give considered opinions. These responses added richness and depth to those already obtained during Phases I and II. These responses also allowed triangulation of the research data because the interview questions addressed the same themes explored in the surveys and also allowed the interviewees to make any additional comments that they deemed appropriate to the themes. Analysis of the interviews yielded seven main themes and a number of sub-themes. The fully coded analysis of these themes and sub-themes is shown in Table 4.34. The themes which were strongly iterated by the group are highlighted in this section with exemplar quotes.

Theme number	Identified theme		Number of comments
1.0	**Formal science background**		
1.1.1	A little		3
1.1.1a	One semester of "science"	- both pedagogy and content	2
1.1.1b		- mostly specific content	1
1.1.1c		- mostly pedagogy rather than content	1
1.2	High school science - Years 11 and 12		1
1.3	None		2
2.0	**Subject(s) having priority at participant's school**		
2.1	Literacy and numeracy		6
2.1	*Reasons for these priority subjects:*		
2.1.1a	NAPLAN results	- results set direction for successive years	4
2.1.1b		- being pushed especially by the executive of the school and/or parents	3
2.1.1c		- parent expectations	2
2.1.2	- literacy is the thread that runs through all KLAs		1
2.2	Maths and English		4
2.2	*Reasons for these priority subjects:*		
2.2.1	- in the school plan – the drive we are pushing		1
2.2.2	- based on our NAPLAN results		7
2.2.3	- they are fundamental to all subject areas		3
2.2.4	- no data on the other KLAs to give is direction there		1
2.2.5	- National Partnerships funding for English and maths		2
2.2.6	- Need to teach the basics at primary school – if anything goes its not these		1
3.0	**Confident enough to teach science?**		
3.1	Yes		4
3.1.1	- passionate about science and all subjects can be taught through science		1
3.1.2	- using the inquiry method takes a bit of pressure off the teacher needing a deep science content knowledge		1
3.1.3	- only from experience gained over the years		1
3.1.4	- but more on the technology side of things		1
3.1.5	- years ago there was an environmental push in primary schools and I was involved in that and its stayed with me all of these years [to give me more confidence].		1
3.1.6	- before I started teaching science I was apprehensive. The more I get into finding things that the kids enjoy. . . I get into it a bit more myself.		1
3.1.7	- quite an experienced teacher		1
3.2	No		5
3.2.1	- still not after many years of primary teaching		2
3.2.2	- I like teaching science but because I haven't taught it for so long I find it difficult.		1
3.2.3	- I still feel intimidated by it [after teaching for more than 25 years] - a specialised subject		1
3.2.4	- only felt mildly confident during my time trialling the Primary Connections package		1
3.2.5	- but I want to make sure that I teach it properly		1
3.2.6	- science is on the bottom end of my preferred list		1
3.2.7	- not a lot of teachers are confident with it		1
3.3	Unsure		1
3.3.1	- don't know the new syllabus well-enough to comment. I'll find out when I get to something I don't know!		

Table 4.34 Continued

4.0	**Time spent teaching science**	
4.1	Not taught daily – about 1 - 1.5 a week if we can	1
4.2	- about 30 – 60 minutes a week	1
4.3	- there's not enough of it [science teaching]. It's a fairly neglected area	1
4.4	-science is only taught in two terms each year - about 2 – 3h each week - I don't think it is enough	1
4.5.1a	- the curriculum - the new curriculum is better for science. If you had said a year ago that we needed to fix science I wouldn't have been keen. Now I don't have time get it all done.	1
4.5.2b	- The curriculum is overcrowded – less time to teach Science and other areas after English and maths (Literacy and numeracy) are taught	5
4.5.3c	- Science and creative arts, etc. aren't as high a priority	4
4.6	- taught as a stand-alone subject because the COGs didn't integrate it well	1
4.7	- we do one unit a semester – I intensified it over about 3 or 4 weeks ....I spent maybe an hour or so each week	1
4.8	- with our previous principal, we spent about 2h per week each term [teaching science] – now we spend less.	1

5.0	**Participating in science-related professional learning activities**	
5.1	Formal – organised by external providers/arranged by school	3
5.1.1	- one meeting day with local science advisor and Stage 3 partner to go through outcomes and content	1
5.1.2	- involved in Primary Connection trials – professional support over this time	1
5.1.3a	- attend regional science network meetings occasionally and organised meeting with local science advisor to help staff unpack new syllabus (science co-ordinator for the school)	1
5.1.3b	- science PL is not available very often	1
5.1.3c	- tried partnership with local country secondary school - unsuccessful	1
5.2	Informal – working with Stage colleagues; mentoring and being mentored; etc.	2
5.2.1	- share some information with other Stage 3 teachers at school or in local area	2
5.2.2	- I get sites from some of the other, younger teachers	1
5.2.3	- for someone like me in science I find it hard to know where to start. Sometimes my [Stage 3] partner and I just sit there and look at each other and say "OK, what do we do now?" "Is there a right way to do it?" – we need more support	1
5.2.4	- we collaborated with some of the other small [provincial] schools around us to do some science programming.	1
5.2.5	- we do try to work collegially	1
5.3	None	5
5.3	*Reasons for not participating:*	
5.3.1	- not the school's focus at the moment	4
5.3.2a	- teaching in provincial schools - very few courses offered in country areas	3
5.3.2b	- expensive to get to major centres to attend courses/long travel times involved	3
5.3.3	- If we want to go to a course we can but I haven't seen anything good to go to	1
5.3.4	- no support offered by the school for science-related PL	2
5.3.5	- I have never been to a formal science in-service course [in 36 years of teaching]	1
5.3.6	- There are too many time constraints	1
5.3.7	-not a full-time teacher, therefore limited access to PL	1
5.3.8	- new national curriculum... school has prioritised English and maths but things might be changing?	1
5.3.9	- no … maths oriented therefore get sent to maths PL	1
5.3.10	- not much on offer in the science KLA	1

Table 4.34 Continued

6.0	**Use of ICT-based science resources to enhance content knowledge**		
6.1	Uses these ICTs:		9
6.1.1a	- site mentions	- I'm very big on "Pinterest" – I probably spend more time than I should looking for information	1
6.1.1c		- I use Primary Connections a lot	1
6.1.1d		- on some sites you need to spend too much time searching for things.	1
6.1.1e		- the occasional TED talk	1
6.1.1f		- Some of the DEC resources online are good	1
6.1.1g		- The NSW Science Teachers Association and other education sites provide some good links	1
6.1.1h		- our school is still using Primary Connections . . . but I still prefer to do the research myself [on the net]	1
6.1.2	- maybe once a term when I'm organising my programmes		2
6.1.3	- I get sites from some of the other, younger teachers		2
6.1.4	- no particular "go to" sites – just use search engine		3
6.1.5	- I have some favourites but that depends on the topic I'm teaching and researching		1
6.1.6	- share sites with other Stage 3 teaches at the school		1
6.1.7	- I use lots of "YouTubes" to learn the stuff before I do it in class		2
6.1.8	- happy to search for content and improve understanding		1
6.2	Doesn't use these ICTs:		1
6.2.1	- I have a phobia about using computers – I'm not good at doing my own research		1
	- I didn't even avail myself of internet links to information because I didn't like using the computers		1

7.0	**Where was this research carried out?**	
7.1	Only at home: *Reasons:*	6
7.1.1	- no time at school	5
7.1.2	- more convenient	1
7.1.3	- gives me time to read it and understand	1
7.1.4	- more resources and better computer/internet at home	1
7.2	Only at School *Reasons:*	2
7.2.1	- too much going on at home with family	1
7.2.2	- internet is pretty shocking at home [provincial]	2
7.3	Combination of both school and home: *Reasons:*	1
7.3.1	- most of it at home as there's more time to surf the internet	1

8.0	**Other considerations:**		
8.1.1a	- equipment	- not available or lost/maintenance; cost a problem/storage issues	8
8.1.1b		- lack of space to store resources and/or	3
8.1.1c		- difficult to obtain all of the supplies needed/competition to use the same equipment at the same time	3
8.1.1d		- resources are good – I'm pretty lucky	1
8.1.1e		- not enough resources to teach the curriculum	1
8.2	- attempts to share science focused programs with local high school not successful		1
8.3	- need a space in which to teach science/ carry out investigation		3

Table 4.34 Continued

8.4.1a	- Primary Connections	- the old Primary Connections has been shuffled around now for the new syllabus and that never works	2
8.4.1b		- we rely on Primary Connections - I haven't gone into how well it fits the new syllabus	1
8.4.1c		- we were a pilot school for Primary Connections	1
8.4.1d		- literacy is key – particularly with using Primary Connections	1
8.5.1a	- the principal's impact	- our principal is supportive.	2
8.5.1b		- supportive principal - but its really the teacher in the end who is responsible for what they are teaching	1
8.5.1c		- we used to do a lot of science . . . it has changed since the new principal arrived a few years ago.	1
8.5.1d		-with the new principal it's [science] more at the discretion of the classroom teacher so there's less science	1
8.6.1a	- teaching science	- required to do risk assessments for all science activities at the school – . .. if this becomes mandated by [the governing body] then many staff wont do the science practicals?	1
8.6.1b		- RFF teachers teach science because it can be a stand-alone subject (not integrated)	1
8.6.1c		- I like the extra detail need you need in teaching Stage 3 [science] Syllabuses. You need to learn more things yourself.	1
8.6.1d		- we don't have a co-ordinator looking after science	1
8.6.1e		- science wasn't big when I was in primary school so I guess I have carried that on	1
8.6.1f		- even though maths and English are our school's focus, we're still pretty driven by science . . . because we know its needs improvement too	1
8.6.1g		- Stage 3 [science] is very hands-on - I don't think that enough teachers value science enough	1
8.6.1h		-over the last few years the RFF has been teaching the science – it gets palmed-off a bit	1
8.7		- I didn't avail myself of internet links to information because I don't like using computers	1
8.8		- not really at a disadvantage being in the country – everything is on the internet	1
8.9		- too many teachers see the KLAs in boxes – I think we should be integrating all disciplines in our teaching	1
8.10		- some people's gifts as teachers give them different abilities and ideas on how to teach [science] but some have to be more guided	1
8.11.1a	- Other comments on NAPLAN	- I fear that if they have a science exam like NAPLAN then all they will do is highlight those who can read or write and not the children who are capable of carrying out experiments.	1
8.11.1b		- A NAPLAN science test wont incorporate [i.e., be able to test] all of the things important to doing science	1
8.11.1c		- NAPLAN is an all-consuming thing in many schools . . . it has the ability to make or break schools	1
8.11.1d		- parents and the community want test results which only give a small picture of a student's development in the classroom	1

The first of such themes - Theme 1.0 - was that relatively little time was spent by the interviewees on studying science content at a tertiary level as exemplified by these comments: "[*one*] *science minor unit which was mostly focused on the methodology/pedagogy of teaching science ... Not much focus on the actual content.*" (P1, teacher interview, April 13, 2015, 1.1.1c); "*I had mostly social sciences and arts period - I was three year trained*" (P5, teacher interview, May 8, 2015, 1.3); "*no*

formal [science] *training that I recall"* (M3, teacher interview, April 13, 2015, 1.3); and *"a small amount of science was covered during the standard primary teacher training course"* (M1, teacher interview, March 26, 2015, 1.1.1).

The responses to the question about whether interviewees thought that any subject(s) had priority at their current school, and why they thought this was the case, revealed a quite dominant theme. The recurring theme identified from the surveys was that literacy and numeracy, and English and mathematics were major priority 'subjects' at their current schools - Theme 2.0. Five teachers nominated literacy and numeracy, two identified literacy and mathematics and the remaining three nominated English and mathematics. Exemplifying this point were comments such as: *"most definitely English and mathematics"* [M1, teacher interview, March 26, 2015, 2.2]; *"*[There is] *definitely a focus on literacy and numeracy over science and other disciplines"* (M5, teacher interview, May 12, 2015, 2.2)*; and *"Oh, definitely English and maths"* (P3, teacher interview, May 6, 2015, 2.2).

In addition to the prioritisation of subjects in the school, it should be noted that every interviewee mentioned NAPLAN during their discourse on why they thought that their school prioritised these subjects. This is exemplified by the following comments: *"*[literacy and numeracy] *... are the really big focus ... this is obviously based on the NAPLAN results. You use your (sic) NAPLAN results from previous years to set our direction for the following years and the future"* (M2, teacher interview, March 30, 2015, 2.1.1a); *"NAPLAN is a bit of a driving force ... we have targeted intervention money specifically for the NAPLAN preparation* [for certain students]*"* (M3, teacher interview, April 13, 2015, 2.2.2); *"*[the parents] *ask at the beginning of the year 'so what are you doing for NAPLAN?' or 'what can I do to help [my child] with NAPLAN?'* (M4, teacher interview, April 21, 2015, 2.1.1c); *"Maths and English ...* [our priorities, are] *where our school is lacking at the moment ...*[this prioritisation is informed by] *NAPLAN results largely"* (P2, teacher interview, May 5, 2015, 2.2.2); *"Maths and English ... because they have the data now to back it up so that's why they need to push [these] subjects but there's no data on the other KLAs"* (P3, teacher interview, May 6, 2015, 2.2.2 and 2.2.4); and, *"Literacy and numeracy by far ... In my experience, it's the pressures of NAPLAN. You don't have to look far"* (P4, teacher interview, May 7, 2015 2.1.1a). Comments made by the

interviewees in relation to their confidence - Theme 3 - varied considerably. The comments ranged from the confident *"Yes ... quite an experienced teacher. Yes... to a degree* [the inquiry method] *probably does* [take a bit of pressure off] (P1, teacher interview, April 13, 2015, 3.1.7); to the unsure *"I don't know* [the current curriculum] *well enough to answer that fully...it's a lot more science-based than the old syllabus used to be. I'll find out when I come to something I don't know I guess!"* (P5, teacher interview, May 8, 2015, 3.3.1); to decidedly not confident at all *" NO! Still not!* [after many years of teaching] (M3, teacher interview, April 13, 2015, 3.2.1).

The time spent teaching science - Theme 4 - varied considerably between the interviewees' schools: "*30-60 minutes* (P3, teacher interview, May 6, 2015, 4.2) and *"there's not enough of it* [*science teaching*] *... It's a fairly neglected area"* (P4, May 7, 2015, 4.3); and *"we used to just teach science twice a year - say, term one and term three. We spent about two hours a week that was actually looking at the science component"* (M2, teacher interview, March 30, 2015, 4.4).

Among the teachers interviewed, there was little engagement in science-related professional learning - Theme 5.0 - and this was for a number of different reasons: *"no - because the new curriculum has just started so we haven't really done anything on science"* (P5, teacher interview, May 8, 2015, 5.3.1); *"no, not much offered in the science KLA"* (P1, teacher interview, April 13, 2015,); and, *"no ... I'm sort of maths oriented so I get sent to maths things"* (P2, teacher interview, May 5, 2015, 5.3.9), and, *"[as] school science co-ordinator ... I go to science network meetings ... [and] ... I have being consulting with the science advisor* [on the scope and sequence of our science units]" (M3, teacher interview, April 13, 2015, 5.1.3a). *"[Living in a provincial area makes it] a bit of a trip* [to get to PL courses] *and a deterrent for going to courses"* (P2, teacher interview, May 5, 2015, 4.3.2b).

The interviewees were also asked directly if they accessed any ICT-based science resources - Theme 6 - to assist them in understanding the curriculum topics before they taught them. There were a quite a few websites mentioned as well as usage of 'YouTube' videos, one social media site -'Pinterest' - and various occasional uses of this type of resource. With the exception of one of those interviewed, all interviewees

said that they used ICT-based science resources. The degree of use, however, varied from teacher to teacher. Some of the comments made by the interviewees included: *"Generally websites - some of the DEC resources are very good"* (P1, teacher interview, April 13, 2015, 6.6.1.f); *"Yes, I go to 'Google' a lot to find the content that I need. I'm very big on Pinterest"* (P3, teacher interview, May 6, 2015, 6.1.1a); *"I use Primary Connections and things like that the most. ... I get some of the sites from the younger teachers at school"* (P5, teacher interview, May 8, 2015, 6.1.1c); *"No, never because when it comes to the computer I have a phobia"* (M1, teacher interview, March 26, 2015, 6.2.1) and, *"Yes, I definitely use a lot of 'YouTube' [videos] ... I do use the ICT resources to help learn the science. I actually practice/learn it at home the week before"* (M2, teacher interview, March 30, 2015, 6.1.1b).

The seventh theme related to where the teachers preferred to conduct their searching for science content using ICT-based resources and to explain why that was the case. Six of the teachers' preferred use was at home - for varying reasons - but, for the most part, the main reason was that there was no time at school for such pursuits. Two undertook their searching at school either because the internet connection at their homes were inadequate or there was too much going on at home with family life. One teacher searched for ITC-based resources mostly at home because there was more time available. Some of the comments in relation to this were: *"Yes, at home ... I really don't have time to do that type of research at school"* (M5, teacher interview, May 12, 2015, 7.1.1); *"I do - pretty much, almost exclusively at home ... [because of available] ... time"* (M4, teacher interview, April 21, 2015, 7.1.1); *"At home ... I have better resources at home and a better computer too"* (P5, teacher interview, May 8, 2015, 7.1.4).

Finally, there were mentions of some of the other factors - grouped under Theme 8 of 'Other Considerations' - that could affect the teaching of science in the interviewees' schools. In summary, eight of the teachers commented about the equipment at their current school and related issues. The comments covered a number of points which had already come to light through the surveys; some were positive comments and others less positive. The comments included: *"[There is a problem with maintenance and the equipment isn't easily at hand] ... there's no dedicated teacher overseeing*

the science equipment, no-one has responsibility ... another of the challenges is that there isn't even a designated area for storing the equipment" (M4, teacher interview, April 21, 2015, 8.1.1a.); *"resourcing the teaching of science is so expensive and it would be great to have a space in which to teach science and keep all of the resources. Budgeting is a problem"* (P1, teacher interview, April 13, 2015, 8.1.1b and 8.3). Also under Theme 8 were five comments made in relation to the 'Primary Connections' online units: *"the old 'Primary Connections' has been shuffled around now for the new Australian Curriculum and that never works"* (M1, teacher interview, March 26, 2015, 8.4.1a) and *"We were using 'Primary Connections' up until last year but it isn't aligned with the NSW syllabus so they [sic] aren't a good fit anymore"* (M2, teacher interview, March 30, 2015, 8.4.1b).

Another theme which did not emerge through the surveys but which was commented upon by two teachers, was the principal's impact on science teaching at their schools. These were two polar principal influences: *"Our principal is very supportive of our science teaching"* (P2, teacher interview, May 5, 2015, 8.5.1a) compared with *"[the amount of science teaching at my school] has changed since the new principal arrived a few years ago ... now there's less science"* (P4, teacher interview, May 7, 2015 8.5.1a). However, for many and varied reasons, all but one teacher made some attempt to use ICT-based science resources to enhance their content knowledge, albeit mostly at a very low engagement level: *"I mainly go to the internet probably only once a term when I'm doing the programming mainly"* (M4, teacher interview, April 4, 2015, 6.1.2) and *"Over a term I would average about 25 minutes a week on* [science] *content"* (P2, teacher interview, May 5, 2015, 6.1).

4.14.3   Other Considerations from the Interviews

The interviewees mentioned a number of other considerations relating to the teaching of Stage 3 science in primary schools. These included issues related to science practical work - such as equipment issues - and the space required for carrying out science practical work, in addition to other general science teaching issues for primary school teachers. Some issues arose in relation to the primary schools working with other schools to share resources and considerations for those working

in provincial areas. There was also some discussion around the 'Primary Connections' resources and further comments on the impacts of NAPLAN testing in the teachers' schools. The implications of all of the above themes are considered in the following Discussion chapter.

4.15 Chapter Summary

The data for this study, which involved a small sample of NSW primary Stage 3 primary teachers, were gradually collected during three research phases using a combination of surveys, personal logs and interviews over a period of approximately two years. In Phases I and II, the participating schools - representing a spread of demographic-types - were from both metropolitan and provincial areas in approximately equal numbers. However, more metropolitan teachers than provincial teachers participated in the study. The numbers of teachers representing each regional grouping were much closer to being equally proportional to the state's population distribution. The teachers and principals provided data on their school's demographics, priority teaching areas and policy in relation to teaching science, and factors which affected the teaching of science. There was a high degree of agreement between the principal's perceptions of their school's priorities and those of their teachers in this area. Few schools had an actual, well-defined policy on the teaching of science. High stakes testing (i.e., the NAPLAN testing programme) was identified as having a large impact on the priority subjects/competency areas focused on in the schools.

The time spent teaching science to Stage 3 students varied considerably, but was lower than desirable in relation to the BOS NSW guidelines. The majority of teachers from both the metropolitan and provincial groups considered each of their school's science resources to be 'OK'. With the majority of teachers having had a broad tertiary level primary education background, and very few having had any formal science education at this level, the majority also agreed that there was a need to supplement their science content knowledge to enhance their ability to effectively teach science. Resources identified as being used by the teachers where examined for commonalities. Some of the identified ICT-based science resources useful for

enhancing science content knowledge were incorporated into a pamphlet and distributed by the author to the teachers for their use.

When participation in professional learning activities - both formal and less-formal - was surveyed, it was evident from the Phase I responses that, in general, many teachers only considered a very narrow range of activities as contributing towards their PL. The Phase II survey elicited evidence of more PL activity being undertaken by the teachers, with a broad range of examples being listed in the question options. While 40 teachers identified a need for professional learning of this kind, and notwithstanding the increased number of responses, very few of the teachers had relatively recently participated in PL activities of any kind. Only 27 of the teachers attended any sort of organised PL activities and the vast majority of these were from metropolitan areas. The data from the interviews corroborated this finding. The poor attendance at science-related PL was largely a reflection and implied consequence of the high priority assigned to literacy and numeracy/English and mathematics - both a supply and demand issue. In provincial areas, this was exacerbated by the time needed to be set aside, and the potential costs incurred, to travel to major centres to attend PL. Analysis of survey data from Riggs and Enochs' (1990) STEBI-A indicated that the metropolitan and rural teachers have quite similar confidence levels in terms of their Science Teaching Outcome Expectancy and Personal Science Teaching Efficacy scores, but that these confidence levels were not strong.

Computer access was generally not a problem for these teachers - with only one teacher from the total cohort confessing an aversion to computer use. Some teachers, however, needed to limit their searching for science content to either school or home because of relatively poor or unreliable internet connectivity at the alternative venue. Most teachers preferred to undertake their searching at home. Seventy five percent of the participants identified a need to improve their computer skills to assist with using ICT-based resources to enhance their science content knowledge.

Whilst there was a substantial body of science resources available - particularly accessible ICT-based science resources - via the internet to assist teachers to enhance their science content knowledge, the metropolitan teachers spent, on average, 58 minutes/week (σ = 11 minutes/week) and provincial teachers 37 minutes/week (σ =

17 minutes/week) over the same period using ICT-based resources to achieve this goal. The combined average for both groups was 48 minutes/week ($\sigma = 17$ minutes/week). The implications of each of these findings are discussed in the following chapter.

Chapter 5: Discussion

5.1 Introduction

This study was designed to investigate the use of Information and Communication Technology-based science resources by NSW Stage 3 primary school teachers to enhance their science content knowledge. The study sample involved principals from 31 schools - 15 provincial and 16 metropolitan - and 47 teachers from these schools. The teachers from each sector - 29 metropolitan and 18 provincial - represented 62% and 38% of the total participants, respectively. Data were collected in both Phases I and II using surveys. Eleven of the teachers each completed a log of the use of their ICT-based science resources use over a period of a number of weeks. In Phase III, a sample of ten teachers - five each from metropolitan and provincial schools - was interviewed on the same major themes as those covered in the surveys.

In order to investigate primary teachers' use of ICT-based science resources to enhance their science content knowledge, it was first necessary to establish the context in which the participating teachers were working towards their students achieving the outcomes of the NSW Stage 3 S&T KLA syllabus. These contextual considerations included, for instance, those related to each school's demographics such as the number of students attending the participating schools; the schools' cultures relating to teaching science; whether or not any subjects at the schools were given a higher priority than science; and other factors which might have influenced science teaching. Also established were the teachers' science education backgrounds; their perceptions of any deficit that they might have had in their science content knowledge; their teaching experience; and how they perceived their self-efficacy with respect to their science teaching. Further, there were issues surrounding the teachers' computer and internet access which also needed to be discerned.

In Flores' (2004) introduction to her research into the impact of school culture and leadership, she describes how "workplace conditions play a key role in enhancing teacher learning" (p. 299) and that it is particularly important to identify practices

that could have a positive or negative impact on this learning. She identifies schools as communities which should not only be viewed "as a physical setting and a formal organisation, but also as a social and psychological setting in which teachers construct a sense of practice, professional efficacy and professional community" (p. 299) and where teachers adopt the school's "norms and values" (p. 314). "Schools are places where teaching occurs, but they are also places for teachers to learn and develop" (Flores, 2004, p. 299). According to Flores, therefore, it is important to view teachers' learning practices in the context of their school setting and the professional community to which they belong. This chapter is a discussion of the results pertaining to each of my research questions and the implications of my research.

5.2 Recruitment and Participation in the Research

Approval to conduct this research was given across all NSW DEC primary schools and four geographically large Catholic dioceses. As noted in a previous chapter, blanket approval was not needed for the independent schools' participation. The successful and large-scale recruitment of principals and teachers as research participants is a difficulty experienced by many researchers. In a paper examining survey non-response issues, Welsh and Barlau encapsulated their findings on acceptable response rates through conducting an extensive literature review. In summary, they found that "most texts recommend 70-80% [as acceptable response rates]. Not all journal articles report their response rates but when provided, generally they are in the 50-65% range. The range for the articles we reviewed was 26% to 100%" (2013, p. x). Angus et al. (2007) report a response rate of 25% to their research which compares with the lower end of Welsh and Barlau's findings. Interestingly, Sheehan notes that, in the decade preceding 2006, it had been reported in the popular press that, across the spectrum of research survey types, research response rates had declined. He discussed studies which concluded that, because of an ever-increasing volume of approaches which were being made to people requesting that they participate in surveys, these individuals were no longer interested. Sheehan further suggests that the response rate could be lowered because of potential participants feeling as though they were "oversurveyed" (2006, para. 7),

as the opportunities to complete surveys - especially those online - loses their novelty value. This effect might wholly or partially account for the relatively low response rate of those approached to participate in my research.

More recently in the Australian context, a national survey was conducted in 2013 across both primary and secondary school sectors by the Australian Science Teachers Association (ATSA) and The Office of the Chief Scientist (OCS) to gauge the interest and needs of teachers in order to develop a new suite of science teaching resources. It was found that very few primary teachers responded compared with secondary teachers. In order to gain better insight into the needs of the primary teachers, ASTA & OCS conducted another survey in 2014. The authors revealed that the online survey results were skewed because only a small number of government primary school teachers from NSW and Victoria responded compared with a disproportionally large number of teachers from independent schools. Although the online survey results could not be considered representative of all primary teachers, many aspects of the results, nevertheless, were of direct interest to the researchers. The initial recruitment for my research was conducted only a short time before the ASTA & OCS experience and the low response of the primary teachers was similar. As noted in the Research Methods chapter, approaching principals and teachers directly, in most cases via telephone calls, boosted the response rate for my research from 3.9% to 13% of the number originally contacted. Embedded in these responses to my research were the principals' commitments to invite their teachers to participate. This provided a small overall increase where more than one teacher from a school participated. This process differs slightly from that reported by Welsh and Barlau (2013).

The sentiments of some of the principals' statements noted in the Results chapter were iterated by a number of principals, indicating that they weren't interested in their own participation or that of their staff in any research at that time. If the principal did not give consent for the school staff to participate, then none of the teaching staff could be approached. Several relieving principals were reluctant to commit the school's teachers to the research in the absence of the principal. It must be considered, then, that some interested and willing classroom teachers might have missed out on participating in the research because of a lack of willingness of their

principals - or those representing their principals to participate - regardless of the reason(s).

With respect to the completion of the logs of ICT-based science resource use to enhance science content knowledge, on more than one occasion, principals said directly that teachers would not be forthcoming in completing the logs because they wouldn't want the researcher - or the community at large - to know what they weren't doing. Sheehan (2006) expressed concern around these types of circumstances because non-respondents' possible responses to research surveys might have differed considerably from those who did respond. Therefore, the absence of these responses could, in effect, skew the survey's results. It follows, then, that "low response rates are a concern for researchers" (Sheehan, 2006, para. 7) and needed to be considered in the interpretation of my results.

Such considerations must be kept in mind during the analysis of any research results as, indeed, they were in this instance. The findings of my research reflect the situation garnered from the data collected from a small number of NSW school principals and teachers. It would, therefore, have been misguided to attempt to extrapolate the findings to the broader teaching community even though it is possible that they could ultimately be a reasonably close reflection of it. This latter case could only be substantiated by a second, much broader study. Where appropriate, therefore, specifics have been highlighted where broader generalisations could not be made. Nevertheless, the information gleaned through the participation of the school principals and their Stage 3 staff has made a contribution to the body of knowledge that currently exists in relation to the types of school cultures in which primary teachers were teaching; some of the factors which could impact on their science teaching; and the ways in which the teachers sought to enhance their science content knowledge, particularly the use of ICT-based science resources to achieve this.

5.3 Research Qn. 1 - What is the Current Status of the Teaching of Science in Stage 3 in NSW Primary Schools?

In the Introduction of her book on primary school science, Fitzgerald reports the

general status of science in Australian schools. Based on the work of a number of researchers, she reports the continuance of "low levels of student engagement in school science, and the downward trend in studying science beyond the compulsory years" (2012, p. 1). Fitzgerald discusses the key role that teachers have in strengthening the place of science in Australian schools. A number of factors contribute to the status and effective teaching of any subject in the school context. Flores (2004) writes that the school community and its culture can impact on its teachers and the way in which they perceive their role as teachers and in relation to their professional development. Therefore, it was important to investigate the demographics and cultures of the schools in which the teachers worked, insofar as they had the potential to partially impact, in different ways, the teachers themselves and their teaching of science in the primary school curriculum. Ultimately, there can be a subsequent flow-on effect to their students' learning. The factors affecting the status of science education in the participating schools have been distilled from the survey data. This section relates to research question 1 on the status of science teaching in Stage 3 in NSW primary schools.

5.3.1 Comparing the Participating Schools' Demographics

5.3.1.1 School Sizes

There is variation in the sizes and types of NSW schools in which the primary years of Kindergarten to Years 5 and 6 (i.e., Stage 3) are taught. They can operate as: 'central schools' that teach Kindergarten through to Year 12 students and which typically have small single-year classes or combined years groupings; the standard primary school with Kindergarten to Year 6; or larger schools teaching Kindergarten to Year 12. In some of the latter schools, specialist teachers, or resources, or both from the secondary section can support the primary school section; this can depend upon the school's internal organisation. It was important to know what categories of schools the teachers were working in, particularly to ascertain whether or not the participating teachers might have been supported by either science specialist teachers and/or resources - material and/or intellectual - from the secondary school. None of

the schools in this study was supported in this way.

5.3.1.2 Teacher Age and Experience

Figure 4.1 shows that the participating cohort was, in terms of years of teaching, quite experienced. A relatively large proportion (i.e., 37) of the teachers had taught in primary schools for more than 6 years, with 26 teachers having more than 10 years of primary teaching experience. Within this group, 17 teachers had been teaching Stage 3 students for over 6 years, and 7 teachers had between 11 and 20 years experience with Stage 3 students. While these teachers had been employed as teachers for a substantial number of years, it could not be assumed that they also had satisfactory levels of science content knowledge or the confidence to teach the subject. Both of these issues are addressed in a later section of this chapter.

5.3.1.3 Employment of Specialist Science Teachers

As a result of their research on a random sample of 160 Australian primary schools - which had been organised by the Australian Council for Educational Research (ACER) - and published in 2007 - Angus et al. reported that only 8% of those schools employed specialist science teachers. This was in contrast to the frequency of employment of teachers in other specialist areas: library (63%), Languages Other Than English (58%), literacy (51%), music (47%), physical education (46%) and numeracy (10%). Although these statistics are not particularly recent, more recent studies with comparable information are currently not available. Ardzejewska et al. (2010) corroborate this situation in their research on delivering the NSW primary curriculum.

While none of the provincial schools in this study employed specialist science teachers, four of the metropolitan schools did - representing almost 13% of the total schools. Of these, however, only one teacher was employed on a full-time basis as a specialist teacher with the other three schools employing specialist teachers on a

part-time basis. This employment level varied from 0.1 to 0.6 of full-time face-to-face equivalent. This situation was also consistent with the Angus et al. (2007) findings that the majority of specialist teacher positions were part-time. While the full-time teacher was fully responsible for teaching science to Stage 3 students at the school, the other specialist teachers fulfilled roles as co-ordinators and/or advisors to varying degrees. This situation still left the generalist classroom teachers in those schools needing to teach some or all of the S&T KLA to their classes, therefore relying upon their own science content knowledge or that of colleagues whose science content knowledge might have been equivalent to their own. This situation is consistent with the results of the survey which accompanied the Australian 2012 NAP-SL sample test. These results indicated that almost 72% of the participating students - 13,000 from 633 schools - were taught science by their usual, generalist, classroom primary teachers (ACARA, 2012).

5.3.2 Teachers' Education Backgrounds

Henderson (1992) highlighted a link between the science content background of primary teachers and the way in which they deliver the science curriculum in primary schools. Even those teachers who had only studied science subjects in their senior school years (i.e., Years 11 and/or 12) had an increased level of confidence in teaching certain science topics compared with those teachers who had no science background beyond Year 10. He also noted that these findings were congruent with international research. It is interesting to consider Morgan's (2012) report to the contrary that some primary teachers, who rely upon their secondary school science experiences, are often left with negative feelings towards those experiences because they perceived that the science lessons at school were presented more for the benefit of the higher-achieving students. While there were no reports of such feelings resulting from poor secondary school experiences in my study, one provincial teacher, P2, did reflect on his own poor primary school science experience and proffered the suggestion that this negatively impacted on his own searching for content information and teaching of science (teacher interview, May 5, 2015, 8.6.1e).

Fensham's (2008) report on worldwide science education, which was sponsored by

UNESCO, found that many primary teachers tend to study science in junior high school with only some continuing into the later secondary schooling years, perhaps studying one science subject which is usually biology. Other reports in the literature are a little more specific and show that pre- and in-service primary school teachers felt that they had a better knowledge of and more positive self-perceptions for the biological sciences, and enjoyed teaching biology-related science topics (Danielsson & Warwick, 2014; Grinrod, Klindworth, Martin & Tytler, 1991; Jane et al. 1991, Kahle et al., 1991).

This type of pattern was reflected in my research. In their secondary schooling, 12 of the teachers discontinued their studies in general science at the end of Year 10 - this included two of the ten interviewees - while 35 teachers had completed one or more science subjects to the equivalent of the NSW HSC level. Of this group of 35 teachers, 22 had completed studies in HSC-equivalent biology. Interviewee M2 commented on this point: *"I did biology in Years 11 and 12 and you do sometimes go back to that"* (teacher interview, March 30, 2015, 1.2). At the tertiary level, one teacher studied a physics major, and another teacher had a major in earth and environmental science. Twenty seven (= 64%) of the teachers had an undergraduate degree with a major emphasis on primary education. Three of these teachers had a minor in science of one semester's duration. However, interviewee M2 reported completing *"one unit* [of science] *at university"* [and] *... "it wasn't very helpful* [with respect to the science content]*"* (teacher interview, March 30, 2015, 1.1.1a) while P1 commented that the science minor unit studied at university mainly focused on pedagogy with *"not much focus on the actual content"* (teacher interview, April 13, 2015, 1.1.1c), both indicating that some science subjects incorporated into pre-service teacher education might not have delivered much science content. The third teacher indicated that the semester of science focused on both content and pedagogy. Four teachers from the total cohort combined a primary education major with a science major which, in the majority of cases, was biology. This pattern of study is consistent with the higher degree of enjoyment reported by primary teachers in teaching aspects of the curriculum related to the biological sciences noted in the literature. For example, Morgan (2012) reports that, at a small, metropolitan Australian school, "biology was taught more than other areas of science" (p. 79). Other studies which reflect similar findings are Danielsson and Warwick (2014),

Jane et al. (1991) and Skamp (1991). The remaining 12 teachers in my research had majors in physics (= 1), earth and environmental science (= 1) or other non-scientific fields (= 10).

To summarise these findings, the schools in this research had only 7 primary teachers who had some form of science study at tertiary level. Even though my sample was relatively small, the findings are a reflection of those of larger studies. Teachers' limited backgrounds in science can be a contributing factor towards the low status of science in their schools (Aubusson, Schuck, Ng, Burke, Pressick-Kilborn, & Palmer, 2015). The possibility that teachers' science education backgrounds can have an impact on their confidence to teach science is examined in a later section of this chapter.

5.3.3 School Policies on Teaching Science

Flores (2004) notes that there are two main factors affecting teacher learning and professional development at the school level: "school culture and leadership" (p. 299). Hongboontri and Keawkhong (2014) argue that what teachers teach "could be determined by [the] teachers' association with their school cultures such as school policies, school traditions, school structures, and teacher interactions" (p. 68). Therefore, a school's culture - that is, "the shared orientations, values, norms, and practices that hold an educational unit together" (Kaplan & Owings, 2013, p. 2) - can be a strong influence on its teachers. In keeping with this definition of culture, the subjects taught, why they are taught, to what degree they are taught and how they are taught are part of a school's culture.

Tilgner (1990) and Anderson (2002) demonstrated that the influence of principals on their schools has a trickle-down effect which can have positive and/or negative impacts on the progress of the school. These impacts can be manifested in areas such as, for example, prioritisation and emphasis of certain subjects taught in schools, teacher attitudes and motivations, and teacher engagement in PL. The standing of science in a school's curriculum compared with other subjects can, therefore, be a

part of this strong influence on how much science is taught in a school.

Both principals and teachers were asked if their school had a policy relating to the teaching of science. This question shed light on the schools' cultures and the status of science therein. Some additional information was also obtained through the interview responses. School policy is a major factor which influences the way in which a curriculum is implemented in a particular school. School policies are generally considered to be a set of guiding principles on methods and behaviours which guide the direction of the school. In the Department of Education, Training and Employment section of the Queensland Government's website, it is stated that "policies outline what the government or department intends to do through stated plans of action" (http://ppr.det.qld.gov.au/pif/policies/Pages/default.aspx) while iterating that "school education procedures describe the responsibilities and processes to be followed by staff involved in school management, student learning and well-being, and school communities" (http://ppr.det.qld.gov.au/education/procedures/Pages/default.aspx). Flores (2004) discusses the impact of leadership teams - including the principal - on school policy and comments that despite the fact that governmental departments of education "may have a say in determining the goals and norms of the school, the leadership team … have a crucial role in making or approving decisions concerning school policy" (p. 309). Whilst it was not mandatory for NSW primary schools to have a policy in the above sense for each KLA - because the BOS NSW provided the mandatory curriculum and specified teaching hours - schools are expected by the BOS NSW to have implementation documents which provide guidance for units of work taught in subjects such as science within the S&T KLA. The responses given by the principals in this study varied between what could be considered to be policies and what could be considered to be procedures. Nevertheless, it was important to obtain some indication of the direction that the schools were taking or, at least, intended to take in delivering the content of the S&T KLA.

Anderson (2002) noted that a principal can have an impact on the progress of the school and its teachers. This implies, therefore, that it is important that principals have clear perceptions of the expectations of society, the needs of the students and curriculum implementation across all KLAs. Comparing the metropolitan and

provincial schools in my sample, 8 of the 16 and 4 of the 15 schools, respectively, had no specific policy on the teaching of science. One principal commented that the school had a technology policy, but none for the science component of that KLA. As principals were not restricted to one-statement answers to the policy question, there were multiple statements made by them. Some of these statements related to having nominated skills and knowledge foci, how much science was to be taught each week, using the BOS NSW syllabus guidelines, and using some of the scope and sequence from the old syllabus and incorporating it into the new curriculum (Figure 4.9). Apart from the prescribed syllabus documents, did these types of 'policies' leave schools without a firm direction to guide the staff through this curriculum area? For example, only two of the interviewees reported that they felt that their principal was supportive of teaching science in their respective schools (Interview Code 8.5.1a). The impacts of school principals - both positive and negative - were also highlighted by some of the interviewees. The degree to which these negative impacts influenced school cultures, and therefore the associated teachers' engagement with all aspects of teaching science, was beyond the scope of my research but was kept in mind during analysis.

Further to this, two of the more substantial and positive additional comments on teaching science came from the survey responses of two principals who had employed specialist science teachers: *"we believe that specialist teachers with expert knowledge, skills and content knowledge are required to support classroom teachers in the delivery of mathematics and science"*; and *"as a school for* [students] *who are academically able, we place great emphasis on the teaching of STEM [science, technology, engineering and mathematics] courses"*. At these two schools, positive principals seem to have assisted in establishing positive environments for teaching science.

Principal impact on the status of science teaching in a school was further exemplified during an interview with one of the provincial teachers (P4) who described the situation at a previous school in which the RFF teacher taught all of the science at the school. P4 commented that *"it* [science] *was solidly in place. That has changed since the new principal arrived a few years ago. It's more at the discretion of the classroom teacher now so there's less science. ... the science has weakened"* (teacher

interview, May 7, 2015 4.8). However, M5 made a point regarding the school's policies on science, other subjects and teachers' responsibilities: *"we have a plan that is put together by the principal and a team of people, but its really the teacher in the end who is responsible for what they are teaching"* (teacher interview, May 12, 2015, 8.5.1b) - a salient point. This statement raises questions around teacher self-efficacy, professional responsibility and other issues confronting teachers in their schools.

5.3.4 Prioritisation of Subjects in Schools and Principals' Reasons

All participants were asked to nominate the subjects which, in their opinions, were given priority in their schools. The proportions of the metropolitan and provincial principals and teachers who nominated 'subjects' as having had priority in their schools are shown in Figures 4.3 and 4.4. The two groupings of literacy with numeracy, and English with mathematics could not realistically be combined further into one overall group because this might not have correctly represented the principals' or teachers' true intentions. This is because literacy and numeracy are not, and should not, merely be taught during English and mathematics. Ideally, literacy and numeracy should be taught across all subject areas as appropriate. Proportionately, the nominations for literacy and numeracy and English and mathematics by the principals and teachers were quite similar. Calculation of the Pearson product-moment correlation coefficient (Figure 4.5) suggests that the principals and teachers had very similar perceptions of their school's priority 'subjects'; science did not rate in those priorities. 'Literacy' and 'numeracy', which were often nominated as 'subjects', are not recognised by the BOS NSW as 'subjects' in their own right. The NSW Department of Education and others have made statements to this effect:

> … while literacy comprises a complex repertoire of knowledge and skills
>
> that develop throughout the years of schooling, its practical application is
>
> at the core of teaching and learning. Accordingly, literacy is not a subject

in its own right but is fundamental to all learning areas. (An introduction

to quality literacy teaching, NSW DET, 2009, p. 11). (NSW DEC, 2013a,

p. 1)

However, despite such clarifications in the education sector in times prior to this research being carried out, many principals and teachers still referred to literacy and numeracy as subjects in their responses. Approaching the teaching and learning of literacy and numeracy with this mindset could, and probably does, result in extra time being devoted to their teaching rather than distributing that time across all KLAs in which literacy and numeracy could be taught as is the intended case: "literacy will be taught in a balanced and integrated way … [and] … teachers of K-12 across all key learning areas, are responsible for the teaching, running and learning of literacy skills, knowledge and understandings" (NSW DoE, 2017b, 1.2.1 & 1.2.5). As noted by P1 "[literacy and numeracy] *are important skills to have across all learning subjects"* (teacher interview, April 13, 2015, 2.2.3); and P5 "*because* [literacy and numeracy are] *the basis of everything"* (teacher interview, May 8, 2015, 2.2.3); and P3 *"*[literacy and numeracy] *are very fundamental to everything that the kids do"* (teacher interview, May 6, 2015, 2.2.3).

Two participants, P3 and P5, noted that, because their schools had Australian Federal Government 'National Partnership' funding specific to the teaching of literacy and numeracy, this obliged their respective schools to pursue an emphasis on literacy and numeracy over the period leading up to the interviews. As P5 elaborated, *"there's an accountability on using that* [i.e., the National Partnerships funding] *as well, and the focus on it for our school is just for literacy and numeracy because of our socio-economic status"* (teacher interview, May 8, 2015, 2.2.5). On the Australian Government's - Department of Education and Training - 2016 "StudentsFirst" website (http://www.studentsfirst.gov.au/teacher-quality), it is stated that a "quality education, which is so critical for the future of young Australians and our nation" (para. 1) is dependent upon raising the "quality, professionalism and status of the teaching profession" (para. 1). Further perusal of this page reveals no mention of science teaching while literacy and numeracy are mentioned many times. The most common reason for both metropolitan and provincial principals suggesting that literacy and numeracy had the highest priority at their school is that these capabilities

were targeted by the NSW DEC. These findings were in keeping with some of the NSW Department of Premier and Cabinet's targets detailed in the "NSW 2021 - A Plan to Make NSW Number One" (September, 2011).

The NSW syllabus mandating of English and mathematics was given as a reason for these two subjects being prioritised by six of the metropolitan principals. In contrast, though, no provincial principal cited this as a reason or gave any indication why this might have been the case. International studies have reported the dominance of English and mathematics in the curriculum. For example, Murphy and Beggs (2005) report that 79% and 74% of the teachers whom they surveyed reported the perceived importance of English and mathematics, respectively, in their teaching. As P2 and P5 noted during their interviews, *"maths and English ...*[are] *in our school plan - it's the drive we're pushing"* (P2, teacher interview, May 5, 2015, 2.2.1) with P5 having added *"*[English and mathematics are the priorities], *if anything has to go it's the other subjects!"* (P5, teacher interview, May 8, 2015, 2.2.6).

Given the NSW Government's targeting of literacy and numeracy and the use of the data to inform stakeholders of students' progress against set standards, it was not surprising that the reason given for the prioritising of literacy and numeracy in some schools was data-driven - as a result of the schools' previous NAPLAN results which needed improving upon. As one interviewee with over 30 years of teaching experience remarked: *"NAPLAN is an all-consuming thing"* (M1, teacher interview, March 26, 2015, 8.11.1c). This reason was given by 2 of the metropolitan and 5 of the provincial principals for prioritising literacy and numeracy, and by 4 and 10 principals for these groups, respectively, for prioritising English and mathematics. The large discrepancy between provincial and metropolitan schools' needs to prioritise literacy and numeracy based on NAPLAN progress data was a result of a trend highlighted in an ACER publication. In this publication, it was noted that the NAPLAN results of 2013 demonstrated that, for literacy and numeracy and for each of the school years assessed around Australia, "students attending schools in metropolitan locations have the highest mean score, followed by students from provincial schools ..." (ACER, 2014, para. 2). This trend, which continues into secondary schools, was consistent with the research based on Australian 2012 PISA scores - for 15 years olds - as noted by Lietz et al. (2014). Similar findings are

echoed in the ASTA & OCS's 2014 report, in which schools' teaching staff through to principals reported literacy and numeracy as having higher priorities than science across the schools surveyed. The authors commented that this is "possibly due to [science] not being included in NAPLAN" (p. 4).

It is evident from my study's data that, at least for this teacher cohort, the NAPLAN high-stakes testing programme had a high degree of impact on time spent teaching science in their schools. The prioritisation of subject emphasis on the primary school curriculum, the measurement of which was outside the scope of my research, seems to be one such case-in-point. NAPLAN is worthy of some discussion in this research because it emerged through the data as a prominent theme in relation to school priorities - and, therefore, school cultures - and because of its impact on the teaching of science. NAPLAN, in relation to science teaching, was noted in responses to the written surveys - as seen in Figure 4.6 - and every one of the ten interviewees made mention of its impact on their school's prioritisation of subjects. This was despite there having been no direct questions in relation to NAPLAN either in the surveys or the interview protocol.

In its 2013 Green Paper, the University of Melbourne Graduate School of Education (UMGSE) notes that the current focus in Australia on standards scores - for a narrow range of subjects - generated by tests such as NAPLAN distracts educators' attention away from measuring how student learning has progressed or grown over time compared with whether or not prescribed standards have been met. These data from my study might suggest that a shift in emphasis away from NAPLAN scores is indicated to avoid its negative impacts on the subjects not tested by NAPLAN. Specifically in relation to NAPLAN testing, M1 highlighted that *"parents and the community want a lot of results, results, results - as in testing. But that only gives you a small picture of how a child is developing in the classroom ... these things* [i.e., the child's developmental progress] *are very important"* (teacher interview, March 26, 2015, 8.11.4).

The emphasis on NAPLAN results continues to be debated as is evident in a report entitled 'Widening Gaps - What NAPLAN tells us about student progress' released in 2016 by Goss, Sonnemann, Chisholm and Nelson. One of their key findings is that

the "NAPLAN national minimum standards (NMS) are set *very* low" (p. 2) and it is suggested that these should be raised to allow a more meaningful interpretation. The report notes that using the NAPLAN scale makes it difficult for schools to compare student groups. It details a newly developed "time-based measure" (p. 1) to assist schools and teachers to better interpret NAPLAN data to inform their teaching strategies. It additionally notes that education policy makers should take the report findings and new measurement scale into account to inform future policies and funding. The report precipitated an article in the Australian newspaper 'The Financial Review' headlined "NAPLAN standards too low, says Grattan Institute in new report" (Dodd, 2016). In this article, Dodd reports that "minimum standards in NAPLAN tests are set too low and give a much rosier picture of the achievement level of Australian school children than the dismal reality" (2016, para. 1). While he does briefly describe the implications of the report in the article, these need to be interpreted in light of the whole report to avoid unnecessarily emphasising the impact and importance of NAPLAN. However, the lengthy and sometimes numerous articles that appear in the media when NAPLAN results are released does reflect society's predilection for discussing this high-stakes testing regime and the implications for schools, the education sector and the broader Australian community. Such media reports and discussions can themselves have an impact on schools and the teaching of subjects such as science as indicated by Fensham's model - Figure 2.1 - and the model depicted in Figure 2.2.

During my data collection, no principal or teacher mentioned the NAP-SL testing perhaps because none of the participating schools had taken part in it. It is possibly worth speculating, that if NAP-SL were to be tested annually across Australia as are literacy and numeracy in the current NAPLAN programme, then there might be a renewed surge of interest in teaching science. Pringle and Martin's (2005) research uncovered such an effect. They reported that primary teachers in the state of Florida in the USA found it necessary to teach science not because of any renewed enthusiasm for the subject, but out of fear of the negative consequences if their students failed to produce the desired results through the implementation of a high-stakes testing regime. However, as one interviewee in my study noted insightfully, "*I fear that if they have a science exam like NAPLAN ... all they will do is highlight those who can read or write and not the children who are capable of carrying out*

experiments ... [doing this is] not valid for assessing how a child is progressing and growing in science ... [the NAP-SL test will not] incorporate any of those things ... that are important to [doing] science" (M1, teacher interview, March 26, 2015, 8.11.1a and 8.11.1b).

After the release of the 2016 NAPLAN results, the popular press reported the plateauing of results under headlines such as "2016 NAPLAN results not good enough, says federal Education Minister Simon Birmingham" (Browne & Cook, 2016) and "ACT's [the Australian Capitol Territory's] 2016 NAPLAN results worst in recent years" (Hardy, 2016). Under the former headline, it is said that the NSW premier had "identified lifting the state's NAPLAN results over the next three years as a priority" (Browne & Cook, 2016, para. 16). After such wide publicity surrounding the release of the 2016 results, it must be asked what the impact of the last three years' plateauing scores will be on the teaching of subjects such as science in primary schools, and the pressure that such an impact might ultimately place on the staff who are required to teach science and other subjects.

The prioritisation of subject areas - regardless of the reasons and/or justifications - does appear to have had quite an impact on the teaching of science within this study's school sample. Further, the impact of NAPLAN high-stakes testing on the teaching of science in these schools also cannot be underestimated. The time spent teaching science could be one such impact.

5.3.5   Time Spent Teaching the S&T KLA to Stage 3 Students

International and Australian studies have found that the limited amount of time spent teaching science in primary schools is an issue. For example, the CCST 2010 report on the status of science in elementary schools in California - a state generally regarded for being a leader in the sciences in the USA - noted that many of its students were typically achieving at or below that nation's proficiency benchmarks for science. One of the reasons found for this deficiency was the diminished amount of time spent on teaching science in elementary classrooms. In Australian studies, Angus et al. (2004), for example, reported that over half of the available teaching

time in primary schools was devoted to the teaching of the English and mathematics KLAs; and Masters (2009) reported that the teachers in the schools on which he was reporting were spending around 1.2 hours per week - approximately 5% of the available teaching time - teaching science.

As highlighted in the Results chapter, some positive general comments were made by a few of the principals of the metropolitan and provincial schools on the teaching of science. Some of the principals expressed hope for positive change resulting from the mandatory introduction of the Australian S&T curriculum for K - 6 Years from 2015. However, as a result of their findings in the state of Queensland, Lowe and Appleton (2014) disagree that this will actually be the case. They found that the introduction of a new curriculum in that state was the source of new stressors.

Table 4.11 summarises the results of the survey questions relating to the time which generalist teachers spent each week teaching the S&T KLA to their Stage 3 students: it is represented graphically in Figure 4.7. These data give overall figures that of the total cohort, 28 teachers spent 1 to 2 hours per week teaching science, but with 12 teachers teaching science for less than 1 hour per week. As noted earlier, there had been a directive from the NSW DEC in relation to the time spent teaching the S&T KLA which made it necessary to pose a question about teaching the Science and Technology KLA rather than just the science component. Therefore, it is important to stress that, in the analysis of the data, these figures represent the total time teaching the KLA and, therefore, the time spent teaching science might, in fact, be less than represented from the responses.

Is this amount of time spent teaching science actually enough? Eight of the 29 metropolitan and 5 of the 18 provincial teachers commented that they felt that they spent less time teaching science than they should. Another teacher from each of the metropolitan and provincial groups avoided teaching science whenever possible. Some teachers in both groups made additional comments that they - or teachers in their schools - just tried to teach science with inadequate content knowledge. These two sets of data suggest that, perhaps, not enough time was spent by these teachers in teaching science to students at this level.

Comments made by a number of the interviewees highlighted the disparity in the amount of time spent teaching science across their schools; and some expressed concern that they were not spending enough time teaching science. One interviewee commented that, at her school in the past, there had not been enough time dedicated to teaching science. But, with the early implementation of the Australian Curriculum at her school - *"which is better for science ... [I am now] … stressing at the fact that"* … [I no longer have enough time allocation to get] … *everything done"* (M2, teacher interview, March 30, 2015, 4.5.1). Other comments included, for example, "[In the last 12 months we were] *looking at about 2-3 hours a week for each of ...* [a maximum of] *two terms"* - the interviewee was of the opinion that this amount of time was not enough (M2, teacher interview, March 30, 2015, 4.4) and *"there needs to be more science taught ... I didn't do it on a weekly basis over a whole term - I intensified it over 3 or 4 weeks and over that time I spent about maybe an hour a week at the most. It isn't enough. We do one unit a semester"* (P4, teacher interview, May 7, 2015, 4.7).

The allocation of science teaching time by the school because of timetabling - which might have been the result of school policy or lack thereof - in combination with an overcrowded curriculum reduced the time spent teaching science in some schools. This is reflected in some of the principals' comments relating to their schools' greater focus on technology, or reliance upon the expertise of their RFF teachers to teach the science curriculum as highlighted in the Results chapter. As demonstrated in the following, the allocation of time dedicated to teaching science in Stage 3 is not totally at the discretion of the teachers

5.3.6 Additional Factors Affecting the Teaching of the S&T KLA

Tilgner observed in 1990 that for primary school teachers, nothing had changed in the years since Hove (1970) and then Mittelfehldt (1985) had reported on the main three hindrances for effective science teaching: inadequate science content knowledge, equipment, and time and space. This situation is reflected in more recent literature and has not changed in recent times, but other factors also come into play (Aubusson et al., 2015; Lunn, 2008; Smith, 2015) as discussed in this section.

The teachers' responses to an open-ended question regarding positive and negative influences which affect the teaching of science in their schools were thematically grouped and shown in Tables 4.12 and 4.13. Table 4.12 summarises the positive factors considered to affect the teaching of the S&T KLA in their schools. The percentages quoted in this section are of the total of all responses to the question for each of the two groups - some teachers listed more than one factor. The factors which had positive effects as reported by metropolitan teachers were a supportive school policy and/or effective, high-quality programmes, followed by the availability of good resources at their school or the opportunity to share resources with other institutions - such as secondary or other primary schools. Student motivation ranked equal second for this group. Other factors of positive influence were teachers' enthusiasm for science; their science qualifications; adequate time allocation for science teaching; and effective ICT support within the school. Interviewee M2 noted that, at his school, *"there's no science co-ordinator at the moment. Our previous co-ordinator was really good ..."* (teacher interview, March 30, 2015, 8.6.1d). M2 continued that *"before this year, we used to just teach science twice a year - say terms I and III. We spent two hours a week looking at the science component"*. This led to a less-than-desirable status for science as a subject at that school up to that time. The interviewee suggested that the situation in her classroom had changed for the better since then.

The provincial teachers noted only three positive factors which influenced the teaching of science in their schools and they, too, rated highly the supportive policy and/or effective, high-quality programmes, but this factor was slightly behind student motivation. One provincial teacher listed good resources as an important factor. From the surveys, resource-sharing with other institutions was not mentioned by the provincial teachers as it had been by their metropolitan counterparts. This could have been a consequence of the relative isolation of some primary schools or for other reasons. However, one provincial interviewee did discuss this in the context of participating in a programme with local high schools in a large, provincial township. The teacher saw this as being a potential PL opportunity in addition to resource-sharing. She lamented that the programme slowly came to a halt after the secondary teachers who initiated it stepped away from the programme. This provincial teacher

postulated that the secondary teachers' motives for having set-up the programme were for the benefit of someone who was preparing their CV:

> *The primary schools* [pushed] *to get it going and to share things and build up partnerships ... but the secondary teachers didn't seem too interested and didn't show up. A lot of people saw that as probably more like someone wanting to start to put it on their curriculum vitae.* (P5, teacher interview, May 8, 2015, 8.2)

In comparing the metropolitan and provincial teachers' responses, the top three factors were the same for both, albeit in a slightly different order: supportive school policies (the impact of which was discussed above), good resources and effective/high quality programmes which, in most cases, can typically be traced back to the school's principal. As Tilgner (1990) revealed, a school's administration can positively reinforce teacher attitudes and the setting of goals. Such goals can reflect a solid philosophy towards the teaching of science and are of great importance. These school administrators can be either a school's governing body and/or a primary school principal. Tilgner (1990) also proffered that principals who had been actively engaged in science PL programmes and other activities had the capacity to develop a leadership role in the teaching of science in their school. They then had the ability to influence the degree to which science is emphasised in their schools and to be a positive influence on their teachers' morale. This situation was evidenced in one of the metropolitan schools.

At the school under consideration, the principal had actively kept up-to-date through science PL and was very enthusiastic about the subject being taught in the school in the best way possible. Consequently, the school's science resources were appropriate, well organised and well maintained. This was witnessed by the researcher during a visit to the school staff - at the invitation of the principal - before data collection had begun. The school principal's active encouragement of teaching the science curriculum had filtered-down through the school - an observation confirmed by Stage 3 staff during the visit. As a counterexample, within weeks of a

new principal - who was not particularly interested in science being taught - taking up appointment in a NSW provincial primary school, he/she gave away or sold off a large quantity of materials needed for science teaching that had been built-up by his/her predecessor (name withheld, personal communication, June 29, 2017). It was reported in the same personal communication that these actions had a very negative impact on the staff and on science teaching at that school.

The factors which exerted a negative influence (Table 4.13) on the teaching of the KLA were, again, very similar and the top three were ranked in the same order for both groups. For the metropolitan and provincial groups, respectively, these were: inadequate time allocated for teaching science and an overcrowded curriculum; insufficient budget and/or time to maintain resources; and teachers' poor science qualifications. The metropolitan group mentioned a lack of and/or availability of teaching space for science - ranked fourth - followed by team-teaching opportunities for science teaching - because, the teachers report, they can be difficult to organise - and other staff not being interested in teaching science. As with the positive factors noted above, the provincial teachers' responses were very similar to those of the metropolitan group, namely that team teaching opportunities for science teaching are difficult to organise and that there was a lack of appropriate teaching spaces for science. The timetabling of science classes in the afternoons at some schools was also found to be a negative factor.

Some of these negative factors were mentioned on a number of occasions throughout the interviews. There were eight comments which related to equipment issues having had a negative impact on science teaching, such as *"we do have a problem buying resources. ...*[no-one is] *in charge of the science equipment ... things get lost, rundown and broken and they aren't replaced"* (P5, teacher interview, May 8, 2015, 8.1.1); and *"there's no dedicated teacher overseeing the science equipment so no-one has responsibility. ... there isn't even a dedicated area for storing the equipment and doing practicals* [and] *... the maintenance of the actual equipment and storage of resources becomes a challenge"* (M4, teacher interview, April 21, 2015, 8.1.1 and 8.1.2). As with many schools, the equipment for science investigations was shared between a number of classes, which presented further supply-and-demand and maintenance problems (8.1.3). These results are similar to those of Mansfield and

Woods-McConney (2012).

From Tables 4.12 and 4.13, there was a lesser number of negative-impact factors mentioned by the metropolitan group compared with the provincial group. This was largely a reflection of the larger proportion of provincial teachers citing inadequate time allocated for science teaching combined with an overcrowded curriculum and lack of resources. As provincial teacher P1 said, *"resourcing science teaching is expensive and it would be great to have a space in which to teach science and keep all of the resources"* (teacher interview, April 13, 2015; 8.3). This negative-impact factor is reflected in the data for the amount of time spent teaching the S&T KLA (Table 4.11), with proportionately fewer (6 teachers = 21%) of the 29 metropolitan teachers spending less than an hour each week teaching science compared to their provincial counterparts of whom 6 teachers (= 33%) of the 18 estimated teaching science for the same time range. (Again, it must be noted that these figures are for the teaching of the S&T KLA, and therefore, the teaching of the science component could be much less across all of the figures reported in Table 4.11.) These results, again, could be aligned with the provincial principals' citing the prioritisation of literacy and numeracy - and to a lesser extent English and mathematics - as being NAPLAN-data-driven compared with the metropolitan group and, consequently, the time dedicated to teaching science was reduced.

Several other factors were mentioned during the interviews as coming into play. For one teacher, his own school background impacted on his teaching: *"science wasn't a big focus when I was at primary school ... I guess I sort of carried that on"* (P2, teacher interview, May 5, 2015, 8.6.1e). Even though this was a reported impact of a primary school science experience, this comment relates back to Morgan's (2012) findings that poor secondary school science experiences can flow-through into a primary teacher's own teaching experiences. M3, while discussing the possible future mandating of risk assessments for all primary science experiments in one education sector, observed that *"if people have to fill in risk assessments for every piece of science experiment then ... at primary school, people just won't do it!"* (teacher interview, April 13, 2015, 8.6.1a). As noted in the literature review, the ASTA & OCS report of 2014 noted that "introducing formal risk assessments into primary schools could be challenging and additional support resources will be

required for teachers" (p. 7), and suggests that teachers will need "substantial assistance to minimise the burden" (p. 7) on them.

In summary, my school sample was one for which the generalist teachers were quite experienced with only one specialist science teacher participating in this study. The metropolitan schools were, on average, larger than their provincial counterparts. Science as a subject - a component of the S&T KLA - was not a priority subject in any participating school whereas literacy and numeracy/English and mathematics were reported as being highly prioritised - seemingly to the detriment of science teaching. The influence of NAPLAN testing was a frequently recurring theme amongst factors which negatively impacted the teaching of science. Even though there are positive and negative influences on the teaching of science, teachers with determination and high self-efficacy and motivation can, to a degree, overcome some of these factors which influence the teaching of science in their school.

5.4   Research Qn. 2 - What is the Level of Teacher's Self- efficacy with Respect to Teaching Science?

5.4.1   Teacher Confidence Levels

Self-efficacy is not viewed as a personal character trait but as being dependent on context. For example, a primary school teacher might exhibit a high degree of self-efficacy in teaching languages or the arts but lower self-efficacy in respect to teaching science (Mintzes, Marcum, Messerschmidt-Yates & Mark, 2013). Mansfield and Woods-McConney support this assertion and consider that "teachers' efficacy is ... a situation-specific construct, meaning it is both context specific ... and subject matter specific" (2012, p. 37). Four of the ten interviewees thought that they felt confident enough to teach science because they had built up their confidence levels over the period they had been teaching. However, some of the other interviewees who were also quite experienced teachers felt the opposite, as exemplified by the comment *"No. Still not!"* (M3, teacher interview, April 13, 2015, 3.2.1).

Loughland and Nguyen (2016), in the introduction section of their study into aspects of a professional learning programme for primary teachers, state that primary teachers "generally tend to have negative attitudes toward science and their pre-service teacher training in science has not equipped them with enough knowledge to be confident in their science teaching" (p. 499). Tilgner revealed that "a problem exists in today's elementary science programs. Little time is being spent on science, and the time that is spent is often of low quality because of the teachers' negative attitudes and feelings of inadequacy" (1990, p. 428). This pattern also aligns well with findings of Riggs and Enochs (1990) and Bandura (1981) as discussed in a previous chapter. Anderson (2015) describes the role of teachers' beliefs in directly influencing teachers' knowledge development. It was important in this study, then, to examine the participating teachers' self-efficacy because it could have been influenced by both their school context and how they perceive themselves in relation to their knowledge of the subject matter that they were required to teach.

As described in the Research Methods chapter, the STEBI-A instrument of Riggs and Enochs (1990) was designed to measure two scales relating to teacher efficacy. The Science Teaching Efficacy Scale - or STOE - is a reflection of a teacher's beliefs in how effective instruction can influence students' learning whilst the Personal Science Teaching Efficacy Scale - PSTE - reflects teacher confidence in his/her science teaching ability. The STEBI-A data are discussed in more detail below. However, of the ten teachers interviewed, four teachers felt confident that they had enough science background to teach the current science curriculum. Two of these teachers were quite confident as was evident from their remarks such as *"I would believe so ... maybe because I'm a bit nerdy. ... I'm pretty comfortable with the technological aspect"* (M4, teacher interview, April 21, 2015, 3.1.4); and *"I do, yes, I'm very passionate about science"* (M5, teacher interview, May 12, 2015, 3.1.1). Two other teachers from this group emphasised, however, that their confidence was gained by virtue of their long years of teaching experience: *"Yes ...* [I'm] *quite an experienced teacher"* (P1, teacher interview, April 13, 2015, 3.1.7); and *"... just from experience from over the years"* (P4, teacher interview, May 7, 2015, 3.1.3).

The influence of science background on teachers' confidence was highlighted in the literature (for example, by Gess-Newsome, 1999; Hensen, 2001; Bilali, 2013) as is

the effect a teacher's confidence in the classroom (Anserson, 2202; Danielsson & Warwick, 2014). From the five interviewees who did not feel confident that their science background was adequate enough, there were some quite negative answers. To illustrate, these comments ranged from the categorical, unqualified and previously quoted *"No, definitely not!"* (M2, teacher interview, March 30, 2015, 3.2) and *"No, not really"* (P2, teacher interview, May 5, 2015, 3.2) to *"over a long teaching career ... I always felt intimidated by teaching science"* (M1, teacher interview, March 26, 2015, 3.2.3) and *"for sure, science would be at the bottom end* [of my preferred teaching subjects] (P2, teacher interview, May 5, 2015, 3.2.6). P5, who liked teaching science, had a negative anticipation of needing to teach the subject after not teaching it for some time. This was as a result of the Stage 3's science classes having been taught by the RFF teacher: *"because I haven't taught it for so long I find it's a bit difficult"* (teacher interview, May 8, 2015, 3.2.2). Working at a school which had just begun introducing the 'new' Australian Curriculum, P5 felt unable to quantify his/her level of confidence due to a lack of familiarity with the syllabus but did note that *"I'll find out when I come to something I don't know!"* (P5, teacher interview, May 8, 2015, 3.3.1).

STOE and PSTE data reported in Figures 4.14 and 4.15 indicate that, overall, the total cohort had slightly more positive personal science teaching efficacy beliefs than their science teaching outcome expectancy. As these data could mask deeper trends relating to specific aspects of STOE and PSTE - and the teachers' confidence in teaching science - closer examination of the data were warranted.

5.4.1.1 Science Teaching Outcome Expectancy Scale (STOE)

Riggs and Enochs (1990) acknowledge that Science Teaching Outcome Expectancy (STOE) is a difficult construct to define and measure but that the STEBI-A provides an adequate measure of each of the STOE and Personal Science Teaching Efficacy (PTSE) scales. With respect to the STOE scale, the similar means and small standard deviations for the metropolitan and provincial teachers reported in Table 4.30, $\bar{x} = 30$ ($\sigma = 3$) and $\bar{x} = 28$ ($\sigma = 7$) respectively, indicted that, overall, there was a reasonably high degree of agreement between the metropolitan and provincial

teachers that effective instruction can influence students' learning. Two metropolitan teachers and one provincial teacher scored 36 or more on the STOE scale, which indicated that they shared a higher degree of uncertainty than the group *in toto*. Mean scores - as shown in Figure 4.12 - might also have indicated that the group as a whole was mainly in agreement with the statements on STOE. However, two of the item means were ≥ 3 - items 7 and 10 - with a further two means being ≥ 2.5 - items 13 and 25. The percentages of the group who were undecided about particular items - see Table 4.27 - also indicated that there was a lack of agreement on some items.

Items 7 and 10 relate, respectively, to the likelihood that students' underachievement in science is due to ineffective science teaching and that the low achievement of students is largely the teacher's fault. There was a slightly higher level of disagreement within the group for these two statements than with any other STOE item - see Figure 4.12 for item medians and IQRs. This disagreement for these two items was less pronounced within provincial teachers - whose means were, respectively, 0.6 and 0.5 below the total - and metropolitan means. As there was no clear agreement or disagreement with the statements, these two items do not appear in Table 4.28. The data for Item 7 showed that 19 teachers (= 45%) - a relatively large proportion - agreed that the underachievement of students was most likely due to ineffective science teaching. However, in contrast, 12 teachers (= 29%) were either uncertain about this and 11 teachers (= 26%) disagreed; a sub-total of 23 teachers (= 57%). (Again, rounding of percentages has resulted in some sets of figures not adding to exactly 100%.) In this case, no teacher strongly agreed or disagreed. Similarly for Item 10, which stated that teachers could not be blamed for some students' low science achievements, 17 teachers (= 40%) strongly agreed or agreed compared with 15 teachers (= 36%) who were uncertain and 10 teachers (= 24%) who disagreed - no teacher strongly disagreed with this item - giving a sub-total of 25 teachers (= 64%). There was also some disagreement - albeit to a lesser extent - on Item 13 relating to increased effort on the teacher's part in science and teaching bringing about science achievements in some students; and Item 25 concerning that some students cannot be helped even by teachers who have good science-teaching abilities.

As noted in the Research Methods chapter, because mean and median scores occasionally mask some of the intent in responses, STOE scores - and correspondingly the PSTE scores - were further analysed to compare the percentage of respondents who selected 'strongly agree' or 'agree' with the percentage who selected 'uncertain', 'disagree' or 'strongly disagree' - that is, the persistent minority (PM). As noted in pervious chapters, a small IQR (<1) indicates a clustering of responses and thus agreement. Larger IQRs (≥ 1) indicate a relative spread of responses and disagreement amongst those surveyed. The items for which the IQRs were ≥ 1 (see Figure 4.12) - indicating a relative lack of consensus with the item - had been further analysed for PMs. Eight items out of 12 - namely, Items 1, 11, 13, 14, 15, 16, 20, and 25 - showed large PMs. These are itemised with item statements, percentage of the cohort in agreement with each other (whether this was agreement or disagreement with the item statement) and the percentage of the total cohort in disagreement with the majority - that is, the PMs - in Table 4.28. The percentages of 'undecided' responses for the STOE items were also graphed and shown in Figure 4.13. The average level of item indecision was quite high at $\bar{x}$ = 19%. Six items showed levels of indecision above this: Items 7, 10, 11, 15, 16 and 20. As noted above, Items 7 and 10 had the highest levels of indecision at 29% and 36%, respectively.

Other items with higher than average levels of indecision are discussed below in combination with items which showed large PMs (discussed in order of decreasing PM size). Despite the overall mean for this scale indicating efficacy beliefs on the slightly positive side of the mid-point between maximum and minimum scores, the overall analysis of the STOE items for this group of teachers indicated that there was a lack of consensus on many issues related to their overall beliefs that effective teaching can influence student learning.

5.4.1.2 Personal Science Teaching Efficacy Scale (PSTE)

The method and rationale of analysis used for the STOE scale scores, were applied in the same way as PSTE scale scores. Examining the means and standard deviations for the total PSTE scores (Table 4.30) for the metropolitan and provincial teachers of

$\bar{x} = 29$ ($\sigma = 5$) and $\bar{x} = 27$ ($\sigma = 4$), respectively, indicated that the pattern for both groups was towards agreement and, therefore, reflected an overall degree of teacher confidence in their science teaching ability. However, the standard deviation of 5 for the metropolitan teachers suggested a slightly higher degree of uncertainty in this confidence than for the provincial teachers with a standard deviation of 4. Four of the metropolitan teachers scored slightly higher than 39 - indicating that they had a slightly more negative perception of their efficacy than the rest of their cohort. This was in contrast to the provincial group in which no teacher scored higher than the mid-point score of 36. As for the STOE responses above, it is worthwhile noting that there was a high frequency of 'undecided' for some items - as shown in Table 4.27. Whilst the mean percentage of 'undecided' responses for the PSTE items, as seen in Figure 4.13, was reasonably low at $\bar{x} = 13$, the means of 24, 19 and 31 for Items 3, 5 and 19, respectively, were quite high and are discussed further below in combination with item PMs.

The mean scores for the individual items of the PSTE scale and the minimal variation between them - as shown in Figure 4.9 - were further support that the group was mainly in agreement with the statements on PSTE. For Item 21, for the metropolitan group and Items 3 (comparing the teaching of science to that of other subjects), 8 (teaching science effectively) and 21 (inviting the principal to evaluate the respondent's science teaching) for the provincial group, the means were 21 which suggested a tendency towards some uncertainty about these statements. With all means at 2.4 for Item 24 - which raises questions about whether the teachers have the skills necessary to teach science - there was also a degree of uncertainty.

The medians across all items of 2 (= agree) and with all IQRs being ≤ 1 suggested that most teachers were in agreement. For a number of items in Table 4.29, though, there was a relatively large PM which gave a better indication of how this group of teachers felt regarding their abilities to teach science. Eight out of 13 PSTE items had large PMs indicating a large degree of disagreement between teachers on certain items. The group's responses to Items 3, 19 and 6 are considered first as they had the largest PMs.

The data for Item 3, which related to how well teachers' teaching of science compared with how well they taught other subjects - even when they tried very hard - had a large PM of 15 teachers (= 36%). There was quite a degree of uncertainty within this group with 10 of the teachers (= 24%) being uncertain about this concept. Item 19 indicated that there was fairly strong uncertainty or disagreement with respect to teachers considering that they had the necessary skills to teach science. This was the strongest PM grouping of 17 teachers (= 41%) with a group of 14 teachers (= 31%) being uncertain about this. As interviewee M1, who felt intimidated by teaching science, noted *"the only time I really did feel mildly confident was when we were a part of the 'Primary Connections' trial"* (teacher interview, March 26, 2015, 3.2.4).

Finally, for Item 6 (teachers' effective monitoring of science experiments) and Item 21 (inviting the principal into the classroom to evaluate a teacher's science teaching), there was a PM of 13 teachers (= 31%) for both items. This, however, might not just have been a result of the low science teaching efficacy of some teachers. It could also have been related to teacher's' overall lack of confidence, personality traits and/or attitude that their classroom was their domain and therefore classroom observers were not welcome.

In summary, notwithstanding the PSTE mean score of 27 (σ = 4) which indicated a slightly higher level of confidence than for the STOE items, the above analysis of individual items suggests a lack of teacher confidence in quite a number of areas related to personal science teaching efficacy. The statistics for the PSTE items might not be surprising given that 34 of the teachers of this total cohort reported that they felt that they needed to supplement their science content knowledge. Interviewee P4 summarised this by commenting that *"not a lot of teachers are really confident with it"* (teacher interview, May 7, 2015, 3.2.7) with self-identified, under-confident P3 having added *"but I want to make sure that I teach it properly"* (teacher interview, May 6, 2015, 3.2.5) - an aspiration which would befit all teachers regardless of their confidence levels.

5.4.1.3 Differences in the STEBI-A Data Between Teachers with Science and Non-science Backgrounds

A comparison of the STEBI-A item responses of teachers who studied a science major at tertiary level (n = 6) with teachers who did not (n = 36) - Table 4.31 - highlighted a few differences between the two groups. As noted in the Research Methods chapter, items for which the differences in response percentages within each group were less than or equal to 15% of the group are not shown, as they were considered to be too close to be meaningful. A total of 10 items are discussed here with the first four being STOE items. Also noted in the Research Methods chapter, percentages are not used for the analysis of these data as the sizes of the sub-groups were small.

For Item 4, relating to the improvement of students' science grades being most often the result of teachers developing a more effective teaching practice, 7 of the non-science background teachers disagreed, or were undecided, whilst all teachers with a science background were in agreement. Item 11 showed few teachers doubted the effectiveness of increased teacher attention for improving the achievements of low achievers in science. Eight of the non-science background teachers, who either disagreed with or were undecided about this, chose similarly to the three science background teachers who were also undecided. Item 15 about students' achievement in science being directly related to the science-teaching effectiveness of the teacher was agreed to by all of the teachers with a science background compared with the non-science group for which 13 teachers were either in disagreement or undecided. Finally for Item 20, which presented an interesting contrast of perceptions, 26 of the non-science-background teachers disagreed that effective science teaching had minimal impact on student achievement for students whose motivation is low. This is in contrast with teachers with a science background, who were equally divided between agreeing and disagreeing/undecided about this concept. Because of the nature of the STEBI-A survey, no indication could be given as to why this was the case.

Some of the results for the six PSTE items are possibly not surprising given that one small group of teachers had some tertiary science background. For Items 3, 8, 12, 19

and 22 - relating to the teachers' science teaching efficacy - this group of teachers had a very positive view of their science teaching skills. However, the responses for Item 18 are intriguing as three - that is, half of the group - of science-background teachers disagreed that they were typically able to answer students' questions in science whilst the other three teachers were undecided. These responses could have been an artifact of the cohort being small and/or a low level of overall teaching confidence among the individuals involved. Mansfield and Woods-McConney (2012) report that confidence can be both specific in context and in subject matter, so that a teacher who has a major in biology, for example, might have low self-efficacy when faced with teaching a physics topic. The preference of primary teachers towards the biological sciences is supported by the literature (Danielsson & Warwick, 2014; Kahle et al., 1991; Mansfield & Woods-McConney, 2012). Therefore, the responses of this small group to Item 18 could also have been the result of these teachers typically having a tendency towards a biological orientation. Consequently, they might have felt limited in their capacity to effectively answer questions relating to other areas of science. The same holds true for teachers with a background in any science discipline possibly experiencing lower confidence levels when teaching other science discipline areas. As Harlen, Holroyd and Byrne (1995) note, a thorough understanding of specific science concepts does not always translate into teacher confidence (as cited in Sweeney & Alexander, 2002).

Table 4.31 does not include the results for Items 7 and 10, because there was a similar pattern of disagreement within and between the groups as that noted above. In order to allow for proportionate comparisons, these data are presented as percentages in Table 5.1 for the six teachers who had a tertiary major in a science ('science') and the 36 who did not ('non-science').

Table 5.1. Percentages of different responses to STEBI-A Items 7 and 10 for teachers with science and non-science backgrounds at tertiary level.

Response	Item 7		Item 10	
	Science (%)	Non-science (%)	Science (%)	Non-science (%)
Strongly agree/agree	34	42	0	33
Undecided	50	31	84	46
Disagree/strongly disagree	16	27	16	21

The focus of Item 7 is the likelihood that students' underachievement in science is the result of the science teaching being ineffective, and the focus of Item 10 is that teachers cannot be blamed for some students' low science achievement. For Item 10, all six of the science-background teachers were either undecided (= 84%) or in disagreement (= 26%), whereas the proportions were similar for each response category amongst the non-science teachers. Similarly, for Item 7, there was also a large degree of indecision/disagreement. It was not unreasonable to expect high similarity of responses for these two groups because these items probe STOE elements which are more related to expectancies based on teachers' effective instruction influencing students' learning than teachers' confidence in their science content knowledge. Whilst these PSTE and STOE scores gave some indication of the overall science teaching efficacies and outcomes expectancies of the teachers in my study, these results could not be extrapolated to the broader primary teaching community because the sample was limited.

For an Australian case-study of university graduates teaching science, Henderson observed that "their confidence in teaching science, actually decreases as their teaching experience increases and that curriculum work at college seems to lose its impact within a year or so, if graduating teachers are not placed in a school where science is highly valued and where there is sufficient science equipment" (1992, p. 192). In contrast to Henderson's findings, the 2014 ASTA & OCS survey indicated that "confidence to teach science increases with length of service" (p. 5). Mintzes et al. (2013) cite research which supports this latter statement by reporting that self-efficacy increases with "years of elementary school science teaching (Cantrell, Young & Moore, 2003; Liu et al., 2003)" (p. 1203). In this latter study, some of the online survey results were skewed due to the nature of the sample of teachers but especially because the teachers interviewed were particularly interested in teaching science.

Whilst the results of my study are cionsistent with those of scope and sample size of this research was too limited to draw parallels with the findings of ASTSA & OCS (2014), Henderson (1992) or Mintzes et al. (2013), but my findings highlight the intricate interdependence of science teaching practice and teachers' confidence. As previously established, many teachers in my study considered that they had limited

science backgrounds and needed to enhance their science content knowledge. Teachers' overall science teaching self-efficacy - which was just on the positive side of the mid-point between maximum and minimum scores - could have been partly attributed to their school's context in addition to their deficit in content knowledge. If these teachers were operating in a school in which science was not particularly valued, did not provide enough equipment or space to teach the syllabus effectively, and/or did not make provision for adequate access to science-related professional learning, then their self-efficacy could be lower than expected. In turn, their self-efficacy could negatively impact their teaching of science. Additionally, those who had content deficits in specific areas of science - for example, physics or geology compared with biology - might have been experiencing lower self-efficacy in relation to teaching those areas (Mansfield & Woods-McConney, 2012).

Mintzes et al. (2013) refer to a number of studies showing that high levels of self-efficacy have a significant correlation with a number of variables for the teaching of science. They document examples of such variables which have been the focus of particular researchers:

> … the number and quality of high school science courses taken (Mullholland et al. 2004; Watters and Ginns 1995); the number of college science courses taken (Enochs et al. 1995); conceptual understanding of central ideas in science (Schoone and Boone 1998); … a science teaching methods course (Yilmaz-Tuzun 2008), and a preference for activity-based rather than textbook based instruction (Enochs et al. 1995). Not surprisingly, these findings suggest that the highest levels of self-efficacy are found in those who have a strong science background. (p. 1203)

For primary school teachers, self-efficacy is critical (Palmer, 2011). The self-efficacies demonstrated through STEBI-A responses in the current study were not

particularly positive, especially for some STOE and PSTE items because self-efficacy can be partly attributed to a deficit in content knowledge, and the teachers were aware that they had this deficit. This awareness provides one strong reason why teachers might seek to enhance their science content knowledge. However, as Sweeney and Alexander (2002) note, it might be a somewhat unrealistic expectation that primary teachers be "fully confident … [since] … scientific knowledge and understanding changes constantly with new discoveries and new insights" (p. 55). They suggest that it could perhaps be more realistic to expect teachers to be "confident with a little help" (p. 55). Therefore, it was necessary to examine from where the extra help might come to assist primary teachers to improve their science-teaching confidence to a level that they consider acceptable. One way might be through self-initiated learning using ICT-based science resources to improve their science content knowledge or through various forms of PL. The latter is discussed in the following section.

5.5 Research Qn. 3 - Do Teachers Participate in Professional Learning Activities to Supplement Their Science Content Knowledge?

One of the implications of case-study research conducted by Loughland and Nguyen (2016) into the outcomes of primary teachers' participation in a professional learning programme was that *'professional learning needs to address the instructional core of* [science] *content ...''* (p. 515). PL, in combination with other instructional cores, is important for teachers' students to achieve positive learning outcomes. As noted above, various forms of PL could be used, not only to enhance teacher science content knowledge, but also to enhance their confidence in teaching science. Among a number of recommendations, the 2009 report on the 2007/2008 TALIS Survey, recommended that professional learning for teachers should "update individual's knowledge of a subject in light of recent advances in the area … [and be designed to] … exchange information and expertise among teachers and others … to help weaker teachers become more effective" (OECD, 2009, p. 49).

Smith and Lindsay assert "teachers need to be positioned as active learners and key decision makers about what matters in terms of professional learning ... [and that] PL

recognises teachers as 'intellectuals'" (2016, p. 245). Therefore, if teachers perceive themselves to be active learners - for reasons which are discussed herein - and seek to engage in PL, then they will play a major role in deciding for themselves the type of PL. Therefore, it was considered worthwhile to examine certain aspects of the professional learning of my research participants. The choice to use ICT-based science resources to enhance teachers' science content knowledge is, and when convenient could be, an example of Smith's and Lindsay's (2016) assertion in practice.

It was noted in the Research Methods chapter that the human interactions, as collaborations with others to enhance science content knowledge listed in Table 4.17, can also be considered to be a form of professional learning. Tables 4.20 to 4.23 list various forms of professional learning and are categorised as 'formal' or 'less-formal' PL. For example, mentoring or being mentored are forms of formal PL while other collaborations, such as engaging in informal dialogues with colleagues, are less-formal. These collaborations are discussed in the next and a later section of this chapter.

5.5.1 Teachers' Participation in Activities to Supplement Their Science Content Knowledge

As evidenced through the literature, there is an important need for PL for primary teachers for a number of reasons, not the least being to improve their own confidence in teaching science (Murphy & Beggs, 2005) to enable them to contribute towards the quality of their students' education. Sweeney and Alexander (2002) also note the importance of having specific forms of PL available to help teachers to achieve appropriate levels of confidence. "Many initiatives across the world have focused on increasing the quality of science teaching by investing in professional learning programmes for science teachers" (Loughland & Nguyen, 2016, p. 499).

Figure 4.8 shows a comparison of metropolitan and provincial teachers' overall perceptions of their need to participate in activities to enhance their science content knowledge, as well as their need to improve their ICT skills to do this. Eighty percent

of metropolitan and 100% of provincial teachers identified some degree of overall need to achieve each of these outcomes. As identified through the surveys, 78% of the total cohort felt a low to moderate need for such PL activities, and 43% identified a low need to improve their ICT skills to access online science content knowledge.

From the Phase 1 results, only five of the total cohort of teachers responded that they had attended any subject-specific PL activities and, of this group, only one teacher - from a provincial school - attended any activities at all. Another provincial teacher was forthcoming in stating that "more child exploration [required by the new curriculum] means [that] less teacher understanding [is] deemed crucial". Therefore, the latter teacher did not recognise a need to enhance his/her science content knowledge. This notion, however, is contrary to discussions found in the literature. For example, Kirshner, Sweller, and Clark (2006) propose that inquiry-based "learning is successful only when students have prerequisite knowledge" (p. 82) and that some students need a high level of guidance and scaffolding to be successful inquiry learners. It could be argued, that the teacher should, therefore, have a deep science content knowledge to empower the student to successfully progress through the inquiry learning process. Keys and Bryan (2001) further contend that "teachers who use an inquiry approach must have a rich and deeply developed understanding of science content" (p. 637).

The open-ended structure of the Phase II survey questions elicited a greater range of responses concerning enhancing these needs: twenty three teachers responded that they had engaged in formal PL and a higher number - 35 teachers - responded that they had been involved in informal PL. This might suggest that a degree of memory prompting was needed and/or, more likely, that a number of teachers did not consider some activities - such as being mentored or having professional discussions with colleagues - as contributing towards their own professional learning. This is consistent with Mayer and Lloyd (2011) who argued that the term 'professional learning' (PL) has largely replaced the term 'professional development' (PD) in many Australian school communities. They maintain that this change is the result of a shift in the perceptions of what PD entails, as well as, the "presumed 'baggage'" (p. 4) that result from their attendance at poorly organised and/or conceived in-service courses and other activities that were formerly referred to as PD.

The PL activities were categorised as being 'formal' or 'less-formal'. For example, 'formal' PL could entail courses/workshops, education conferences, visits to other schools for the purpose of observation, while 'less-formal' PL could encompass professional reading and/or engaging in less-formal dialogue with colleagues. Tables 4.20 and 4.21 summarise the responses for the total cohort for each of these categories together with the participants' consideration of the impact that each type of activity made on their development as teachers. These statistics were further analysed according to the participants' classification as provincial or metropolitan as shown in Tables 4.22 and 4.23 and are discussed in the following sections.

5.5.2   Engagement in Formal PL Activities

"A lack of adequate professional development opportunities for in-service teachers in [science] has been reported across the education sector" (Aubusson et al., 2015, p. 7). Analysis of the teachers' participation in formal PL activities showed that it was predominantly the metropolitan teachers who were engaging in these types of activities. However, across both groups, the highest participation rate of 14 teachers (= 35% of the total cohort) occurred for engaging in individual or collaborative research on a S&T KLA topic. These findings were in keeping with those of Hackling et al. (2001) that primary teachers have only occasional PL opportunities for enhancing their teaching of science. As M2 said, *"we learn that* [science] *on our own ... the only PL that I have had was ... when we met the science advisor* [external to the school staff] *who went through the syllabus ... the content, outcomes and indicators"* (M2, teacher interview, March 30, 2015, 5.1.1). P1 corroborated this by commenting that *"not much* [PL was] *offered in the science KLA. ... more focus* [was] *on the literacy and numeracy areas"* (teacher interview, April 13, 2015, 5.3.10).

Out of ten teachers who attended courses or workshops, six found them to have had a large impact on their development as teachers (Tables 4.22 and 4.23). Of these 10 teachers, 8 were metropolitan teachers. Only six metropolitan teachers attended any relevant education conferences or seminars and, of these, four teachers found them to have had only a small impact. Table 4.22 shows that, for teacher engagement in other

PL activities such as (e) - teacher networking (specifically for the S&T KLA) - and/or (f) - participation in individual or collaborative research on a relevant topic - metropolitan teachers' participation rates were again higher than those of their provincial counterparts. More specifically, for activity (e), five metropolitan teachers attended compared to one provincial teacher. For activity (f), there were 10 metropolitan attendances compared to 4 for the provincial group of teachers. This imbalance might be attributable to provincial teachers needing to travel large distances, and incur travel costs. Often this could be compounded by cost(s) of the course(s). In relation to the costs of provincial teachers attending PL activities, of the nine provincial teachers who attended formal PL courses, the attendance of six teachers was partially subsidised by their schools. Two teachers reported that they covered their own costs of attending their PL courses. In some instances, the availability of technological links - such as, video conferencing and 'Skype' - has the potential to reduce costs for PL.

During her interview, P1 commented that *"not much* [was] *offered in the science KLA especially to teachers in remote country areas.* [There was] *more focus on the literacy and numeracy areas"* and *"*[it's] *too expensive to go to a short course in a metropolitan area - travel and accommodation costs add up"*(teacher interview, April 13, 2015, 5.3.2b). For some of the provincial teachers, their apparent lower attendance could be because of their schools' priorities. For example, P2 pointed out that he had attended a course over a six-month period during the previous year that focussed on improving comprehension. During 2015 "… *we are working on writing, … that's the school focus"* (teacher interview, June 5, 2015, 5.3.1). P4's comments agreed with those of the other provincial interviewees: *"I've never been to any formal in-service for science at all … there is a bit of a disadvantage living in a country area because the* [science] *courses seem to be pretty thin on the ground and it's expensive to get to them in metropolitan areas"* (teacher interview, June 7, 2015, 5.3.2a & b). Four provincial teachers participated in observational visits to other schools - compared with two metropolitan teachers - and these visits were rated as having had a large impact.

A large proportion of the Phase II survey questions relating to PL was directly based on the 2007/08 TALIS Survey (OECD, 2009) conducted with teachers of lower-

secondary classes (which would approximate Stage 4 in NSW as described in the Research Methods chapter). As the TALIS survey questions were not subject-specific and some were modified for the Phase II survey to directly target the S&T KLA, a broad comparison can be made on some relevant points between the 2013 TALIS findings published for the Australian cohort and my research findings.

Across all areas in which PL was offered in the form of courses/workshops, Australian teachers had a high participation rate of 86% (OECD, 2014). This percentage was considerably higher than the 25% of Stage 3 teachers who attended courses/workshops related to the S&T KLA in this research. Similarly, attendance at education conferences or seminars was, again, higher in the broader Australian cohort at 56% (OECD, 2014) in comparison with this study's Stage 3 teachers' attendance of 15%. Similar rates of participation of 51% were reported for Australian teachers' networks (OECD, 2014) in contrast with the Stage 3 teachers' lower participation rate of 15% in my study. A metropolitan teacher outlined how attending network meetings could be of benefit by explaining that, after science consultants had given to teachers samples of work from a number of schools to adapt to their own classes, successive network meetings had been scheduled with the consultants to develop *"a scope and sequence for the school ... and then following-up by teaching us how to write units and really looking more deeply into the content"* (M3, teacher interview, April 13, 2015 5.1.3a). Again using data from the OECD (2014) report, participation of Australian teachers in individual or collaborative research (37%) compared with the Stage 3 teachers was quite similar (35%). Similarly, the Australian numbers participating in observational visits to other schools was the same as for Stage 3 teachers (15%).

With the exception of the last two modes of PL, in which the Stage 3 teachers had comparable attendance to the broader Australian cohort, the participation rates of the Stage 3 teachers were below those of the broader Australian cohort. Some of the reasons which could account for these lower-attendance patterns in my study, as mentioned in previous sections, include the somewhat critical lack of appropriate science-related PL activities on offer to teachers, the travel distances involved for provincial teachers and the associated time commitment and costs, and the primary schools' priorities which might have dictated which PL activities the teachers were

permitted - or were paid - to attend. Many teachers were not able to avail themselves of more opportunities to attend science-related, formally organised PL activities even though a substantial number of them identified that they needed PL to enhance their science content knowledge.

With respect to other forms of PL, only one teacher was being mentored. This early-career teacher was from a provincial school and identified this collaboration as a resource for enhancing science content knowledge (Table 4.17). Additionally, eight metropolitan and one provincial teacher participated in mentoring other teachers. In their study of a mentoring programme for new teachers of science and mathematics, Bradley-Levine, Mosier and Lee (2016) note that "the most important qualities that novice teachers in this study sought in their mentor were content expertise and contextual knowledge" (p. 80). They also comment that their findings align with those of other researchers such as Smith and Ingersoll (2004) who additionally found that being mentored by a teacher with the same subject expertise correlated positively with the mentee's retention in the profession. "Mentoring appears to be a key for enhancing the knowledge and skills of primary teachers and this includes preservice teachers" (Hudson, 2007, p.1). Hudson (2007) also notes that Edwards and Collins (1996), Reiman and Thies-Sprinthall (1998) and Tomlinson (1995) made similar findings and stated that "identifying effective mentoring practices for teaching a specific subject may lead towards developing quality mentoring programs for learning how to teach this subject area [of primary science]" (Hudson, 2007, p. 2). The use of mentoring programmes might be of particular importance to provincial teachers who, for a number of reasons given above, had a relatively low participation rate in other formal forms of PL activities. Hudson (2007) also postulates that there may be reciprocal benefits for the mentors in being a part of a mentoring programme and this, in turn, might enhance their confidence in teaching the subject.

The low participation rate in PL is mirrored in other parts of Australia. For example, in its audit published in 2012, the Victorian Auditor-General reported that, excluding primary teachers' involvement with 'Teaching and Learning Coaches', as few as 1% of the primary teachers in that state took part in formal, science-related PL. The report notes that the amount of PL undertaken by the teachers was "demonstrably insufficient" (p. 31). As noted by Lowe and Appleton (2014), making science

content- and teaching-oriented PL available to primary teachers on their school campus - as well as direct assistance in the classroom for a period of time - did not seem to guarantee teacher participation in the PL and/or a transfer of knowledge. In their study, not all teachers attended the workshops provided by the visiting secondary science teacher. A part of the reported problem with the workshops, though, was that they were not ideal as the science teacher sometimes spoke 'over the heads' of the primary teachers and assumed that they had understood what was being said. Consequently, the primary teachers felt intimidated which ultimately hindered the success of the programme. This finding is consistent with the statement of Aubusson et al's. (2015) identification of a widespread lack of adequate - and appropriate - professional development throughout Australian education sectors.

Finally, the use of video conferences must not be discounted as a form of formal PL as they are organised by either providers who are external to the school or organised from within the school. As considered in the Research Methods chapter, these conference sessions were included in the human resources table (Table 4.17) rather than the ICT-based resources table (Table 4.16). Video conferencing was only referred to by provincial teachers - with 11 mentions in Table 4.17 - although, at the time of the research, it was available to teachers across the state. Specifically, although the 'DART' resources were available to all teachers, those in metropolitan areas didn't use them. This could be for several reasons. Firstly, the resource is labelled as a 'distance' and 'rural' resource so the metropolitan teachers might not have been aware of it; or, secondly, teachers might not have considered that the resources could be put to good use in the metropolitan context. Thirdly, the resources on offer might be readily accessed in real time in most metropolitan areas and, therefore, be considered as a better option. The provincial teachers also mentioned video conferences twice as having been used to connect with 'other smaller schools' and an outside agency (e.g., 'Questacon'). Making use of available human resources - in the formal sense as considered here - appeared to have been recognised as being of more benefit to the provincial teachers in this study than to those in metropolitan schools.

5.5.3 Engagement in Less-formal PL Activities

In Morgan's study into teachers' feelings of well-being and competence to teach science in the primary school setting, the Australian metropolitan school involved engaged a science co-ordinator. This teacher's function was, among other things, to "provide science information to the staff … organise professional learning … and to model science teaching practice" (2012, p. 81). All of the teachers in this study indicated that they would like more discussion at school which was specifically on science. Science was included in the staff meeting agendas twice each term, but teachers still indicated that they wanted "to engage with each other in dedicated science teaching professional learning (for science teaching discussion), to improve their … content skills, and to build confidence to teach science" (p. 82). For the purpose of this study, this type of teacher engagement is an example of PL which spans the border between 'formal' and 'less-formal' PL activities. That is, to the extent that the teacher-discussions were organised at the school level, they were formal and, when they occurred incidentally as subject-related dialogue with colleagues rather than because they were organised, they were less-formal. Another example of less-formal PL noted in an earlier chapter is reading professional literature.

The relatively large number of 35 teachers (= 88% of the total group) reported that they engaged in informal discussions with their colleagues on how to improve their teaching for the S&T KLA. Seventeen and 11 teachers claimed that such activities had either a moderate impact or a large impact, respectively, on their development as teachers (Tables 4.20 and 4.21). With only 18 teachers (= 45%) engaging in the reading of professional literature, 10 of these teachers found that it had moderate impact or large impact. When these statistics were broken down for metropolitan and provincial groups (Table 4.22), 24 teachers (= 83%) of the metropolitan group each participated in informal dialogue to improve their S&T teaching compared with the provincial group, in which all participated to some extent. Similarly, 12 (= 41%) of the metropolitan teachers engaged in professional reading of different types compared to six (= 54%) of their provincial counterparts. These statistics might be a reflection of the provincial teachers using these forms of PL to compensate for their diminished access to more formal PL activities compared with their metropolitan

counterparts. Perhaps they rely more heavily upon their interactions with other colleagues out of necessity because they can't attend more formal PL activities as metropolitan teachers do? Quotes from several provincial interviewees were noted in the previous section in reference to their attendance at science PL. P4 noted that *"we do share information between us* [i.e., the other Stage 3 teachers] *at school"* (teacher interview, June 7, 2015, 5.2.1). P5 echoed the comments of the other provincial teachers interviewed. When asked about professional leaning opportunities in his regional area, he also added that, in the town, *"there was very much a push from the primary schools and to share things and build-up partnerships with the secondary schools and the primary schools"* (teacher interview, August 8, 2015, 5.1.3c). As reported above, though, the partnerships didn't really gain any lasting momentum, although the primary schools were hoping for some assistance from the secondary school's science staff.

Within the interview group, the experiences of PL were similar to those of the total cohort with only three teachers attending formal PL organised by external providers and three participating in informal PL modes. However, engagement in some of the less-formal PL modes discussed was fairly limited. For example, P4 related that the Stage 3 teachers *"do share information between us at school"* (teacher interview, May 7, 2015 5.2.1) and M5 stated that he didn't *"get to any PL but we do try to work collegially"* (teacher interview, May 12, 2015, 5.2.6) within the school and with some other teachers in the local area. However, collaborating with fellow teachers might not necessarily result in success. This was highlighted during an interview with M2 who commented, *"coming up with the activities. For someone like me with science, I just find it hard. ... I think where do I start??? [My Stage 3 partner and I] ... sometimes just sit there and look at each other and say "ok, what do we do now?"* (teacher interview, May 12, 2015, 5.2.3). The importance of support from colleagues, which makes a positive contribution to the enhancement of science content knowledge, has been demonstrated by Anderson's research (2015). Interviewee P5's brief discussion of what proved to be a discontinued partnership between the local, provincial high school teachers and other local primary schools in the context of a potential science-related PL opportunity has been reported above. Consistent with the above findings, the remaining four provincial teachers interviewed considered that they had participated in the less-formal forms of PL such as professional dialogues

and reading. Fantilli and Dougall (2009) note that this type of less-formal PL is "vital [to early-career teachers] in easing their transition to teaching" (p. 17). I would further content that it is also important to provincial teachers in the Australian context given the difficulties associated with attending organised PL (as discussed in another section) and that Australian provincial schools often have small numbers of teaching staff.

As noted earlier, Table 4.17 lists forms of human resources - collaborations with others - as nominated by the teachers in the survey's section relating to resources used to enhance science content knowledge. Suggestions made in the surveys included working collaboratively and sharing ideas with other Stage 3 teachers; collaboration with secondary science teachers or teachers with a science background; and team teaching to assist another teacher to gain confidence in teaching science. While these forms of human resources were considered by the teachers who nominated them as resources in their own right, they also fit into the previously-discussed less-formal PL as identified in Table 4.20, the interviews and the above discussion. Getting assistance from professionals/scientists was also listed in Table 4.17 as a resource and is also a form of less-formal PL. This is discussed in a later section in relation to ways in which teachers can be assisted to enhance their science content knowledge, especially in relation to the CSIRO's Scientists and Mathematicians in Schools programme.

5.5.4 Factors Affecting Attendance at Formal PL Activities

The main factors, previously mentioned, which affected the attendance of teachers at PL activities of any category are now considered. When the formal PL activities in Table 4.20 were further categorised (Table 4.24) and analysed in terms of the number of teachers participating, only 12 teachers participated in both Category I (courses and activities organised by an external provider) and Category II (those formally organised at the school level). For the 18 Category I PL opportunities documented by the teachers, 10 (= 56%) where reported by them to have been of only moderate to no impact. Similarly, for the 36 Category II PL opportunities documented, 27 (= 64%) of the activities were reported as having a moderate to small impact. The importance

of teachers having access to PL activities which are of maximum benefit and meet their needs is addressed below.

Nine teachers spent 30 full days in participating in PL activities with both metropolitan and provincial groups accounting for 15 days each. However, within the metropolitan teacher group, these 15 days were shared among just six teachers. One teacher attended three compulsory days and another attended one compulsory day. Within the provincial group of teachers, only three teachers accounted for the 15 days of PL activities, with one taking 7 days and another 5 days - none of which was deemed compulsory by the schools.

Fifty two percent of the metropolitan and 78% of the provincial teachers - that is, 58% of the total cohort - responded that they wished to participate in more PL than they had. Table 4.25 shows that the most common reasons given were that, firstly, the cost was too high for either the teachers or their schools - 56% metropolitan and 72% provincial (= 62% overall). For example, P1 noted in the interview that, for provincial teachers, "*it is too expensive to go to a short course in a metropolitan area - travel and accommodation costs add up*"(teacher interview, April 13, 2015, 5.3.2b). Secondly, there was also a lack of suitable science-related PL on offer - 56% of the metropolitan and 71% of the provincial (= 61% overall); and thirdly, the timing of the PL often conflicted with their work schedules - 50% metropolitan and 29% provincial (= 44% overall). "*There are too many time constraints*" (M2, teacher interview, March 30, 2015, 5.3.6).

Some of the overall findings of the 2007/2008 TALIS Survey (OECD, 2009) are similar to those of this research. For example, the types of PL that the majority of teachers considered most effective had, on average, the lowest participation rates; conflicts with work times and work loads were the main reasons for non-participation in PL in the TALIS survey. This was reflected, to some degree, in this study with NSW Stage 3 teachers. A lack of appropriate PL opportunities was a big factor in non-attendance, and a number of teachers noted that they did not get enough PL opportunities to satisfy their needs. The findings of the 2007/2008 TALIS Survey suggested that there is "a need not just for better support for teachers to participate in professional development, but for policy makers and school leaders to ensure that the

development opportunities available are effective and meet teachers' needs" (OECD, 2009, p. 48). The findings of this research suggest that this important need had not been met at the time when my research was undertaken.

As noted in the Research Methods chapter, a systematic search was conducted across external professional learning providers for courses/activities which were appropriate for Stage 3 teachers and teaching the S&T KLA. One service provider of PL directly related to the NSW curriculum science content, 'Michael' (personal communication, February 15, 2015) had found that, over a period of about 5 years up to the end of 2015, individual primary teachers tended not to attend the company's science PL courses. Therefore, the PL had to be taken to the primary schools and it gradually evolved to become more focused on the provider running activities for the students at the school with little or no transfer of knowledge or skills to the teachers. (In accordance with ethics criteria, a pseudonym has been used here as the provider wished to remain anonymous.) This observation was corroborated through a statement by CEO and Education Manager at Teacher Training Australia (TTA) Pty. Ltd. - Liz Germani - who commented that the company had, in the past, offered a course designed to assist NSW primary school teachers to enhance their science content knowledge. However, the company's science PL for primary teachers "has not run recently as the pattern of attendance for primary teachers is the most influential factor" (personal communication, September 18, 2014). The company's experience was that many primary teachers seemed to "like to do group PD where everyone is being up-skilled at the same time and do not, therefore, attend the company's face-to-face workshops or participate in the online individual-based courses" (personal communication, September 18, 2014). One case in point was an online, Australia-wide TTA course run over a number of weeks in 2014 - in which the researcher was enrolled - and which related to teaching the 'new' science Australian Curriculum. While this course was open to all primary teachers across NSW, only seven primary teachers enrolled in this relatively inexpensive, online course.

The BOSTES NSW (Board of Studies Teaching and Educational Standards, NSW - formerly known as the BOS NSW and referred to in several chapters) Teacher Accreditation site (http://www.nswteachers.nsw.edu.au/) was surveyed for any

science-based PL courses for primary teachers. This site listed BOSTES NSW-approved science related PL/PD courses and programmes available to primary teachers for accreditation at the Proficient Level from the beginning of 2014 to June, 2016. The survey revealed 9, 15 and 11 courses/programmes, respectively, for those years (http://www.nswteachers.nsw.edu.au/). Some of these, though, were the same courses repeated several times at different venues. The course durations varied between 1 hour and a 3-day course of 5 hours per day. In total, 35 opportunities for science PL were offered over the 3-year period. Education institutions, government bodies and teacher organisations and one private company ran 27 of these courses. The education institutions and government bodies included universities, The Australian Nuclear Science and Technology Organisation (ANSTO) and the Australian Academy of Science (Primary Connections). The governing body of one major school sector provided the remaining eight courses. The majority, or 29 of the 35 courses offered, was only available in metropolitan areas. In accordance with the above discussion, this would have been a major impediment to provincial teachers' attendance and limited to the opportunities that they had to improve their science content knowledge.

Some schools had already prioritised their teachers' PL opportunities leading up to the introduction of the Australian National Curriculum. Science-related PL did not appear to be a priority in the experiences of the interviewees. M4 stated that teachers couldn't juggle too much PL at once and that the school had initially prioritised attendance for English and mathematics PL. However, this teacher was hopeful that "*things might be changing*" (teacher interview, April 21, 2015, 5.3.8) in science's favour. Another interviewee, P5, commented similarly that '*the new curriculum has just started, so we haven't really done anything in science at all actually. … We had a bit of training on English and a bit on maths but nothing yet to go with the others. … I don't think we will get much support to implement* [the science curriculum]" (teacher interview, May 8, 2015, 5.3.8).

The literature provides evidence that, for a range of reasons, many primary teachers do not avail themselves of opportunities to engage in PL activities. Skamp (1991) notes that, for recently graduated teachers, PL contributed only a very small proportion (5 - 14%) towards the teachers' science base knowledge: the teachers

were not engaging in appropriate science-based PL opportunities. However, attending PL has been shown to be beneficial for teachers' learning. It was reported by Schibeci and Hickey (1996), that primary teachers showed an increase in their science content knowledge after attending a course designed to enhance their science teaching self-efficacy. Smith's (2015) research supports this finding through his study in Ireland. This study showed that professional development can positively impact a teacher's learning but that there was a lack of appropriate PL for pre- and in-service primary teachers. In New Zealand, Anderson's (2015) findings echo this. Koul (2010), Loughland and Nguyen (2016), Lowe and Appleton (2014) and Peers (2007) refer to the positive benefits of primary teachers having PL opportunities. For example, research into the use of 'Primary Connections' (Peer, 2005; Tytler, 2007) and Western Australia's 'Primary Science Project' (Koul, 2010) demonstrated that the implementation and use of these programmes provided beneficial PL for the teachers involved. Regarding her involvement with the trialling of the 'Primary Connections' project, M1 commented that *"science PL is not available very often ... I was quite involved in* [the trial in my school of] *'Primary Connections' ... we had lots of professional support ... it was a wonderful opportunity"* (teacher interview, March 26, 2015, 8.4.1c).

Recently in Australia, the 2014 ASTA & OCS survey further confirms that, while the primary teachers surveyed demonstrated high levels of interest in attending PL, the costs and time commitment involved attending were often high. This is especially the case for those who need to travel long distances from provincial areas. These observations are supported by the provincial teachers interviewed - as noted above. Part-time or contracted teachers, who often work for many years under this type of employment - and often in the same school - frequently miss out on the benefits of attending formal PL courses for financial reasons or because of the school's philosophy towards teachers who aren't employed on a permanent, full-time basis. When interviewed, M5 raised these points by commenting that *"because I'm not a full-time teacher, I don't have access to the PL that most other teachers have and they don't have the money to spend on us"* (teacher interview, May 12, 2015, 5.3.7). The principal's stance on these teachers attending PL opportunities can sometimes work in their favour if the principal holds a 'big picture' approach and values the

contributions made by long-term contracted teachers to the education of a school's students.

The principal can be very influential in curriculum development and implementation and, as Anderson noted, principals' personal involvement and support can directly influence positive teacher progress when they "proactively engaged their staff and external resources in a collective sustained implementation effort" (2002, p.360). In 2001, Garet, Porter, Desimone, Birman and Yoon stated that "professional development is likely to be of higher quality if it is both sustained over time and involved a substantial number of hours" (p. 933). Ingvarson, Meiers and Beavis (2005) advise that school policy makers need to keep this in mind and give due consideration to establishing conditions for schools which are conducive to providing PL that is continuous and frequent so that teachers are able to derive maximum benefit. "The lack of resources and the limited time to attend workshops because of their classroom responsibilities do not help [teachers] to meet [their] career-long professional needs" (Guemide & Benachaiba, 2012, p. 34). Added to those constraints are also family and other commitments that many teachers must juggle throughout their teaching careers. The use of ICT-based resources potentially can provide accessible means through which content knowledge can be enhanced.

5.6 Research Qn. 4 - What ICT-based and Other Science Resources are Available to and/or Used by Both Metropolitan and Provincial NSW Stage 3 Teachers to Supplement Their Science Content Knowledge?

5.6.1 How Teachers Rated Their School's Science Resources

The many factors which might influence the teaching of a subject - such as those mentioned above - include the availability of a suitable range of resources both for teachers' use to find information relevant to their teaching and material resources for use in the classroom. The successful implementation of a science curriculum is dependent, in part, on the availability of resources which are specific to the topics to be taught. A lack of such resources might act to discourage the teaching of certain topics. Idris, Cheong, Nor, Razak and Saad (2007) and Aubusson et al., (2015)

identify the lack of resources among a number of challenges to primary science teaching. Lowe and Appleton also found that the teachers participating in their study "viewed the implementation of the ... science curriculum as being equivalent to selecting and teaching suitable activities from the resources provided" (2014, p. 18). In her interview, M1 commented on the problem of equipment in primary schools: *"We bought new equipment - which is key to* [teaching] *any science curriculum. In most of the schools I've been in, we never had enough equipment for the science curriculum"* (teacher interview, March 26, 2015, 8.1.1e).

The majority of the teachers reported that the resources for science teaching in the school were 'OK'. Although the ratings were arbitrary and subjective, they gave an indication of what resources teachers had to assist them with their science content knowledge and for planning lessons. If resources were considered to be 'poor' or 'OK', then perhaps teachers might not maximise their use or even to use them at all. Some of the interviewees - for example M4 and P1, among others - reflected on their frustration over a lack of equipment, the expense involved in purchasing and maintaining the equipment, and lack of storage for the equipment (teacher interviews, April 21, 2015, & April 13, 2015 respectively, 8.1.1a & b). This was in contrast to the enthusiasm with which one of the teachers participating in this study described her metropolitan school's science reference and teaching resources (name withheld, personal communication 12 September, 2013). This enthusiasm, and that of her fellow teachers - who also took part in a previously mentioned introductory discussion with the researcher - for using all of the carefully-chosen and well-maintained resources was inspired by her principal. These resources were for the purpose of enhancing the science content knowledge of all of staff at the primary school, for lesson preparation and for use in the classroom. This school's staff provided an excellent example of top-down leadership, policy- and goal-setting by the principal and of the executive member overseeing science curriculum implementation and providing the necessary materials.

5.6.2 Teacher's Science Content Knowledge and Their Use of Resources

The data - and percentages where shown to highlight proportions - collected through

the surveys showed that, within the metropolitan group, 21 teachers (= 72%) felt the need to supplement their science content knowledge but, of these, 16 teachers (= 55%) used resources and the remaining 5 teachers (= 17%) did not access resources of any kind to achieve this. However, one of these teachers did comment that their accessing of resources was dependent upon the topic that was being taught. The eight teachers who felt that they did not need to supplement their content knowledge at all, nevertheless, continued to use resources for this purpose.

Similar to metropolitan teachers, the majority of 13 provincial teachers (= 72%) acknowledged a need to supplement their science content knowledge and used a variety of resources to achieve this. Of the further five teachers (= 28%), two continued to use resources to add to their existing knowledge while one teacher felt no pressing need to do so because the school's RFF teacher often taught the S&T lessons. P4 noted that, at his previous school, *"the RFF teacher taught the science. ... there was one topic per term"* (teacher interview, May 7, 2015, 9.6.2). Perhaps the presence of an RFF teacher in a school could have a negative impact on the Stage 3 teachers' needs to hone their science content knowledge because they don't need to actually teach science for long periods at a time. Several interviewees reported on the impact of having RFFs in their school. For example, P5 commented *"over the past 5 or 6 years, science has been taught by the RFF teachers as its an easy stand-alone subject"* (teacher interview, May 8, 2015, 9.6.2). This teacher had only just been required to start teaching science again after many years, and the RFF teachers had been given other KLAs to teach because of a shift in the school's priorities. As noted earlier, M3 commented on being in a similar situation as his school's *"RFF has been teaching science* [for a number of years]. *It* [science] *gets palmed off a bit!* (teacher interview, April 13, 2015, 8.6.1) so there was not much need for the classroom teachers either to teach the S&T KLA or to consolidate or enhance their science content knowledge. Teacher P1 did concede that the newer curriculum, which has a greater emphasis on inquiry-based learning, might take some pressure off teachers to have a deeper science content knowledge: *"using the inquiry method takes a bit of pressure off the teacher needing a deep science content knowledge"* (teacher interview, April 13, 2015, 3.1.2). This comment implied that some teachers might feel less obliged to enhance their science content knowledge if the students are learning more of the content themselves through inquiry learning.

Tables 4.15 and 4.16 show, respectively, teachers' uses of print and online ICT-based resources to enhance their science content knowledge. There was quite a large difference between metropolitan and provincial teachers' use of printed resources, with the former group indicating that it made far greater use of these resources than the latter group - 34 mentions compared with 10. The use of 'Primary Connections' material dominated the number of mentions for resources used in the print category for both groups of teachers - metropolitan teachers made 17 mentions (= 50%) and 2 mentions were made by provincial teachers (= 20%). The 'Primary Connections' material also received the most specifically cited mentions for the use of online (ICT-based) resources (mentioned by 17 teachers). There were 55 mentions of general (i.e., not specifically named) sites made by metropolitan teachers. The same online resources received more mentions among the provincial teachers: 'Primary Connections' online was mentioned 3 times (n= 26) and general online sites were given 13 mentions. *"I use 'Primary Connections' and things like that the most. As well as using the resources that the teachers next door will have used because they will have done it before me. We are pretty good at sharing things* [resources] *at school"*, commented P5 (teacher interview, May 8, 2015, 6.6.1c).

There may, however, be a shift away from the use of 'Primary Connections' with the introduction of the Australian National Curriculum. Some pertinent comments relating to this were made during the interviews. For example, *"we rely on 'Primary Connections' ... I haven't gone right into how well it fits the new curriculum because we already have the scope and sequence to fit into"* (P2, teacher interview, May 5, 2015, 8.4.2) and "['Primary Connections'] *was a wonderful opportunity actually. It is now being shuffled around to fit the new Australian Curriculum and that never works"* (M1, teacher interview, March 26, 2015, 8.4.1). While the dedicated 'Primary Connections' FAQ (Frequently Asked Questions) factsheet points out that each 'Primary Connections' unit had recently been aligned with the Australian Curriculum: Science (Australian Academy of Science, 2016) this teacher might not have seen or been satisfied with the updated resources. At another school, the teachers had attempted their own alignment with the older 'Primary Connections' units which is not recommended in the 'Primary Connections' literature - *"we looked at the 'Primary Connections' units that we had. We looked at the units in our*

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scope and sequence over a two year cycle and tried to match up the outcomes and the content with what we had with the PC units" (M3, teacher interview, April 13, 2015 8.4.1). The use of ICT-based online science resources is discussed at length in a later section.

The 'use' of human resources - that is, collaboration with others (Table 4.17) - received fewer mentions (i.e., 41 mentions) compared with the use of online resources. The survey data showed 14 mentions made by metropolitan and 27 mentions by provincial teachers, perhaps because metropolitan teachers did not think that they benefitted from these types of collaborations with others compared with the provincial teachers. It might also suggest that ICT-based resources might figure more prominently in the lives of metropolitan teachers simply because they are more readily accessible in their areas?

Working collaboratively and sharing ideas with fellow Stage 3 teachers figured prominently in both groups, with the metropolitan group registering 6 of 14 mentions (= 42%) and the provincial group proportionately higher at 9 mentions in 27 (= 33%). Metropolitan teachers made three mentions of swapping classes to allow one teacher to teach science to another class as a viable way of assisting those teachers who are under-confident in their science teaching. It might have been an avoidance measure, or a short-term solution, for under-confident teachers. However, three of the six metropolitan staff mentioning collaboration worked together at the same school, and one of these teachers had an undergraduate degree in biology. Although not employed as a specialist teacher, this teacher had team-taught with the classroom teachers, assisted with lesson planning and guidance, and clarified the science content when necessary. Therefore, considering that three teachers represented collaboration at one school, the data suggests a diminished degree of collaboration of this kind for four rather than six schools. Collaborating with other Stage 3 teachers and sharing ideas seemed to be of greater importance for the provincial teachers who did not attend as many PL courses and therefore relied on co-operating with other teachers to compensate.

This pattern might also account for 11 (= 65%) of the provincial teachers' mentions of the use of 'DART Connections' video conferencing - which provides virtual

excursions and gives teachers and students direct access to experts in various fields of science - to supplement their science content knowledge. The place of video conferencing in the 'human resources' category was discussed in the Results chapter. No metropolitan teacher mentioned using 'DART Connections', although it is available to all schools across the state of NSW. In contrast, while both groups mentioned team-teaching to assist another teacher to gain confidence in teaching science, this form of collaboration had far fewer mentions than did working collaboratively and sharing ideas; as it was mentioned only once by a teacher from each group.

In summary, a large percentage of participating teachers acknowledged that they had some need to supplement their science content knowledge. This is consistent with the literature (Gees-Newsome, 1999; Fitzgerald, Dawson & Hackling, 2013). Metropolitan teachers reported that they used printed resources more than their provincial counterparts. The 'Primary Connections' resources, in both the print and online formats, rated many mentions across both groups. Overall, however, there were more mentions in total of the usage of online ICT-based resources (68) than of printed resource materials (44), human resources (41) and other kinds of resources (16). The use of human resources was noted by both groups but was mentioned more frequently by provincial teachers who reported a greater use of instances of interactions with other people than did their metropolitan counterparts. The provincial cohort mentioned the importance of working collaboratively with others featured and the use of the 'DART Connections' video conferencing resources.

5.6.3 Device Access and Searching for Science Content

It has already been established that, for my research into whether teachers were using ICT-based resources to assist them with enhancing their science content knowledge, contextual and other influences needed to be investigated. For information access to ICT-based resources, teachers need access to electronically reliable devices and reliable internet services. It was necessary, therefore, to consider teachers' access to electronic devices such as computers and tablets which enable searching for science content. 'Smartphones' could also be used to search for science content.

Anshari, Alas, Hardaker, Jaidin, Smith, and Ahad (2016) and Reese Bomhold (2013) provide two examples of research on the use of smartphones to search for academic information that revealed no impediment to learning. The former group found that, within a sample of 589 people representing a wide spread of ages and backgrounds, online learning activity was recorded by 59% of the participants. However, the researchers note that this result "was unsurprising, as 60% of respondents were students" (p. 723). The latter researcher found that 76% of his research group of 62 students - the majority of whom were between the ages of 18 and 24 years - used smartphone applications to find "academic information" (p. 430). In my research no teacher mentioned in either the surveys or interviews that they used their smartphones to find science content knowledge. This could have been for any number of reasons, including smartphone screen-size, the nature of the information research, little or unreliable Wi-Fi, or the participants' socio-economic status. The type of device used by the teachers was not important as long as it was reliable, and met the teachers' needs to carry out searching for content when required.

Overall, device use was not a major problem for metropolitan teachers, with 28 of the 29 teachers, claiming no access problems. For metropolitan teachers, their major hindrances were typical for urban technology users - network issues, internet speeds

and maintenance issues. For a few, computers shared with other staff and/or students were not always available when needed at school. Within the provincial group, only ,one teacher owned a device for use at home and at school, and the rest either shared with other staff and/or students. Of the total provincial group, four teachers had no access problems but six did experience access issues because of needing to share devices within their school/staffroom. In some provincial regions, the internet was either too unreliable or too slow for the teachers to have reasonable access either at home or at school. No teacher reported having access difficulties both at home and at school.

Using the data provided in the Results chapter, 12 teachers (= 26%) of the total group had a preference for carrying out their searching at school. Although each of these groups constituted a small sample, proportionately, the interviewees' data were

similar. Within this group, two teachers (= 20%) had a preference for searching at school and one had no preference either way. The interview data also supported the reasons given for these preferences. For example, *"I really don't have time to do that type of research at school"* (M5, teacher interview, May 12, 2015, 7.1.1), half of the interviewees cited no time at school as a major factor; and *"I have time to sit there* [at home] *and read it and go 'oh yeah' and understand it"* (M2, teacher interview, March 30, 2015, 7.1.3).

Notwithstanding their actual preferences for where to conduct searching for information to enhance their science content knowledge, metropolitan teachers spent less time per week at home, on average, in this pursuit than their provincial counterparts. Some of the reasons cited for this during the interviews were exemplified by the following quotes: *"I have better resources at home and a better computer too"* (P5, teacher interview, May 8, 2015, 7.1.4); *It's more convenient at home. There's not enough time to do it at work"* (P3, teacher interview, May 6, 2015, 7.1.2); and, *"more time to surf the web there. My internet ... is probably better than at school"* (P4, teacher interview, May 7, 2015, 7.1.4).

Within the metropolitan teacher group of 29 teachers, 8 teachers (= 28%) spent less than half an hour per week and 11 teachers (= 39%) spent between 0.5 and 1 hour information searching. This is in contrast to the provincial group, in which 6 teachers (= 34%) searched for information for 0.5 to 1 hour and 8 teachers (= 44%) searched around 1 to 2 hours (Table 4.26). That more provincial teachers were spending more time searching for science content at home was in keeping with the data discussed earlier in this chapter in relation to teachers' engagement in formal PL activities. This showed that, although 13 teachers from across both groups felt the need to enhance their science content knowledge and also preferred to do their searching at home, a lesser percentage of metropolitan teachers - 19 teachers (= 65%) - actually used resources to do this and had a slightly lower preference to work at home. That more provincial teachers were searching at home was also possibly a reflection of the need to share devices at school and internet access being unreliable in some rural areas - although the latter can be a potential problem both at home and at school in some areas. For example, P2 commented *"the internet is pretty shocking at home"* (teacher interview, May 5, 2015, 7.2.2) and P1 that it *"all has to be done at school"*

because there was no internet access at home (teacher interview, April 13, 2015, 7.2.2): they were compelled to carry out any searching at school. The data from the 11 completed logs corroborated these findings. Three of the six metropolitan teachers spent all of their time searching through ICT-based science resources at home with an overall average across the six teachers of 65% of the time spent using such resources at teachers' homes. Similarly, for provincial teachers, three teachers spent all of their searching time at home with an average of 87% of all of these provincial teachers' searching time being spent at home.

Figure 5.1 graphically summarises the major factors affecting the use of ICT-based science resources for enhancing science content knowledge. Factors were added to the figure as they were suggested in the literature and/or the responses of the participants. Some factors were also added from my professional experience as an educator. One factor noted therein - which came to light through one participant - was some teachers' inability and unwillingness to engage with computers. For example, *"... when it comes to using the computer I have a phobia. I'm very good setting them up and having there what the children need but when it comes to actually using it for my own research I'm not that good"* (M1, teacher interview, March 26, 2015, 6.2.1). Consequently, this teacher did not use ICT-based science resources for enhancing science content knowledge in any way or at any time.

In summary, the main issues relating to device use were teachers' need to share devices at school and the persistent problems of unreliable internet connections and slow internet processor speeds. This latter problem was more prevalent in some provincial areas. The survey data revealed that the majority of the teachers had a preference for carrying out their searching for content at home. Notwithstanding this, the data from the logs completed by a sub-section of the participants showed that those metropolitan teachers spent more time than their provincial counterparts in searching for resources at home. Although there are no data in the literature on the aspect of my research of electronic log-keeping by metropolitan compared to provincial teachers, the ICT usage patters are consistent with issues raised in the literature in relation to ICT use (Bebell, Russell, and Dwyer; 2004), time availability to teachers (Bonk et al., 2014) and internet access in provincial areas (ABS, 2014).

5.7 Research Qn. 5 - How Often Do Teachers Explore Available ICT-based Science Resources for the Purpose of Enhancing Their Science Content Knowledge?

The internet "has moved education to a new era in the context of technology. The internet, above all, offers freedom to individuals … and can compliment his/her deficiencies in the way s/he wants since learning is individual" (David, Edwards & Aldred, 2001, cited in Akinoglu, 2009, p. 98). Akinoglu also mentions some of the benefits of using the internet that have been highlighted by other researchers such as Surratt, 2001; Turkle, 1995; and Webber and Dixon, 2007. These include the many and varied applications that it enables, delivering a "richness of information" (p. 98) and data, facilitating the transfer of information, and offering "free and unlimited access to information" (p. 98) that is up-to-date and drawn from a broad base of sources.

Rouet (2009) notes, in an editorial on learning through the use of ICT, that searching for information is one of "the fundamental components of learning" (p. 1012). This partially depends upon cognitive and metacognitive skills, which are "the learner's ability to identify a gap in his/her content knowledge base" (p. 1012) (See Figure 5.1). Therefore, one of the first steps for all teachers who need to enhance their content knowledge for any subject area - including those participating in my study - is to identify a gap in their knowledge. Most of the teachers in my study were quite experienced. In their interactions with the curriculum of each subject to plan their scope and sequence of teaching and learning for each subject, they would have encountered situations in which they identified some content knowledge which needed to be enhanced. Enhancing this knowledge would enable them to provide a richer learning experience for their students.

The identification of content knowledge gaps is part of a personal educational journey, and each teacher in this research would have identified his or her own knowledge gaps and where they existed at points in their scope and sequence planning. The question of whether or not teachers use ICT-based science resources to enhance their science content knowledge has been addressed in the previous section

of this discussion. Other studies have confirmed that teachers' use of ICTs, for their own study in countries outside of Australia, ultimately assisted in increasing confidence to teach in areas of specialisation (e.g., Mwalongo, 2011).

How often teachers might turn to ICT-based resources could also be related to the size of the identified knowledge gap and their levels of curiosity and concomitant exploratory behaviours (Litman et al., 2005). Litman et al. (2005) also found that personality traits can, to some extent, influence curiosity and exploratory behaviours - thus adding another layer of complication. Some of these behaviours also are accompanied by sets of emotions such as the tension and feelings of uncertainty which reportedly accompany the identification of a 'tip-of-the-tongue' style of knowledge gap. Therefore, depending on the size of the identified gap, these constructs and emotions might ultimately influence the number of times or the time over which a teacher might be prepared to spend searching for content knowledge using ICTs.

Specific self-efficacies also play a part in influencing the patterns of ICT use by teachers. Andreassen and Bråten (2013) recognise that several types of specific self-efficacy impact on a learners' use of the internet. They acknowledge that "Internet Self-efficacy" (p. 822) was known before their particular research into source evaluation self-efficacy (i.e., another variant of self-efficacy). Internet self-efficacy has been shown to be a predictor of learning behaviours using internet technologies (Andreassen & Bråten, 2013). In the theoretical background to her research, Karaseva (2016) summarises the research carried-out prior to hers, making several important points which are reflected in the results of my research. Firstly, Karaseva cites Perrault's (2007) finding that teachers' motivation to find information through online sources is decreased as a result of unfruitful searches. Secondly, she notes that Carlson and Reidy (2004) found that, as a result of this, teachers have a general tendency to just search for information on a few educational sites that have been specifically designed for the teaching of a particular subject discipline. Finally, Karaseva summarises Korobili, Malliari, Daniilidou and Christodoulou's (2012) findings reinforcing that teachers tend to stick to a limited number of educational sites designed specifically for particular subject teaching (also citing Carlson & Reidy, 2004 on this point) or give preference to information sources in print format.

These patterns are consistent with my research, particularly in relation to the 'Primary Connection's' ICT- and print-based resources. In this case, there were several more mentions made by the teachers that they used the printed form of this resource a little more frequently than the online version.

Teachers are able to use their source evaluation self-efficacy beliefs to evaluate what websites have to offer and who/what organisation produced them. These factors are taken into account when judging the website's trustworthiness (i.e., are they 'reliable' sites?) and the teachers' ability to do this can be predicted, to some degree, by their source evaluation self-efficacy (Andreassen & Bråten, 2013). It is also reported by these researchers that the effective use of a teacher's internet and source evaluation self-efficacies have been found to be related to the teacher's level of content knowledge. Therefore, if the teachers' content knowledge is relatively poor, then it is possible that they might become caught in a 'Catch 22' situation because of the intricate interplay of the level of their content knowledge, their science teaching, internet and source evaluation self-efficacies, curiosity and related exploratory behaviours, and the emotions that accompany them. Finally, Andreassen and Bråten also suggest that "efforts to optimise users' beliefs in their capability to evaluate the trustworthiness of internet-based sources may have positive consequences for their ability to do so" (2013, p. 833). If teachers are using ICT-based resources to enhance their science content knowledge, then how often are they doing this?

5.7.1 Discussion of the Data from the Surveys, Logs and Interviews

To reiterate the findings discussed above, within the metropolitan group, 21 teachers (= 72%) needed to supplement their science content knowledge. However, of these, four did not use resources at any time and one teacher commented that his/her use was dependent on the science topic being taught. The remaining eight metropolitan teachers who did not feel a pressing need still continued to use resources. These patterns were again mirrored by the provincial group in which 13 teachers (= 72%) acknowledged the need to supplement their science content knowledge and used a variety of resources to do so. Similarly to the metropolitan group, two provincial teachers did not feel a pressing need but continued to use resources to supplement

their existing knowledge.

The ICT-based science resources used by participants, and included in the surveys, are shown in Table 4.16. The metropolitan teachers made 57 mentions of preferred online resource searching and the provincial teachers made 26 mentions. As previously noted, the 'Primary Connections' online resources were the most frequently noted specific resource with 17 metropolitan and 5 provincial mentions. M2 made a comment on supplementing their science content in 'Primary Connections': *"Our school is using 'Primary Connections' at the moment. We just download it online. I think it's well set-up ... but I still prefer to do the research myself"* (teacher interview, March 30, 2015, 6.1.1h).

Unspecified internet search engines and 'YouTube' searches (mentioned 10 and 4 times by the metropolitan and 4 and 1 times by provincial teachers, respectively) and general teaching and 'how to make things' sites (which were each mentioned once by provincial teachers only) were all reported. Interviewee M2 declared that *"I definitely use a lot of 'YouTube' sites ... I actually learn it at home the week before"* (teacher interview, March 30, 2015, 6.1.1b) and M4 that *"I don't have a stock-standard, go-to site. I probably just 'Google' it and see what's there when I need to"* (teacher interview, April 21, 2015, 6.1.4). Several other interviewees noted these same sentiments. Excluding these aforementioned types of sites, there were 30 other sites mentioned. These sites were not topic-specific but were mostly science-based sites which could be entered and information-searched for specific topic information. For example, the NSW DEC's TaLE (Teaching and Learning Exchange - available only to DEC teachers at the time) contains a myriad of links to detailed information on primary - and secondary - science topics. 'Scootle', 'Understanding Science (Berkeley University)' site and 'BBC Science videos online' are further examples of some of these types of sites which have links to more specific science information.

The time available specifically to work at home and engage in learning is another important consideration and is noted in Figure 5.1. As discussed, the majority of teachers had a preference for working at home to search for content-based ICT resources. Perhaps the amount of time available to teachers needed to be divided

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between the teachers' competing roles? (de Wet & Koekemoer, 2016; Leaptrott & McDonald, 2010). Greenhaus and Beutell (2010) define this type of "interrole conflict" (p. 77) as a the conflict arising from a person's participation in different roles which result in pressures which are at odds with each other. As P2 said, *"there's too much going on at home"* (teacher interview, May 5, 2015, 7.2.1). In contrast to this statement, though, some general comments related to the lack of time at school compared with home (Table 4.34, 7.1 to 7.3). They further note that "multiple roles may compete for a person's time. Time spent on activities within one role generally cannot be devoted to activities within another role" (p. 77). Some of the interviewees did speak of time constraints, for example, P3 who stated *"I probably spend more time than I should looking for information"* (teacher interview, May 6, 2015, 6.1.1a).

Time constraints (see Figure 5.1), which are the result of some aspect(s) of a primary teacher's life, are often outside his/her control - especially aspects such as interrole conflicts - and the workload that many teachers continue to deal with at night or during weekends. The lack of time needed for a teacher to negotiate his/her work, for whatever reason, was one of the major obstacles identified by Bonk et al. (2014) from the findings of their study on SDL in adult learners.

Several social media platforms such as 'Twitter' (1 metropolitan and 2 provincial mentions), 'Pinterest' (1 metropolitan mention) and 'Facebook' (1 provincial mention) were also used by some teachers to provide links to websites in order to gain science content information. These platforms hold a large number of links to information and have great potential as sources of science content. However, scant mention of them suggests that teachers' awareness of these sites as resources (see Figure 5.1) might have been minimal. These types of sites were used by a small number of teachers to information-share.
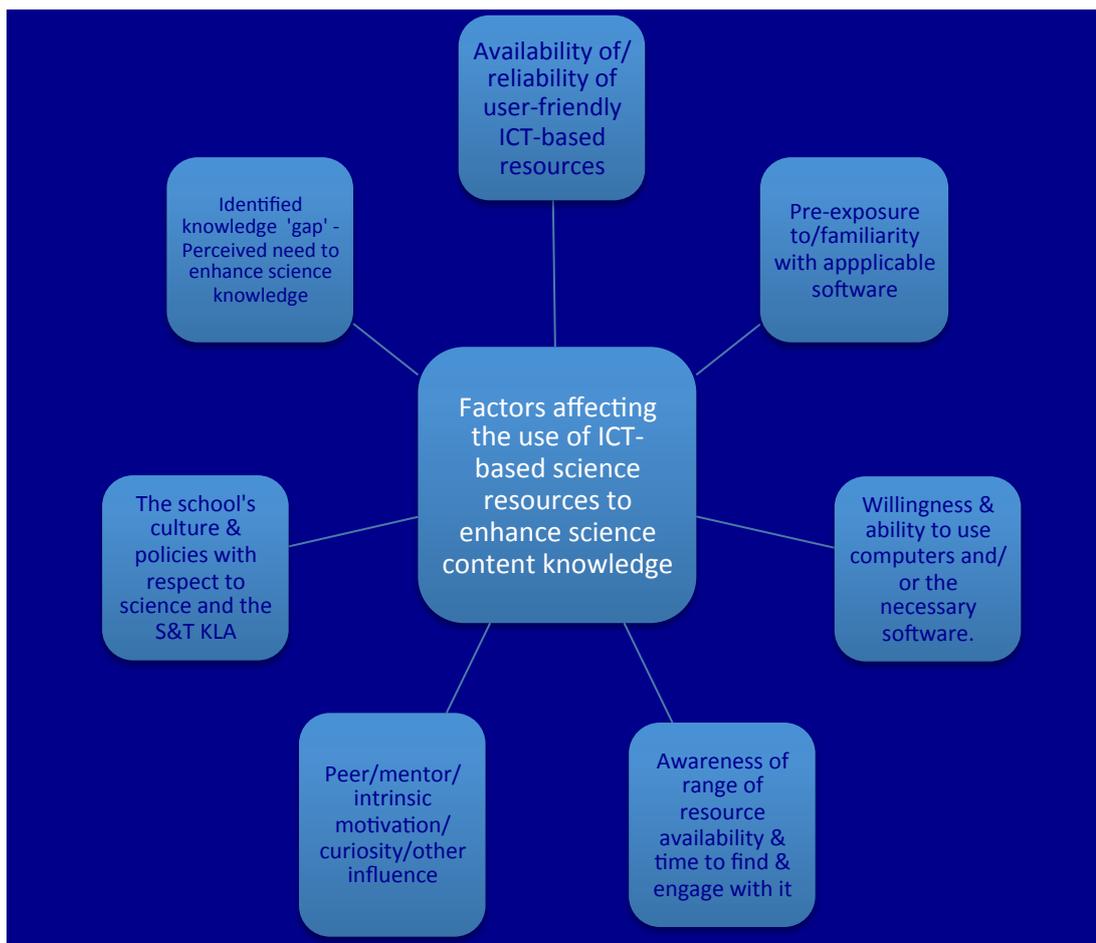
Figure 5.1: Major factors affecting the use of ICT resources for enhancing science content knowledge.

Some of the interviewees were more forthcoming with identifying ICT-based science resources that they had used. But, again, numbers using platforms seem to have been very low. For example, only P3 elaborated on the use of 'Pinterest': *"I'm very big on 'Pinterest'. ... say, if I'm doing electricity, then I'll type in 'electricity' or 'electricity kids' or 'electricity Stage 3' or 'electricity primary school' and just go through the sites there"* (teacher interview, May 6, 2015, 6.1.1a).

In support of the benefits of searching for ICT-based science resources on the internet, M2 (teacher interview, March 30, 2015, 6.1.8) noted that better understanding of the content led to more efficient and informed searches for more information and, therefore, M2 was happy to search for and improve understanding. As M2 was the teacher discussed above who commented on learning from a site the week before, if he/she was building on prior knowledge and was aware of this, then the learning was possibility more meaningful. Searching to enhance content

knowledge, for this teacher, assisted in perpetuating a cycle of more searches which, hopefully, further increased understanding. This exploratory behaviour has been discussed in the Literature Review (Andreassen & Bråten, 2013; Edmonson, Boyer & Artis, 2012)

On the other hand, searching sites which were not 'user-friendly' might also have been a deterrent. P5 alluded to this problem when discussing the use of ICT-based science resources by noting that using a particular site had been a problem because "*you need to do heaps of browsing to find anything that is relevant to what you want*". The 'Get Smart' site, for example, was preferable because "*it's very specific and it's much easier to find what you are looking for content* [sic] *... it gives you heaps of other links to other websites*" (teacher interview, May 5, 2015, 6.1.1d). Considerations such as these could, therefore, either negatively or positively influence the use of ICT-based science resources in the quest to enhance teachers' science content knowledge.

Interviewee P5 noted that sharing information amongst Stage 3 teachers at the same school who passed on the links to useful sites, reduced the need for thorough searches in some instances. This same teacher also noted a reliance on "other, younger teachers" (teacher interview, April 8, 2015, 6.1.3) who had taught the science content at other schools while employed as casuals. This perhaps again might have highlighted a reliance in some schools on casual staff to teach science or to disseminate information and therefore reduce the burden on permanent staff to teach science or search for content. It also highlights the importance of collaboration amongst teachers, as informal PL, and for knowledge transfer.

The role of RFF teachers was spoken of often in the survey responses and interviews and has been discussed previously. In summary, the statements made about RFF teachers were, most often, in relation to the teaching of science being passed to them so that some teachers had not needed to teach science for some time. Only one interviewee commented that the RFF teachers at his school were given science to teach because it was easy to teach as a stand-alone subject: "*I have about and hour-and-a-half down on my timetable for science* [per week] *but over the past 5 or 6 years, science has been taught by the RFF teachers as its an easy stand alone subject*

to do that with" (P5, teacher interview, May 8, 2015, 8.6.1b). During a discussion with a recently-retired primary school principal - given the pseudonym 'Patricia' - on science teaching in NSW primary schools, she referred to the load given to the RFF teachers in *"many schools"* (personal communication, May 16, 2016). Patricia commented in the same discussion that *"lots of* [primary] *teachers don't get to teach science very much in their schools because most schools only teach it for two terms a year and it's often given to the RFF to teach".*

As had been seen in some instances above, more targeted questioning brought about more detail in participants' responses. In this case, the keeping of the logs of ICT-based science resource usage by 11 teachers - 6 metropolitan and 5 provincial - yielded quite a number of sites not mentioned in the earlier surveys. This identification of sites could also have been a function of the time of the academic year when the surveys were conducted and logs had been kept; that is, whether or not science was being taught at all during that time and, if so, which topics were being taught. Did the teachers need to seek more content knowledge on those particular topics? By way of example, as noted elsewhere, two teachers spent time searching specifically for content related to the electricity topic. Spending more time searching for content on a physics-related topic could be an artifact of the documented orientation of primary teachers towards the biological sciences (Danielsson & Warwick, 2014; Kahle et al., 1991; Mansfield & Woods-McConney, 2012) - as was the case for this cohort - and a product of the knowledge gap for this topic or the time of year in which the teachers had to teach the electricity-related topic. If the knowledge gap was large enough - in keeping with a 'don't know' level of content knowledge - it might have elicited the feelings of enjoyment and interest that Litman et al. (2005) described, and account for the relatively sustained searching. Measuring the teacher's knowledge gaps and emotional states was beyond the scope of this study. Further to this, the two teachers who searched for content related to electricity were among those who stated in the surveys that there was a deficit in their science content knowledge. The more sustained searching for content on the electricity topic, then, could be seen as being consistent with the teachers having more limited science content knowledge.

In analysing the use of the identified sites, it was kept in mind that teachers were

asked to keep a log of sites which they used to specifically enhance their science content knowledge. Several sites which could clearly not have been used for this purpose but were listed by some teachers, were not included in the results. It was assumed that all other sites listed by the teachers in their logs were used for the specified purpose and not solely for lesson-planning purposes (i.e., for finding recipe-style activities to follow without gaining deeper understanding of the topic content).

The average times spent by these participants on sites to specifically enhance their science content knowledge is shown in Table 4.32. The mean for the metropolitan group of 58 minutes/week (σ = 11 minute/week) was much higher in comparison with the provincial mean of 37 minutes/week (σ = 17 min/week). One metropolitan teacher spent 77 minutes/week, which was the highest average time of all 11 teachers. The lowest average time spent across all teachers was by a provincial teacher at 20 minutes/week. Breaking down the statistics for the six metropolitan teachers and excluding extra sites for Teacher 3 - who spent an average of 30 minutes/week using many "various" unidentified sites searching for content - only a total of 28 sites were accessed. The 'Primary Connections' site was only used by two teachers over their log-keeping period. Similarly, only one provincial teacher accessed the 'Primary Connections' online site during the time that the logs were kept. These frequencies would not have been predicted using the survey data. However, they might have been a function of the particular science content taught during the time when the logs were kept or because the print versions might have been used at that time. Although these frequencies would not have been predicted by the survey data, they might have been a function of the particular science content taught during the time when the logs were kept or because the print versions might have been use at that time. This frequency might also be a result of the small cross-section of participants who volunteered to complete the logs. That is, whilst the log-keeping teachers weren't using 'Primary Connections', some teachers in the broader sample might have been. This could indeed be the case in my study as a large proportion of the metropolitan teachers in this study mentioned that they used 'Primary Connections' (see Tables 4.15 and 4.16) and the findings in the literature also suggest a wide use of these resources (Peers, 2007; Tytler, 2007).

In a similar way to the metropolitan teachers, the provincial teachers listed the majority - 18 of the 27 - of the chosen sites as being 'most helpful' and the remainder as being 'moderately helpful' for enhancing science content knowledge. Labelling a site as 'most helpful' might be because it was worthwhile engaging with, but also 'most helpful' because the teacher had less content knowledge relating to the topic of the site than with other sites and, therefore, found it much more helpful. Could 9 out of 27 teachers labelling various sites as 'moderately helpful' do so because their content knowledge in that area was slightly stronger? Is this an overall indication of the level of science content knowledge of these particular teachers? The sites used by teachers 5 and 6 indicated that they had been searching for content related to buoyancy and geology - gold mining and extraction - respectively. Again, these are topics outside of the typical primary teacher's subject orientation. No other patterns could be discerned from the many general science sites accessed. Of the total number of sites visited, 16 of 28 and 19 of 27 sites used by metropolitan and provincial teachers, respectively, were visited only once. As interviewee M5 commented *"I do have some favourites that I use but it depends on the area that I'm teaching and researching"* (teacher interview, May 12, 2015, 6.1.5). In order to relate the finding concerning the number of times that sites are visited and the time spent searching for appropriate science content knowledge resources online, the construct of 'curiosity' is useful. As demonstrated in the literature, curiosity in combination with levels of content knowledge, emotions and personality can influence the depth and frequency of a teacher's search and how much searching is engaged in (Hannum, 2015; Litman et al., 2005). The teachers in my study were not questioned directly about their curiosity. However, the possibility of further research in this area and how it impacts the learning of teachers' science content knowledge is addressed in a later section.

In summary, this small sample of teachers who completed logs reported accessing ICT-based science resources to enhance their content knowledge, and were spending an average of 48 minutes/week (σ = 17 minutes/week) across the group. Metropolitan teachers were spending more time, on average, per week than the provincial teachers. Issues related to time constraints, as discussed in relation to the surveys and the interviews, also apply to the lengths of time indicated by the logs. No appreciable overlap or pattern of site-use emerged to convey any sense of systematic

searching by any one teacher. Nor was there any appreciable returning to particular sites to re-engage with the content material to, perhaps, reinforce or deepen the learning. This was despite the use of the online 'Primary Connections' resources being mentioned frequently in the surveys and by the interviewees. Only two teachers showed any sustained searching for content material and, as their science content knowledge was at a deficit, this is consistent with the findings of other studies on curiosity exploratory behaviour (Edmonson et al., 2012; Hannum, 2015; Litman et al., 2005).

A number of sites which are not reliable had been used. Were the teachers aware that this was the case and of the pitfalls of not using reliable sites even for basic science content searching? As teachers and professionals with a tertiary level education, they should have been aware of the need to use reliable sites. In choosing sites using search engines, teachers would have relied upon the search engine's brief description of the site. In areas where their content knowledge was deficient and sites chosen were not appropriate for their purpose (Andreassen & Bråten, 2013), time could have been lost finding additional sites that were appropriate. This would ultimately reduce the available time to learn more content.

The results of this study can only be considered for the group of teachers who provided the logs and, therefore, cannot be generalised to the broader group of 47 teachers nor beyond them to the general primary teacher population. However, my study provided a snapshot of how the teachers who provided the logs used ICT resources to enhance their science content knowledge. Why more teachers did not complete the logs after receiving a number of email and telephone call reminders - these reminders were agreed to - cannot be answered by this study. A few principals warned me during recruitment conversations that teachers would not be too forthcoming in completion of the logs as they would not want the researcher - or the community at large - to know what they were not doing? Could this be the case in my research? Additionally, the participating teachers might not have had enough time to make a long-term commitment to completing the logs.

5.8 Implications of the Research

The findings of my research are consistent with research conducted over many years: many generalist primary teachers are not particularly confident with respect to teaching science; and the teaching of science in many primary schools leaves much to be desired and has generally not improved over time (Aubusson et al., 2015; Kenny et al., 2014; Martin et al., 2012).

Teachers throughout the research - in both the surveys and interviews - frequently mentioned the negative impacts of NAPLAN high-stakes testing on the teaching of science in their primary schools, which is consistent with the literature (e.g., Amrein & Berliner, 2002; Sahlberg, 2010). For example, it was reported by teachers that NAPLAN testing had a disproportionately high negative impact on the time spent teaching KLAs such as Science and Technology (Klenowski & Wyatt-Smith, 2012; Minarechová, 2012; Polesel et al., 2014; Sahlberg, 2010). The teaching which targeted literacy and numeracy/English and mathematics in an attempt to improve students' NAPLAN scores was reported as having high priority in many of the participating schools, despite the fact that literacy and numeracy are considered the building blocks of all learning and are explicitly intended to be taught through all KLAs (NSW DEC, 2013b).

For a society which aims to produce scientifically literate citizens, the teaching of the S&T KLA throughout primary school and into high school must be of high quality (Loughland & Nguyen, 2015; Peers, 2007). Throughout the literature, there are reports from research which has found that the time dedicated to the teaching of science is often contracted (Anderson, 2015; Fitzgerald et al, 2013; Koul, 2010). This is frequently the result of other teaching pressures such as the teaching of other subjects and/or competencies being given a higher priority (Murphy & Beggs, 2005). The results of this study demonstrated that these, and other factors, were consistent with the literature. However, informing educationists of these factors and their interplay is just the preliminary step. In order to overcome these obstacles to efficacious science teaching, there must be strategic planning to alleviate the situation. Finally, action on the planning must be followed through in primary schools.

In very recent years, reducing the large proportion of primary teachers without a strong science background is beginning to be addressed. The problem has been recognised in many countries around the world (HBCSE, 2011; Lee, 2012; Peers, 2007) and programmes to address the situation are being implemented (Koul, 2010; Seung et al., 2014). A number of initial teacher education courses are currently being improved in some Australian tertiary institutions to rectify this, especially as the focus has changed as the result of reforms put forward. Examples of these reforms include those by the Teacher Education Ministerial Advisory Group (2014), implementation of the AITSL Professional Standards for Australian teachers, and recommendations made by Albion and Spence (2013) on the Queensland Government's report on STEM education.

In my study, teachers' confidence levels obtained from the STEBI-A were not particularly positive. As many of the teachers acknowledged that their science content knowledge was lacking, the gradual introduction of the Australian Professional Standards for Teachers (APST) might, over time, encourage teachers to improve their science content knowledge which, in turn, would hopefully contribute towards increasing their confidence and student learning in the S&T KLA. As the third domain of the APST which relates to "Professional Engagement" embodies two standards (Standard 6 - "Engage in professional learning" and Standard 7 - "Engage professionally with colleagues, parents/carers and the community") (AITSL, 2014, p. 3), there is now an even greater imperative for teachers to address the situation. Therefore, one channel through which teachers could self-initiate the learning of science content is through the use of ICT-based science resources. The majority of teachers in this study recognised a need to enhance their science content knowledge; a need which has been highlighted in the literature numerous times (Dokme & Aydinli, 2009; Lunn, 2008; Murphy & Beggs, 2010; Stevens & Davis, 2007).

However, some initiatives are needed for effectively assisting generalist teachers with poor science content knowledge who are already teaching, or who are currently preparing themselves for a career of teaching in primary schools. The recent phasing-in of the Australian National Curriculum and the schools' high prioritisation of English and mathematics/literacy and numeracy have created an education

environment in which there is little opportunity to offer formal PL courses to primary teachers to strengthen their science content knowledge. While opportunities exist for teachers to engage in less-formal types of PL, they need to have the motivation and time to do so. More effective PL opportunities to better support teachers and meet their needs are recommended by the OECD (2009). There is an opportunity for researchers to investigate the types of science-based PL courses which best serve the needs of generalist primary teachers for enhancing their science content knowledge and confidence. Useful and effective PL, together with efficient strategies, would empower teachers to deliver more effective science curriculum content in order to increase student learning.

The large body of reliable ICT-based science resources available to teachers - including networking platforms - could provide them with readily accessible opportunities to enhance their science content knowledge. However, my research demonstrated that teachers neither availed themselves of these resources to any great extent nor used them to maximum benefit. For those who did, there was no means of measuring the degree of learning associated with visiting the sites. Charalambous and Ioannou (2008) found that teachers who had more confidence in their own ICT skills had much more positive attitudes towards using the internet for their own personal development. Strategic planning by educationists and education institutions to assist teachers to build up a base of useful ITC-based science resources and the skills to use them could save time for busy teachers.

A large proportion of teachers in my research identified that they needed to enhance their science content knowledge and many considered that they also needed to enhance their ICT skills in order to make better use of the many ICT-based science resources that are available on the internet. But how, in practical terms, do teachers achieve this, especially in an on-going way? In my study, many teachers noted the scarcity of appropriate formal PL courses available to them for science. Quite a number of teachers engaged with their colleagues in less-formal PL, which might be limited by the science content knowledge of the teachers in the collaborations. Hargreaves (1994) warns of the potential problems of certain modes of collegiality and their ability to limit rather than foster teacher learning opportunities (cited by Flores, 2004).

The use of ICT-based science resources must be effective and efficient (Karaseva, 2016). Not only do primary teachers need more time to enhance their science content knowledge and to adequately prepare lessons for the S&T KLA, they need continued support to do this. The time spent, mostly at home, searching for science resources online might give rise to interrole tensions between the teacher's work and family roles (Greenhouse & Beutell, 2010; de Wet & Koekemoer, 2016). This tension might partly impact on the amount of time spent. A teacher's baseline science content knowledge and the perceived knowledge gap - if there is one - can also impact on curiosity and exploratory behaviours (Hannum, 2015). These, in turn, might additionally have impacted on the time spent using the relevant ICT-based resources without the teacher realising that they were in play. It is important to raise teachers' awareness of these tensions and how they can be overcome in order to make their time using ICT more efficient.

It has been demonstrated by my research that there is a need among the teachers studied to enhance their science content knowledge, and that using ICT-based science resources is one way to achieve this. There is, therefore, a requirement for carefully constructed ICT-based resources that are readily available to teachers across NSW. Ideally, these would be free or low-cost, self-paced, ICT-based - online or in other ICT formats - science-related content learning materials, which target the specific content areas of the S&T KLA curriculum and are designed to supplement their science content knowledge.

It has also been demonstrated that the metropolitan teachers in this study engaged with more ICT-based science resources than did their provincial counterparts. The provincial teachers, however, appeared to be more inclined to engage with others as 'human resources'. The research also suggests that there might be a need for a mechanism - or, perhaps, a better one than might currently exist - to raise teachers' awareness of the availability of ICT-based resources and how to make the most effective use of them within their own context. In the concluding chapter of this thesis, teachers' views of themselves as life-long learners and the question of how to inspire and motivate them to see the importance of their own continued learning are addressed.

5.9   Chapter Summary

The data collected during the three research phases, and pertaining to each of the five research questions, were synthesised and analysed in this chapter. This discussion was undertaken with reference to the relevant, available literature. The most dominant findings are summarised below.

The data have shown that the teacher cohort in my research, being drawn from metropolitan and provincial schools, was a relatively experienced one. It was demonstrated that the current culture of science teaching in the sample of NSW primary schools, which participated in my research, was consistent with the literature. Only a small number of the teachers had some form of tertiary science education. Very few of the schools employed a specialist science teacher in any capacity - only one of these teachers took part in the research. The teachers' generally poor science qualifications influenced their teaching of science and their teacher self-efficacy. For both metropolitan and provincial groups, having a supportive school policy and/or effective, high-quality programmes were identified as important influences on the teaching of the S&T KLA in their schools.

While NSW primary schools are not required to have separate policy statements for all KLAs, there was considerable variation between schools on the types of 'policies' that they did - or did not - have. A large proportion of the schools appeared to devolve the responsibilities for planning, implementing and devoting teaching-time for the S&T KLA to teachers who were not supported by a strong school culture surrounding science teaching. The teachers who were led by a principal committed to encouraging science teaching showed a more positive approach to the S&T KLA and were better supported in its teaching.

Both principals and teachers reported a high prioritisation of literacy and numeracy/English and mathematics in their school cultures. Much of this prioritisation was reported as being the result of the pressures - perceived or otherwise - of the schools' students needing to succeed in the annual NAPLAN testing programme. Much of this pressure is the result of NAPLAN becoming a high-stakes testing programme - as discussed by Minarechová (2012) and Dulfer et al.

(2012) - whose results are reported on the 'MySchool' website. Among the reported repercussions of this dominance of literacy and numeracy/English and mathematics are the negative impacts on the teaching of other non-NAPLAN-tested KLAs such as the S&T KLA. Other factors which affected the teaching of science - such as science resource acquisition and maintenance, and spaces in which to teach science - and the wide variation in the time taught teaching the S&T KLA in the schools were discussed: most of these factors were consistent with the findings in other studies both in Australia and overseas. There was considerable commonality in these factors between the metropolitan and provincial cohorts.

Analysis of survey data from the STEBI-A, indicated that the metropolitan and provincial teachers had quite similar confidence levels on both the STOE and PSTE scales. However, these confidence levels were not, on average, high and were just on the positive side of the mid-point score. Teacher confidence levels correlate highly with a number of factors: "appropriate levels of pre-service training, being supported with suitable resources and on-going professional development are [examples of such] key factors" (ASTA & OCS, 2014, p. 5). A large percentage of the teachers identified a high need to enhance their science content knowledge, and to improve their ICT skills to assist achieving this goal. However, engaging in science-related PL - either formal or less-formal - was low, largely because of the lower priority of the S&T KLA in many of the schools and the scarcity of formal PL opportunities. This further seemed to manifest itself in a supply-and-demand issue for science-related PL. In provincial areas, the lack of engagement in some types of formal PL activities was exacerbated by the cost of travel. However, there seemed to be compensatory behaviours within the provincial groups. That is, compared with metropolitan teachers, provincial teachers in my study demonstrated a higher engagement with other teachers as 'human resources' through immediate interactions and the use of video conferencing opportunities.

Given that teachers identified a need to enhance their science content knowledge, combined with a lack of participation in PL to achieve this, it was hoped that the teachers would demonstrate a high-enough professional and emotional commitment to their students' learning for them to have engaged in some form of self-directed learning to enhance their science content knowledge. Engagement with the

substantial and ever-increasing body of ICT-based science resources provides one approach to achieving content knowledge enhancement. However, the results show that some other factors influence the use of such resources.

Internet access was not a critical factor influencing computer/device-based searching for content for any of the participants. In addition to generally surfing 'YouTube' videos and search engines, quite a few sites and platforms - such as 'Pinterest' and 'Twitter - were identified but not widely used. The online 'Primary Connections' resources received many mentions, but the majority of other sites were mentioned only once. Data gathered from the small group of teachers who submitted logs of their ICT-based science resource use to enhance their science content knowledge showed that, on average, this group spent around 48 minutes per week in this pursuit.

A number of factors can impact the successful use of ICT-based resources, including the time available to teachers for searching; the actual time spent searching; and the frequency of use and the sites used - including their evaluation of the sites as reliable. These factors and the teachers' attributes which can influence them - such as curiosity, exploratory behaviours and the base level of content knowledge - were discussed with reference to findings in the literature. How indicative this was of the broader teaching community cannot be gauged directly because of the limited sample in my research. This issue, together with limitations of the research, is discussed, in the following Conclusion chapter.

Chapter 6: Conclusion

6.1 Introduction

In a piece written for 'The Conversation' entitled 'Aspiring to something magnificent with science in Australia', Australia's Chief Scientist at the time, Professor Ian Chubb, wrote that one of his visions for science in Australia was that "the country can be bold enough to say that every primary school ought to have a science teacher with continually updated knowledge" (March 25, 2015, para.18). At the present time, this vision is very far from realisation. In the introduction to their study, Loughland and Nguyen (2016) stated that "a number of studies both in Australia and other contexts would claim that teachers who want to engage their students in science often struggle with the teaching as most teachers have a low level of science education" (p. 499). The literature demonstrates that a widespread lack of science content knowledge still characterises the primary teaching profession in Australia. All primary school teachers need opportunities to update their science content knowledge and related pedagogical content knowledge as required.

This chapter focuses on the conclusions of my research into the use of ICT-based science resources by a sample of Stage 3 primary school teachers to enhance their science content knowledge. Limitations of the research are discussed in addition to suggestions for the way ahead and for future research.

6.2 Limitations of the Research

There are various limitations to research of this nature and which apply to this study in particular. The limitations relate to the following areas: the duration over which the logs were completed; the small numbers of participants; the impact of the principal's leadership; teacher motivation; and teachers' use of ICT-based science resources. Limitations relating to each of these areas are discussed below.

6.2.1 Duration Over Which the Logs Were Completed

Many teachers see themselves as being 'time poor'. As a result of this and in addition to other reasons discussed throughout the Discussion chapter, a large proportion of participants in this research did not complete the logs of ICT-based science resources used over an extended time period. The teachers who took part in the piloting of the questionnaires, or through other modes of communication, indicated that they would be willing and able to complete logs over a period of a month for the purposes of piloting. This feedback was taken into account in the research design.

The initial aim was for the logs to be completed over a six-month period and the log table was made interactive to make populating it as easy and quick as possible for the participating teachers. While the time over which the completion of the logs during the second phase of the research ultimately varied considerably, it was necessary to analyse them and present the data as an average over a shorter period of time than anticipated. That is, over an average of one week. This eventually became a limiting factor of the study as the end of the research ethics approval period, which had already been extended, drew near and many of the logs had not been returned. Having the logs filled-out over a six-month period would have been more informative, would have been less subject to potential skewing by the activities of one or more teachers and given a more complete picture of teacher use of ICT-based science resources for the investigated purpose. However, because teachers who were - or who perceived themselves to have been - 'time-poor' participated in the research willingly and without coercion, it was difficult to conduct the research over the proposed time period without the complete co-operation of the participants. This situation was not anticipated during the design of the research, and only became apparent towards the end of the data-collection period as the logs were received.

6.2.2 Small Numbers of Participants - Schools and Teachers

For the reasons which have previously been highlighted in the Discussion chapter, this research was conducted with a relatively small number of participants. As for many studies, recruitment proved to be a major difficulty (ASTA & OCS, 2014;

Welsh & Barlau, 2013). Whilst recruitment and, therefore, low response rates always remain an issue for research of this nature, conducting the research over a much larger sample size would have been desirable to allow for a broader generalisation across the target sample population.

6.2.3   Principal's Impact

The impact of the principal - or the school's leadership team - on a school's approach to teaching and learning has been well-established and discussed (Anderson, 2002; Flores, 2004; Tilgner, 1990). It can have a trickle-down effect on a school's staff and what is taught in the school. However, several principal-related impacts could possibly have been limiting factors on the size of this research sample.

Firstly, as some principals either did not see the value of this particular type of research or were just not interested in engaging in research of any kind, their attitude acted as 'blocking' staff recruitment from their school for this research. Such attitudes work against the random selection of teachers for participation. However, the anticipation of this occurring was built into the recruitment process by approaching over 200 school principals to participate. Secondly, the work of researchers such as Anderson (2002), Flores (2004) and Tilgner (1990) has demonstrated that the influence of principals on their school can have both positive and negative impacts on, for example, school progress, teachers' attitudes and motivations, and teacher engagement in PL. These impacts - particularly the negative ones - were also highlighted through the survey responses and by some of the interviewees. The degree to which these negative impacts influenced the school cultures and, therefore, the associated teachers' engagement with all aspects of teaching science was beyond the scope of this research and could be considered indeterminate. The extent to which this research might or might not have been deprived of important insights as a result of principals' impacts on their staff cannot be known.

6.2.4 Teacher Motivation

Once the principal's approval to participate was granted, participation was ultimately at the teacher's discretion. It is not unrealistic to consider that only the more motivated or passionate teachers might bother to participate in such research. If this was the case - whether because of extrinsic or intrinsic influences - it might follow that the participating teachers could be more motivated than non-participants to use ICT-based science resources to enhance their science content knowledge. Therefore, the participation of these more motivated and/or passionate teachers might have skewed the data - in a similar manner as reported by ASTA & OCS (2014) - to give an inaccurate view of what might have been occurring within the broader teaching community at that time.

6.2.5 Teachers' Use of Site Information

Whilst teachers might have accessed a number of ICT-based science resources with the intention of enhancing their science content knowledge and considered that they had engaged with it to the best of their ability, it was not possible in this study to measure how much understanding and learning by those teachers actually took place. The data collected were interpreted based on the assumption that the teachers were not only accessing suitable ICT-based science resources and finding the information that they sought, but also actually learning from them, and thus enhancing their science content knowledge. Therefore, this assumption placed a limitation on the data's interpretation and is addressed further below.

6.3 Findings Relating to the Research Questions

The literature points to the teacher's importance in issues relating to the quality and quantity of science instruction in primary schools. Broadly, education systems must work to ensure that "school children leave our classrooms with a level of scientific literacy that prepares them for further learning, and ultimately for competing in the international economy" (Mintzes et al., p. 1202). These same authors contend that

"the overwhelming weight of evidence points to the teacher as the pivotal player in all of" (p. 1202) the issues pertaining to science education in primary schools. The findings of my research in relation to teachers in the context of their school's culture, and how this might ultimately impact on the teacher's motivation to improve their science content knowledge using current ICT-based science resources are summarised in relation to each of the research questions.

6.3.1 Research Qn. 1: What is the Current Status of the Teaching of Science in Stage 3 in NSW Primary Schools?

As discussed previously, the research sample size did not allow for broad generalisations to Stage 3 teachers throughout all primary schools in NSW. There are many factors - both intrinsic and extrinsic - which influence the status and teaching of science in primary schools (Figure 2.1). Extrinsic factors, such as the school's policies and culture and the teacher's tertiary training, and intrinsic factors, such as the teacher's self-efficacy, were examined.

This relatively experienced cohort, drawn from schools across NSW metropolitan and provincial areas, provided opinions/perceptions about the teaching of science in these Australian primary schools that were consistent with the literature. That is, in many of the participating schools, the time dedicated to science teaching was less than desirable and school leadership in many schools seemed to devolve planning and implementation responsibilities regarding the teaching of the S&T KLA to its teachers. The development of this type of situation can have a negative impact on both student achievements in science and the profile of science in the community. The reported contraction of time in which to teach the S&T KLA is consistent with the literature (Angus et al., 2004, 2007; Kenny at al., 2014). Literacy and Numeracy/English and mathematics were highly prioritised in the majority of the schools because of pressures associated with NAPLAN preparation. This high-stakes testing programme was reported to have overshadowed the delivery of a curriculum, which is often referred to by teachers and others in education circles as being 'overcrowded'. This could be driven, in part, by the teachers' fear of students performing poorly or failing in the tests, and subsequent negative repercussions on

themselves and/or their school. Other factors such as the schools' cultures with respect to science teaching, science resource acquisition, maintenance and storage, as well as the lack of dedicated learning space in which to teach science, were also highlighted across both metropolitan and provincial groups. As reported by teachers, and consistent with the literature (Kenny et al., 2014), limited tertiary-level science qualifications manifested in inadequate science content knowledge in this teacher cohort. Teachers with inadequate science content knowledge, and who develop negative attitudes towards science teaching, can ultimately be another major contributing factor which negatively impacts on the status of science in their primary schools.

6.3.2. Research Qn. 2: What is the Level of Teachers' Self-efficacy with Respect to Teaching Science?

Martin et al. (2012) reported a study - a TIMSS data analysis - of students of similar ages to NSW Stage 3 students. The study revealed a strong correlation between students' achievement and being taught by more experienced, confident teachers. Riggs and Enochs (1990) describe the impact of a primary teacher's negative beliefs - i.e., intrinsic motivations - on their science teaching ability. These negative beliefs can result in an aversion to teaching science which can manifest in avoidance behaviours towards teaching science. It could follow, therefore, that teachers whose confidence levels are close to mid-way between maximum and minimum STEBI-A scores, might not be aware of the ultimate impacts of their low self-efficacy on their students' learning. Analysis of the survey data collected using the STEBI-A instrument (Riggs & Enochs, 1990) suggests that the metropolitan and provincial teachers had quite similar confidence levels on the STOE and PSTE scales. Their confidence levels were not strong and were, on average, just on the positive side of mid-way between maximum and minimum score for both scales. Analysis of the persistent minorities, where appropriate, showed levels of indecision and suggested low confidence levels for some STOE and PSTE items.

Wilson and Crook refer to science as a "high-anxiety, low confidence subject for many primary teachers" (2015, Section 3 heading). They note that the time spent

teaching mathematics has traditionally been decreased when there are unplanned disruptions to the school day and when teachers have low mathematics teaching self-efficacy. The teachers in this research reported that science teaching also suffers a similar fate in many of their schools. This impact is reportedly in combination with the impact of the schools' prioritisation of other subjects. It is stated by Andreassen and Bråten (2013), that a functional form of self-efficacy, which they refer to as 'source evaluation self-efficacy' also impacts on teachers' ability to judge internet-based resources when they choose websites. This is discussed further in a later section of this chapter on the use of ICT-based science resources.

6.3.3. Research Qn. 3: Do Teachers Participate in Professional Learning Activities to Supplement Their Science Content Knowledge?

Although many of the teachers considered that they had a high need to enhance their science content knowledge, few engaged in either formal or informal science-related professional learning. This was found to be attributable to of a number of factors such as the low number of science-based PL courses available - especially compared with those related to literacy and numeracy - combined with other factors such as their school's teaching-and-learning priorities. The costs of travelling to centres for courses, accommodation and course registration fees acted as deterrents to provincial teachers attending PL courses. A small proportion of the teachers, particularly in provincial areas, did engage in less-formal styles of PL either at their school or with staff from other schools, sometimes via video conferencing which made it possible to avoid these costs.

The findings of other studies have indicated that teachers who have more confidence in their own ICT skills have more positive attitudes to working with ICT to increase their professional learning (Charalambous and Ioannou, 2008). Many teachers in my study acknowledged that there was a moderate to high need to achieve this up-skilling. A large proportion of these needed PL to improve their skills in order to maximise their use of ICT-based science resources.

6.3.4. Research Qn. 4: What ICT-based and Other Science Resources are Available to and/or Used by Both Metropolitan and Provincial NSW Stage 3 Teachers to Supplement Their Science Content Knowledge?

The majority of the teachers in this study preferred to use ICTs to search for content at home rather than at school for various reasons - including that busy days at schools didn't allow time to carry out searches. For the majority, the home environment was more conducive to surfing the internet. While metropolitan teachers were generally not hampered by unreliable internet connectivity issues either at school or at home, this was not always the case for provincial teachers.

There is a large number of both print and ICT-based science resources available to primary teachers to assist them to enhance their science content knowledge. The majority of sites mentioned were each only accessed once by teachers during the nominated time period for this searching. Symington and Hayes' (1989) research demonstrated that pre-service teachers used a very limited range of resources to enhance their science content knowledge. This trend among pre-service teachers could continue into their in-service years. The online 'Primary Connections' materials were the most frequently used and mentioned resources. Notwithstanding this, these materials barely rated a mention by the teachers who kept logs. More recently developed sources of science information and methods of connecting with other Stage 3 primary teachers such as 'Twitter', 'Pinterest', '21st Century Ning' or 'We are Teachers', received scant mention.

A case in point, which demonstrates that some teachers do actively seek to enhance their science content knowledge, comes from Anderson (2015). She describes evidence from research conducted by Triplady (2004) which demonstrated that a group of experienced New Zealand primary teachers studied and intentionally sought opportunities and suitable resources to enhance their own science content knowledge. This was done for topic areas that they were required to teach and for which they thought that their knowledge was not adequate. "They did background reading and found appropriate resources" (2015, p. 401). The types of resources were research were not identified.

6.3.5. Research Qn. 5: How Often Do Teachers Explore Available ICT-based Science Resources to Enhance Their Science Content Knowledge?

The data collected from a subset of the participating teachers indicated that metropolitan teachers spent, on average, around 58 minutes/week (σ = 11 minutes/week) visiting an average of 4.6 sites/teacher, compared with the considerably less times spent by provincial teachers of 37 minutes/week (σ = 17 minutes/week) visiting an average of 5.4 sites/teacher, searching for information to enhance their science content knowledge. There was a considerable range of times spent across the whole group and, as noted above, no appreciable overlap of available sites emerged, with the majority only being visited once during the period of log-keeping.

The average amount of time spent by teachers on each site was 12.6 minutes and 6.9 minutes for metropolitan and provincial teachers, respectively. Metropolitan teachers, then, seemed to have spent more time in the pursuit of enhancing their science content knowledge using ICT-based resources than did provincial teachers. However, no clear reason for this discrepancy emerged. Averages can be deceptive and the average times could be too short for any deep or meaningful learning of science content. Additionally, caution must be applied when considering these results as the activities of one teacher as capable of skewing the results of the group.

It was outside the scope of my research, to gauge how effective the use of the ICT-based resources was for the given purpose of enhancing science content knowledge. Nor could the development of misconceptions be elicited - especially given that a proportion of the sites visited were 'unreliable'. There was some evidence that two of the teachers who self-reported as under-confident with their science content knowledge, spent more time looking for content related to 'electricity'. This finding is consistent with Litman et al.'s (2005) findings that large gaps in knowledge are associated with feelings of positive emotions which motivate curiosity and high-level exploration behaviours to find new information.

Harlen (1993) argues that it is important for teachers to develop the ability to negotiate their way through the labyrinth of knowledge available to find appropriate information that is relevant to their teaching. This, combined with the possible inter-role tensions and the impacts of science teaching-, internet- and source-evaluation self-efficacies, could explain why there were patterns neither in systematic searching for content in the websites visited nor in the times and durations of the searches.

6.4 Future Directions and Research

What avenues could be open to the education community to realise goals such as those expressed by Chubb that "the country can be bold enough to say that every primary school ought to have a science teacher with continually updated knowledge" (March 25, 2015, para.18)? Additionally, what can be done to assist generalist primary teachers to improve their science content knowledge and use the of readily accessible ICT-based science resources to their best advantage? This section provides some discussion of and suggests recommendations for the possible future directions for primary science education and future research.

6.4.1 Implementation of the Australian Curriculum

A number of the participating schools had already begun the implementation of the 'new' Australian S&T KLA curriculum - optional in 2014 and mandatory from 2016 (BOSTES NSW, 2013) - during the period over which this research was conducted. This new curriculum has a particular focus on inquiry-based learning - "recognising questions that can be investigated scientifically and investigating them" (NCB, 2009b, p. 7). As commented upon by one of the participating teachers, this style of student learning could possibly engender a false sense of security among some Stage 3 teachers in that, if students are learning from their inquiring, then the teacher might not feel intrinsically motivated to have a well-grounded science content knowledge. Success, however, in inquiry learning depends on understanding the related strand of science which is "evident when a person selects and integrates appropriate science

knowledge" (NCB, 2009b, p. 6). The National Curriculum Board document defines science knowledge as "the facts, concepts, principles, laws, ... that have been established by scientists over time. Science knowledge represents the building blocks of science understanding" (NCB, 2009b, p. 6). Therefore, if a teacher's science content knowledge is lacking, there is a danger that student learning will be flawed. Symington's thought-provoking findings might counter this argument. He stated that "there are abilities possessed by some teachers, for example, the ability to devise investigable problems, which can, in some circumstances, compensate for a lack of scientific knowledge" (1982, p. 70). Such a finding would hold true many years later. Therefore, perhaps, the newer inquiry-based approach might - if managed very carefully - work in favour of some of those teachers who have a deficit in their science content knowledge. There is scope to investigate these notions further after the new curriculum has been more fully embedded for a number of years.

6.4.2   Teacher Professional Learning

There are many questions relating to the complex endeavour of being a 'teacher' and the many facets involved in the pursuit of and practice of high quality 'teaching'. "Professional learning for teachers has been a key issue in enhancing the quality of education" (Loughland & Nguyen, 2016, p. 500). Therefore, pursuit of enhanced content knowledge is important.

Gess-Newsome (2002) claims that generalist elementary teachers typically have deficits in their understanding of science, in pre-service training and in-service professional learning opportunities. She contends that many elementary teachers find it difficult to move out of the comfort zone of their familiar classroom practices into newer practices. Mintzes et al. (2013) therefore suggest that, because the highest levels of self-efficacy are found in teachers who have a better grounding in the sciences, there is "a need to investigate new approaches to preservice and inservice efforts as a way to mitigate these circumstances" (p. 1203).

On the Australian Government's Department of Education and Training's (2016) 'StudentsFirst' website (https://www.studentsfirst.gov.au/strengthening-australian-

curriculum), it was reported in October 2014 that that government's "Restoring the Focus on STEM [science, technology, engineering and mathematics] in Schools" initiative was committed to spending an extra $12 million to assist in refocusing the community on STEM subjects across all school years. $7.5 million of this was allocated to a 'Mathematics by Inquiry' project. The former sum was in addition to the previous financial year's budget allocation of $5 million dollars to 'Science by Doing' for secondary schools and 'Primary Connections'. Some of this money was specifically used for providing STEM summer schools, university/industry partnerships and the introduction of coding across the curriculum (https://www.studentsfirst.gov.au/restoring-focus-stem-schools-initiative). However, as a large proportion of these strategies focus on mathematics - and, by default, numeracy - it remains to be seen how much of this Australian Government funding would eventually filter down to assist primary teachers in enhancing their science content knowledge.

Subsequent to the above announcement, on May 9, 2016, the NSW Premier and the Education Minister announced that, in a first for NSW, courses in science and mathematics specialties were being made available to that state's primary teachers as part of their degree. At least three [un-named] universities would be offering the courses in an effort to allow prospective teachers to become STEM specialists. (NSW Government, 2016). Writing for The Sydney Morning Herald under the heading "NAPLAN 2016: NSW Education Minister Adrian Piccoli gives maths and science push as pressure builds", Eryk Bagshaw, reported that the main thrust of the Minister's discussions of the above announcement concentrated on the NSW NAPLAN numeracy results, Australia's decline in mathematics achievement in the most recent PISA results, and falling numbers of students studying mathematics subjects to Year 12 level in NSW public schools. No specific mentions of science were made in this article. Ominously, though, Bagshaw also further reported in the same article that this announcement came at a time when there were plans "to introduce national reading, phonics and numeracy tests" for Year 1 students. The introduction of such tests, which could ultimately become 'high-stakes', is contrary to world-wide trends (Caldwell, 2010; Sahlberg, 2010; Supovitz, 2009). While these tests would presumably have no direct impact on Stage 3 students and their teachers, this could further exacerbate the reduction of science teaching in primary schools in

general, as it puts further pressure on school communities and might eventually be seen to place more importance on the high-stakes tests.

At the same time, it was also announced that the government was producing 16 new resources to help to improve the teaching of the STEM subjects. Among these resources were newly developed STEM lessons for students in Kindergarten to Year 12 and eight new S&T activities for Kindergarten to Year 6. However, a lesson package will possibly not be sufficient to stimulate and inspire teachers to enhance their own content knowledge in any of the STEM areas, such as science. Appropriate PL activities also are needed for the teachers who must teach the lessons. Giving teachers resources without adequate PL support was frustrating in some primary schools in which teachers were expected to teach using the 'Primary Connections' package without PL support (Lowe & Appleton, 2014).

Do primary teachers realise the value and importance of their own learning - particularly in relation to increasing their capacity to teach science and the potential flow-on effect it should have on the learning outcomes of their students? As interviewee P5 commented, "*I like the extra detail that you need in Stage 3* [science] *syllabuses. You need to learn more things yourself*" (teacher interview, May 8, 2015, 8.6.1c). Further research into the mind-set of primary teachers towards their teaching of science and how they actually perceive their role as teachers of science and facilitators of science learning, would provide valuable insights into primary teachers' motivations with respect to their teaching of the science curriculum. Future research could focus on questions such as: Is the pursuit of teaching excellence driven intrinsically by teachers' personal objectives?; Do primary teachers feel an ethical imperative to have a sound content knowledge of science?; and do they see this as a necessary part of their professional identity as a teacher?

Many primary teachers typically do not attend formal professional learning courses/opportunities as individuals but seem rather to have a preference to attend courses delivered at school and to groups of teachers. Following conversations with professionals involved in private-sector in-service teacher education, it would be of benefit to conduct research related to which PL delivery format(s) encourage teachers to increase their participation in these opportunities. Additionally, the

availability of a greater number and variety of formal, science-related PL opportunities for primary teachers would be of benefit.

It is important that professional learning initiatives for the future are informed by research in an attempt to cater for the needs of the primary teachers who must implement the S&T KLA and who have little science education in their academic backgrounds. For example, Lowe's and Appleton's (2014) study highlights frustration among teachers who had been provided with resources but not with any PL support to assist them to use them more effectively. Therefore, there is ample scope for future research into the types of PL that primary teachers of Stage 3 actually require. Robinson, Lloyd and Rowe (2008) note that the promotion and participation of teachers in teacher-learning and development by school leaders have a very strong effect on obtaining positive learning outcomes for students. In addition to, or in the absence of, an inspiring and insightful school leader implementing a top-down approach to guide teachers into appropriate PL, the availability of appropriate types of PL - both formal and informal - would be beneficial to the school's teachers and, ultimately, the broader community.

The forms of PL discussed in the literature include mentoring, teachers' networks, individual or small-group research and incorporating primary teachers into suitable CoPs that would be of benefit to the group as well as the individual teachers in enhancing their science content knowledge. Appleton refers to the special importance of supporting early career teachers and to previous studies which found that the most beneficial support for primary teachers in their science teaching "was that of colleagues or mentors" (2003, p. 20). Appleton also highlighted that "the importance of colleagues and mentors to answer questions about science content ... and be a general support for novice teachers has been well substantiated (Anderson & Mitchener, 1994)" (Appleton, 2003, p. 20). Appleton (2003) further comments that this aspect of teacher support is critical for supporting those teachers who have low confidence levels.

Teachers meeting with other teachers can, therefore, be an effective form of less-formal PL (Anderson, 2015; Koul, 2010; Morgan, 2012; Tour, 2016). Teachers would benefit from having sufficient time to establish and build strong, trusting

relationships with other teachers or mentors in order to gain the most benefit from their interactions. How much time and how to manage the time effectively to maximise benefits for those involved and the broader school community would be worthy of future research. Among a number of options for this, regular meetings with specialist science teachers, experienced generalist mentors who have a positive outlook on, and demonstrated success in teaching science, or school science co-ordinators can be effective.

By way of example, is the formation of a CoP comprising of a number of primary teachers, a trusted secondary science teacher and/or an academic engaged in science education or a person - such as a parent - with appropriate science education or general science expertise to assist with science lessons or to provide direct or indirect PL opportunities. Astro-physicist at the Australian University and Nobel Laureate, Distinguished Professor Brian Schmidt, commented on the potential of engaging parents - and presumably, any community member with the right science background - to assist with the teaching of science in the classroom:

> … teachers need to have techniques and experiments and ways of exciting kids. That really means having a good professional development system in place ... if you have a confident parent who has the right training, [he/she] can be called upon to show why science is important; why it's exciting". (Schmidt, 2012, para. 8)

This CoP would engage in regular after-school meetings or tutorials or (for provincial teachers or others for whom travel can be an issue) online webinars - to examine and study the science content of future, or even current, units to be taught in that Stage. As Kaplan and Owings have noted, teachers working in this way create spheres of influence and that:

> … in schools with shared influence, positive collegial pressure sways teachers to enact their roles differently than they may have done before.

What teachers give up in individual autonomy, they make up in their collective ability to do things to enhance student learning that the teacher was not able to do while working alone. And when all teachers are working collaboratively to ensure every student is learning and achieving, all students benefit. (2013, p. 9)

Currently, some NSW schools have embedded a practice of mandating that teachers who attend PL courses 'pass-forward' what they have learnt to their peers. This type of embedded and sustained practice maximises the number of teachers who benefit from the PL and includes an element of financial efficiency. There is ample opportunity for more research to be conducted to investigate and evaluate school communities in which appropriate PL opportunities are sought, how attendance opportunities are shared amongst the teachers, and whether or not attendees' learning is shared with other teachers for the benefit of all.

Related to the use of ICT-based science resources, and indeed any resources which can be used to enhance science content knowledge, is the development of PL opportunities which empower teachers to negotiate their way through the many available resources, so that they are comfortable with assessing the relative value of resources that they encounter during self-initiated learning. Can teachers be inspired/encouraged/motivated through well-designed PL activities to develop an enquiring mind? Even in the late 1990s it was evident to Hipkins and English that there was "the need for more focused guidance for all teachers - but especially for those who are still in the process of strengthening their own science knowledge" (p. 11).

Finally, Louws et al. (2017) argue that, with respect to the ongoing debate around teacher PL opportunities, self-directed learning provides a relevant contribution. Louws et al. (2017) studied 309 teachers in The Netherlands in relation to what they want to learn, how they learn it and why they want to learn it. The students had to identify these within their preferred professional learning domains, including knowledge of subject content, classroom management, ICT, curriculum and students'

learning processes. Teachers were also asked why they had chosen their preferred domains. Teachers reported "preferences to be higher for the subject matter-specific domains and ICT than for any other domains" (p. 177) and that these domains were "strongly preferred" (p. 179). Louws et al. (2017) explain this finding in terms of teachers wanting to master their subject content in order to be able to explain and it to their classes. The authors considered that teachers preferred the ICT domain mainly because it assisted them with integrating ICTs into their lessons. The authors consider that this is a reflection of current trends in student learning using devices. While the teachers in this study were secondary, it would be beneficial to conduct a similar study with Australian primary teachers in order to inform future PL opportunities based on teachers' needs. Such opportunities could be aimed at assisting individual teachers, or groups of teachers, with how to navigate their way through online websites and resources to maximise their efforts at self-directed learning.

6.4.3 Impacts Related to High-stakes Testing

The negative effects of high-stakes testing, (Klenowski & Wyatt-Smith, 2012; Minarechová, 2012; Polesel et al., 2014; Sahlberg, 2010) particularly to the contraction of time spent teaching science and the high prioritisation of literacy and numeracy/English and mathematics, with respect to NAPLAN in the Australian context have been discussed in the Literature Review and Discussion chapters,. Further research into the impact of this testing regime on science teaching is suggested.

Two areas could be the focus of future investigations. The first is the effect of preparing for the NAPLAN tests during a concentrated period - in some schools this is reportedly over one whole school term - and the 'washback' effect of this (i.e., its effect on the narrowing of the curriculum). It has been demonstrated throughout the thesis that a primary school's culture can ultimately have an impact on its teachers (e.g., the prioritisation and status of subjects, and the time allocated to teaching KLAs). A teacher working in a school in which a subject - such as science - has low priority and the time allocated to teaching that subject has been contracted might find

this a disincentive to excel in its teaching. It could follow, then, that teachers would not see any need to improve their content knowledge in that subject. This choice, whether subconscious or conscious, would impact the teachers' perceived needs to use ICT-based resources to improve their content knowledge (Figure 2.2). The second, is a comparison of the cultures surrounding science teaching in schools which participate only in the standard, compulsory NAPLAN testing compared with those who also participate in the optional NAP-SL testing. However, given that NAP testing is highly dependent upon literacy skills, it would also be valuable to ascertain to what extent participating schools might place more emphasis on teaching science literacy skills than on a more hands-on, inquiry-based approach to science teaching.

Do schools which approach the teaching of literacy and numeracy by integrating them through all KLAs, rather than by concentrating on them as though they were discrete subjects, have a more balanced approach to teaching science and, therefore, more time to teach it? One of the interviewees commented: *"I don't think that teachers think much about integrating other disciplines in their lessons as we should - they see the KLAs in boxes"*. (M5, teacher interview, May 12, 2015, 8.9)

To many experienced teachers, this integration might be an obvious teaching strategy and to others, it would currently be becoming more evident with the gradual introduction of STEM courses into primary and secondary schools. The teaching of such STEM courses necessitates cross-curricular integration of science, mathematics, engineering and technology and could provide ample opportunities to integrate literacy and numeracy strategies into the teaching of the courses. The Australian 'Primary Connections' resource package was developed to encourage the integration of science and literacy in order to advance learning in both areas (Peers, 2007). However, it seems that, because few principals and teachers commented on the integration of science and literacy in their schools, this integration did not occur to any great extent in the participating schools. The teaching of literacy should, however, be integrated into the teaching of every KLA (NSW DEC, 2011). This goal is achievable if literacy outcomes are built into programming for the S&T, and indeed all, KLAs.

The above sentiments are embodied in the following quotes from a PMSEIC report

on science education and engagement on equipping young Australians for the future:

> … Literacy is a priority in Australian primary schools ... Linking science to literacy will enable a more efficient use of resources, allowing students to develop skills in science and literacy simultaneously ... [and] ... Linking science and literacy provides benefits to both learning areas. Primary teachers are confident and competent at teaching literacy. Using literacy as a vehicle to teach science is an approach likely to appeal to teachers who lack confidence in science. It will also provide an enhanced perspective for experienced and confident teachers of science. (2003, p. 12)

6.4.4 Effective Use of ICT-based Science Resources

Beach and Willows (2017) acknowledge that a teacher's job is multi-faceted and that there is much that teachers have to learn in relation to their employment, such as finding their way around the online environment. "The internet is rapidly becoming an increasingly important tool for the professional development of teachers" (Charalambous & Ioannou, 2008, p. 47). Mwalongo (2011) also comments on the potential of the internet and ICT for assisting with professional development and as an educational tool.

One of the participating teachers commented that an increase in the understanding of a researched topic area can initiate and assist in perpetuating a cycle of further research and deeper understanding. This is probably an example of curiosity and exploratory behaviour after the teacher identifies a gap in her science content knowledge from the 'don't know' level (Litman et al., 2005). But the question could be asked about how much understanding occurred for the teachers who were using the ICT-based science resources. In other words, how effective was the use of the ICT-based science resources? This also opens up further research possibilities into

links between using ICT-based science resources and the development of primary teachers' misconceptions of science concepts. As noted above, there are also possible fluctuations in the usage of sites with the progression through units during the two years of Stage 3. Some teachers might possibly only search for sites to enhance their science content knowledge related to units with which they are uncomfortable. Therefore, a study of teachers' use of ICT-based resources over a full two-year period of Stage 3 teaching might shed more light on this.

Because the 'Primary Connections' online resources were frequently mentioned, it would also be informative to research how much science content learning teacher-users gain from engaging with these types of online (and related hard-copy) units. This could be an example in practice of the documented preference of primary teachers for the printed version of 'Primary Connections' over the online resources because of teachers' unsuccessful experiences when looking for suitable content material (Karaseva, 2016). However, there were other reasons for the lack of use by some teachers. As one science-trained teacher employed in a primary school noted (name withheld, personal communication, March 28, 2016): *there is not enough theory behind some of the investigations. There are some "conceptual holes" in them* ['Primary Connections' units] *which makes it really difficult to teach as they are ... so the children miss out on some basic understandings".* If these observations are a true reflection of the situation during the research period for the participating teachers, they compound the difficulty that some teachers experience because of a limited science background; they might not have arrived at a realisation that there are gaps in their science content knowledge. Further, if the package is a teacher's sole resource, then its limited content would contribute little towards the enhancement of the teacher's science content knowledge.

Reporting teachers' understanding of science content knowledge or concepts, Hipkins and English (1999) consider that it must be very discouraging for teachers who have a deficit of science content knowledge to contend with the complexity of some science concepts. This further highlights the need to study teachers' use of these ICT-based resources. Andreassen and Bråten (2013) suggest a number of ways that teachers can be assisted to improve their effectiveness of source evaluation self-efficacies, including the role that initial teacher education plays in preparing pre-

service teachers to negotiate the online context. They state that, "given that teachers need to evaluate the trustworthiness of sources by attending to relevant source features, concerning a product as well as the producer, throughout their professional careers, efforts to raise source evaluation self-efficacy may even be considered an important aspect of teachers' lifelong learning" (p. 833). They suggest that this is an important issue for teacher pre-service training and in-service professional learning. Research into the inter-relatedness of different aspects of self-efficacy, curiosity and exploratory behaviours and science content knowledge on the use of ICT-based resources by primary teachers would perhaps ultimately pave the way for better professional learning for both pre- and in-service teachers concerning better use of such resources.

6.4.5 Teacher Education Training

Generalist primary teachers have a broad range of subject areas to teach, and it seems logical to begin addressing the many issues that surround the teaching of primary science at the level of teacher education. Primary teacher education is already being addressed in a number of Australian tertiary institutions. However, with more than 6,000 primary-trained teachers graduating in Australia each year between 2005 and 2012 (AITSL, 2014), a considerable amount of work to address these issues remains to be done. "Teacher preparation programs influence preservice elementary teachers' attitudes of teaching science in the classroom" (Lee, 2012, p. 3). This observation about attitudes is supported by other researchers who also reported increased confidence and lower anxiety around teaching science (e.g., Ginns & Foster, 1983; Riegle-Crumb et al., 2015; Tessier, 2010).

The Australian Catholic University (ACU) recently introduced a BOSTES NSW-accredited under-graduate degree - the Bachelor of Education (Primary) - which equips pre-service primary teachers with more science content knowledge than its previous degree courses. At its NSW campuses, pre-service primary teachers must undertake one discipline-based unit in each of science, mathematics, digital communication technologies and literacy. Therefore, at these campuses, it is mandatory for students - the vast majority of whom have not studied science to the

NSW HSC level and/or have low self-efficacy for science - to enroll in three science education courses. "One [course] deals solely with science content knowledge and the other two are science curriculum pedagogy and assessment units" (personal communication, Prof. van Rooy, November 17, 2016).

The science content course comprises 12, 1-hour lectures plus a two-hour workshop and focuses on the "big ideas of science … chemistry (particulate matter, physical and chemical change, everyday chemicals, energy); physics (force and motion, light and sound, electricity, energy); earth and space (astronomy, earth structure including soils, climate) and biology (ecology, biodiversity/adaptation and classification)" (personal communication, van Rooy, November 17, 2016). While van Rooy reports that there is other equally important science content that is not covered in the course, the courses offered encapsulate most of the BOSTES NSW K- 6 primary syllabus for the S&T KLA which teachers must know and understand:

> … whilst [this course] is challenging for many students, the unit has been conceptualised to ensure that pre-service primary teachers are conversant with some of the big ideas of science, have hands-on practical experiences of science content and begin to engage with science as a way of knowing and understanding their world and that of young Australians (personal communication, (van Rooy, November 17, 2016)

As discussed in previous sections, there exist links between teachers' content knowledge, self-efficacies (in science teaching, internet and source evaluation), curiosity and exploration behaviours, and their successful searching for and finding information using ICT-based resources. If primary teachers experience high-quality pre-service teacher courses which improve their science content knowledge, then improvements in the other areas are likely to follow and teachers' use of ICT to further enhance their science content knowledge should improve.

Because teachers are individuals operating in a discrete and distinct school context, they need an awareness of their science content deficits. Given that teacher self-

education is an ongoing and never-ending process, future research might investigate the best approach to guide pre-service, and all teachers, on how to be self-directed learners and on how to make effective use of the ICT-based science resources. This is a reflection of Symington and Hayes' (1989) suggestion about the usefulness of finding strategies to assist teachers to increase their awareness or comprehension of the world of science. Further, investigations of how to better educate teachers to seek out and avail themselves of both formal and informal PL opportunities - in order to address their individual needs, and evaluate for themselves the ongoing benefits of pursing opportunities throughout their careers as teachers - are likely to be valuable for teachers and ultimately their students. The effectiveness of mentors working with new-career teachers over a number of years after initial employment following graduation would also be worth investigating given the attrition rate of these teachers during their early years - typically the first five - of teaching (McKinnon, 2016).

The new NSW Hub School Partnership initiative - launched in NSW in late 2015 as part of the state government's "Great Teachers, Inspired Learning" (GTIL) strategy - aims to develop and deliver improved Initial Teacher Education (ITE) training through university and school partnerships. This approach, which will potentially co-deliver ITE courses on both university and school campuses, might offer part of the solution to better all-round teacher training. Kenny et al. (2014) argue that integrating pre-service primary teacher education into schools to provide pre-service teachers with authentic science teaching experiences" (p. 45) has a positive impact in building the confidence "and preparedness" (p. 61) of those teachers to teach science. Hopefully, the shortcomings related to teaching science might be more thoughtfully addressed provided that school communities are aware that such shortcomings exist. Research on the impacts of this approach would be welcomed as the initiative progresses.

One of the major reform foci put forward by the Teacher Education Ministerial Advisory Group (TEMAG) Report entitled "Action Now: Classroom ready Teachers" (TEMAG, 2014) was centred on teacher education courses having stronger quality assurance and acknowledged that "not all initial teacher education programs are equipping graduates with the content knowledge ... they need to respond to different student learning needs" (p. ix). The Australian Primary

Principals' Association (ASPA) recommended to TEMAG that, with respect to subject content, "primary school teachers must have deep understanding of the principles that underpin the content in all subject areas" (ASPA, 2015, p. 3) whereas secondary teachers must have much more in-depth knowledge of their chosen teaching subject-area(s) and this needs to be reflected in teacher education course design. As noted earlier, with the implementation from 2013 of the AITSL APSTs which detail levels of knowledge and skills required for accreditation at each of the four identified teacher career stages, the inclusion of Standard 2 within the teaching 'domain' of 'Professional Knowledge' - titled "Know the content and how to teach it" (AITSL, Feb. 2011) - hopefully, will ensure that science content knowledge is addressed in an ongoing manner. Whether or not this becomes the case remains to be seen as the accreditation process becomes fully implemented by the end of, and beyond 2017. This area provides research opportunities as new teacher education programmes are implemented.

The ASTA & OCS primary teacher survey results showed that, out of a maximum rating of 10 points, the participants gave ITE in science content a score of 5.2 points. The report noted that "it is clear that pre-service training does not adequately prepare teachers" (2014, p. 5). It might be worthwhile for ITE courses to give primary teacher education students the flexibility to choose subjects which allow them to enhance their weaker content knowledge areas during the course so that pre-service teachers could, for example, pursue appropriate science content-based courses. This strategy could also apply to students entering a Master of Education programme if they lack science subjects at the tertiary level. ITE courses across Australia which address deficits in primary teachers' science content knowledge with agreed subject content knowledge benchmarks and common course assessment requirements might also assist in lifting the status of science teaching in NSW and in primary schools across Australia.

Closer tertiary institution/school partnerships, such as the HUB Initiative described above, allow school communities to interact with tertiary institutions to deliver pre-service teacher education in ways that enhance the preparedness of pre-service teachers. Institutions in partnership are likely to have more accurate perceptions of, and can make recommendations about, which teaching standards need to be

addressed in pre-service teacher education and for early career teachers to meet standard benchmarks. Such partnerships might ensure that areas of weakness such as content knowledge are more rigorously addressed at the tertiary level. In combination with closer monitoring and evaluation of new career primary teachers, would have multiple benefits. As Tilgner (1990) suggests, in order to improve the quality of primary science education, it is necessary to examine, among other things, the teacher education training of those who deliver the curriculum. To a large degree, this still seems to be the case. Again, these areas are open to further research opportunities which can lead to changes in pre-service teacher education, including more effective and appropriate use of ICT-based resources.

6.4.6 Employing Specialist Science Teachers

The employment of specialist science teachers in primary schools has been advocated (Ardzejewska et al., 2010; Gove, 2011; Paton 2011; UMGSE, 2013). A relatively small proportion of primary schools across all sectors employ specialist teachers on either a full- or part-time basis, as was the case in my research. However, as the UMGSE commented in 2013, it is becoming indefensible to expect primary teachers to deliver the curriculum across a number of KLAs with equal expertise. Gess-Newsome (1999) considered the employment of specialist science teachers in primary schools in a leadership position and/or to assist colleagues to be a positive step. Ardzejewska et al. (2010) also commented that their study "demonstrated that there is wider support for and use of specialist teachers in New South Wales government primary schools" (Conclusion section, para. 1). Although there is a case for the employment of specialist teachers, it would be prudent to consider the impact on teachers who have had the benefit of having their classes taught by specialist science teachers and must then move - for whatever reason - to another school where they must again teach science.

It was reported through the surveys and interviews that quite a few primary schools relied upon their RFF teachers to teach science. A primary teacher who transfers from a school where this was the case might have, by that time, become even more distanced from their science content knowledge. This scenario was mentioned during

teacher interviews: *"I like teaching science but because, I haven't taught it for so long, I find it difficult"* (P5, teacher interview, May 8, 2016, 3.2.2). The same scenario might apply to teachers moving from schools which employ specialist science teaches or use secondary teachers to assist.

In the 'Science Spark' programme, Lowe and Appleton (2014) found that some primary teachers felt intimidated by the presence of secondary science teachers who were there to assist them. It was found that this type of strategy can threaten the self-efficacy of primary teachers and, ultimately, their science teaching. There is also the possibility of disempowering those same primary teachers who have had assistance in one form or another when they are moved to another school, because little or none of this knowledge was transferred to them from the specialist teacher (Lowe & Appleton, 2014). Situations such as this could weaken the teacher's confidence if they return to teaching science. Alternatively, teachers who find themselves in this predicament need support - for their own well-being and to enable them to deliver a high-quality science education to their students.

6.4.7 Engaging Volunteers to Assist Primary Teachers

The setting up and maintenance of some of the initiatives mentioned above are always accompanied by a financial cost. In NSW schools, the involvement of community members to assist primary students with reading and other skills - at school and on a voluntary basis - during their K - 6 years is well known and, for the most part, has proven successful (Block et al., 2012; Potter, 1994). Extending the engagement of volunteers into the S&T KLA arena could provide assistance to primary teachers if help is needed. This measure could be useful even as a temporary one to assist with bridging the gap while more new primary teachers with better science qualifications are graduated from their initial teacher education degrees.

There is scope for future research into the possibility and feasibility of initiating community-based programmes to draw upon the knowledge and expertise of community members, especially retired science teachers or those who work part-time, and people who have retired from employment in other science-related careers.

At the present time, many NSW secondary teachers are retiring between the ages of 55 and 60 years and are capable of continuing to work in schools. Their assistance in a voluntary advisory and/or mentoring capacity, after they have been briefed on the teaching culture of a particular school and the primary S&T KLA curriculum, might also give primary school teachers an opportunity to enhance their science content knowledge. These mentors/advisors - effectively 'human resources' - could assist in enhancing primary teachers' science content knowledge through direct knowledge transfer and guidance on how to make effective use of available resources. Whilst improvements to pre-service teacher education and other areas are being made, engaging volunteers with a sound science background to assist primary teachers in any capacity - in an environment that is supportive of both parties - is likely to be a positive step.

6.4.8 Status of Science in Primary Schools

The status of science in a primary school can have an overarching effect on many aspects related to science education in that school (Murphy & Beggs, 2005; Wilson & Crook, 2015). In some cases in particular, there can be an inter-relationship between the status of science teaching in a school and teachers' lack of science content knowledge (Stevens & Davis, 2007). Other impacts, for example, include those on teacher professional learning (Flores, 2004), the availability and use of resources, and the time spent teaching science (Fitzgerald et al., 2013). Concerns have been voiced in the literature relating to the professional isolation of teachers in provincial areas and the impact that this can ultimately have on the learning of students in affected schools (Smith, 2015; Thompson et al., 2015). Future research on the teaching of science in Australian provincial schools relative to that in metropolitan schools could assist with future planning for professional learning and teacher support. Because many Stage 3 staff in provincial schools must operate in relative professional isolation, and with the forecasted improvements in internet connectivity across NSW, there is an opportunity for teachers to engage more effectively with ICT-based science resources to enhance their science content knowledge.

6.5 Concluding Remarks

For some time, Schmidt has promoted science in primary schools asserting that "all the evidence is that if you lose the kids in primary school it is almost impossible to make them able to catch-up on the science and maths later on" (Smith, 2012, para. 6). When it comes to enhancing the outcomes of student-performances in the sciences, primary teachers "are the key" (Smith, 2012, para. 1). However, many generalist primary teachers rely on delivering lesson material that is provided to them by their school, colleagues and other sources rather than developing materials of their own which evolve over time and are informed by the teacher's own experiences and ongoing learning. To maximise the benefits that can be gained from engaging with ICT-based resources, the generalist primary teacher must cross a boundary between being a passive deliverer of pre-organised and 'recipe-style' units of work and become intellectually active in pursuing a level of excellence in his/her teaching consistent with the Australian Professional Standards (AITSL, February 2011).

The enhancement of science content knowledge is an important and integral component of endeavours to assist teachers to further improve their own sense of professional identity - where needed - as successful teachers. Teachers need to be given time to pursue suitable formal, or less-formal, learning experiences. Additionally, teachers need to see themselves as lifelong learners and to be willing learners - even though this would potentially be demanding and challenging for some. Teachers are aware of what is needed to improve the status of science in their schools, and in their classroom teaching in order to maximise student outcomes in science. Extrinsic and intrinsic influences can encourage or discourage primary teachers to continue their self-directed learning in science and continue to enhance their content knowledge and, thus, improve upon other aspects of their teaching.

A media release entitled 'Why is it time to target teaching to the needs of every Australian child', which outlines the findings of the 2015 Grattan Institute Report (No. 2015-6) of the same title, suggests that Australian education systems and their schools make much effort to determine the needs of individual learners and differentiate their teaching to meet those needs. Goss emphasises that teachers must

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"focus single-mindedly on what each student knows now, target their teaching ... and track every student's progress" (Goss, 2015, para. 7). Goss (2015) highlights that Australian students' PISA scores are currently falling behind desired levels and need to be improved. However, even though science scores fall into this category, little mention is made of them by Goss, or to how student progress in science might be aided by simultaneously assisting those who teach science. Most of the report's emphasis is on literacy and numeracy, which is a reflection of societal and political interest in this area. The media outcry and discussion in academic circles in late 2016 surrounding the science results of Australian primary and junior secondary students in the 2015 TIMSS and PISA might prompt continued focus on the status of science in NSW primary schools.

 "Teacher's self-directed learning is influenced not only by their experience in teaching, but also by current national policies and societal discussions in education, … by school context and by individual factors related to teachers' professional and personal lives" (Louws et al., 2017, p. 181). Effective teaching is a complex task which is influenced by many factors, some of which have been examined in this research by way of building a picture of the culture of the schools in which the teachers worked. The culture of a school can have a positive or negative impact on the overall teaching of science and/or directly on the teachers themselves and, consequently, on their approach to science teaching. The education backgrounds of the teachers participating in my study and the professional learning in which they engaged were also investigated to give a more complete idea of their grounding as teachers of science and their ongoing growth and development.

This study has demonstrated that many of the teachers in the research sample, whose self-efficacy with respect to teaching science was not strong, taught in school environments in which the teaching of science was not well supported. The majority of these teachers had a limited science background and identified a need to enhance their science content knowledge. It is worth reiterating Bebell, Russell, and O'Dwyer's (2004) contention that although many teachers make use of available technologies both in and out of the classroom, many more do not. In relation to my research, teachers might not yet maximise the use of ICT-based science resources that provide one way for them to enhance their knowledge and understanding of

science content and, ultimately, assist in maximising learning outcomes among their students. The results of my study indicate that the participating teachers generally did not optimise their use of available ICT-based science resources through persistent, in-depth online searches or the use of other ICT-based resources.

In the Introduction chapter of this thesis, it was highlighted that many students in NSW begin their high school years after varied experiences in their primary schools - both in the depth of the science taught and the amount of time spent engaged in science in the S&T KLA. As demonstrated both in this and in other research, some of the differences in primary student science experiences are either the direct or indirect result of their primary teachers' own levels of science content knowledge. The challenge, then, becomes how to assist primary teachers to deliver effective science learning experiences despite many of them having poor science content knowledge.

At this stage of the twenty-first century, it is no longer acceptable for an early career primary teacher who was a high-achiever amongst her university ITE cohort to state that *"I hate teaching science, and try to avoid it, because I don't really understand it"* (name withheld, personal communication, 25 January, 2015). Therefore, for the benefit of students, the development of their science literacy, and ultimately the benefit of the broader community, the effective use of ICT-based science resources by Stage 3 teachers in NSW to enhance their science content knowledge should be of great interest and consequence to the generalist primary school teacher who is obliged to teach science.

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Appendices

Appendix 1: Ethics Approval Samples

1.1   Curtin Ethics Approval 2013

Curtin University
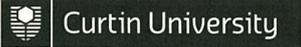
Memorandum

To	Anne Galvin, SMEC	Office of Research and Development
From	Pauline Howat, Administrator, Human Research Ethics Science and Mathematics Education Centre	Human Research Ethics Committee
Subject	Protocol Approval **SMEC-30-12**	Telephone 9266 2784
Date	7 June 2012	Facsimile 9266 3793
Copy	Vaille Dawson, SMEC	Email hrec@curtin.edu.au

Thank you for your "Form C Application for Approval of Research with Low Risk (Ethical Requirements)" for the project titled *"The use of information and communication technology-based science resources by New South Wales stae 3 primary school teachers"*. On behalf of the Human Research Ethics Committee, I am authorised to inform you that the project is approved.

Approval of this project is for a period of twelve months **7th June 2012** to **6th June 2013**.

The approval number for your project is **SMEC-30-12**. *Please quote this number in any future correspondence*. If at any time during the twelve months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately.

PAULINE HOWAT
Administrator
Human Research Ethics
Science and Mathematics Education Centre

Please Note: The following standard statement must be included in the information sheet to participants:
This study has been approved under Curtin University's process for lower-risk Studies (Approval Number SMEC-30-12). This process complies with the National Statement on Ethical Conduct in Human Research (Chapter 5.1.7 and Chapters 5.1.18-5.1.21).
For further information on this study contact the researchers named above or the Curtin University Human Research Ethics Committee. c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth 6845 or by telephoning 9266 9223 or by emailing hrec@curtin.edu.au.

J:\SAE\SMEC\office\Pauline\ETHICS\Ethics Approval Letter 2012\Galvin.docx   CRICOS Provider Code 00301J

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1.2 Catholic Education Office Sydney Ethics Approval 2013

Catholic Education Office Sydney

www.ceosyd.catholic.edu.au

10 September 2012

Ref: Research Application 811

Anne Galvin
4 Adelong Place
WAHROONGA NSW 2076

Dear Anne,

RE: RESEARCH APPLICATION REF: 811 – LETTER OF APPROVAL

Thank you for the submission of your application to conduct research in Archdiocesan Catholic Schools under the jurisdiction of the Catholic Education Office (CEO) Sydney. Approval is given by CEO Sydney to conduct this study. **This approval is granted subject to full compliance with NSW Child Protection and Commonwealth Privacy Act legislation.** It is the prerogative of any Principal or staff member whom you might approach to decline your invitation to be involved in this study or to withdraw from involvement at any time.

Permission is given for you to approach the Principals of the schools nominated, listed below, requesting participants for your study: *"The use of Information and Communication Technology – based Science resources by New South Wales Stage 3 Primary School teachers"*;

Prospective school names deleted

COMMONWEALTH PRIVACY ACT
The privacy of the school and that of any school personnel or students involved in your study must, of course, be preserved at all times and comply with requirements under the Commonwealth Privacy Amendment (Private Sector) Act 2000. In complying with this

legislation, the CEO, Sydney has decided that, for the purposes of research applications, students are not to be identified by anything other than age and/or gender.

NSW CHILD PROTECTION REQUIREMENTS
It is noted that your proposed study methodology **does not involves direct unsupervised contact with students.** Approval to conduct this research study in Sydney Archdiocesan Catholic Schools under the jurisdiction of the CEO Sydney is granted subject to the researcher's **full compliance** with the **'Commission for Children and Young People Act 1998'.**

As a student from Curtin University of Technology, you are required to complete the *Volunteer/Student Declaration* only, the original of which I hold with your application package. Enclosed with this letter is a photocopy of the form; provided for sighting by the Principal at each participating school.

FURTHER REQUIREMENTS
When you have established your participating schools, please **complete the attached form and return it** to this office.

It is a condition of approval that when your research has been completed you will forward a **summary report of the findings and/or recommendations** to this office as soon as practicable after results are to hand.

All correspondence relating to this Research should note 'Ref: Research Application 811:

Please contact me at this office if there is any further information you require. I wish you well in this undertaking and look forward to learning about your findings.

Yours sincerely,
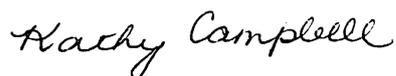
Kathy Campbell

Kathy Campbell
Head: Policy and Corporate Services
Email: kathy.campbell@syd.catholic.edu.au

1.3 Catholic Education Office Wagga Wagga Ethics Approval 2012

8 August 2012

Anne Galvin
4 Adelong Place
WAHROONGA NSW 2076

Dear Anne

I refer to your application seeking permission to contact teaching staff of a number of Catholic Primary Schools in the Diocese of Wagga Wagga in order to conduct research for your study titled "The use of information and communication technology – based science resources by NSW Stage 3 primary school teachers".

I wish to advise that approval is granted for you to approach the primary schools in the Diocese of Wagga Wagga in order to seek their willingness to participate in this research. However, the decision to participate is the prerogative of the Principal.

Should you require further details, please do not hesitate to contact Rosemary Clarke at this office on (02) 69370048.

Yours sincerely

Alan Bowyer
Director of Schools

1.4 NSW DEC SERAP Ethics Approval 2012

NSW **Education &**
GOVERNMENT **Communities**

Mrs Anne Galvin   DOC 11/
4 Adelong Place
WAHROONGA NSW 2076

Dear Mrs Galvin   SERAP Number **2012175**

I refer to your application to conduct a research project in New South Wales government schools entitled *The use of Information and Communication Technology-based Science resources by New South Wales Stage 3 Primary School teachers.*. I am pleased to inform you that your application has been approved. You may now contact the Principals of the nominated schools to seek their participation. **You should include a copy of this letter with the documents you send to schools.**

This approval will remain valid until 06/06/2013.

No researchers or research assistants have been screened to interact with or observe children for the purposes of this research.

I draw your attention to the following requirements for all researchers in New South Wales government schools:

* School Principals have the right to withdraw the school from the study at any time. The approval of the Principal for the specific method of gathering information for the school must also be sought.
* The privacy of the school and the students is to be protected.
* The participation of teachers and students must be voluntary and must be at the school's convenience.
* Any proposal to publish the outcomes of the study should be discussed with the Research Approvals Officer before publication proceeds.

When your study is completed please forward your report marked to Manager, Schooling Research, Department of Education and Training, Locked Bag 53, Darlinghurst, NSW 2010.

You may also be asked to present on the findings of your research.

Yours sincerely

for Bill Tomlin
R/Senior Manager
Student Engagement and Program Evaluation
4 October 2012

1.5 NSW DEC SERAP Ethics Variation Approval 2015

Mrs Anne Galvin
4 Adelong Place
WAHROONGA NSW 2076

BOX/026575
DOC15/157058
SERAP 2012175

Dear Mrs Galvin

I refer to your application for variation to the research project entitled *The use of Information and Communication Technology-based Science resources by New South Wales Stage 3 Primary School teachers*. I am pleased to inform you that your application has been approved.

This approval will remain valid until 25-Jun-2015.

As this research does not involve face-to-face contact with children, no researchers or research assistants have been screened to interact with or observe children.

When your study is completed please email your report to serap@det.nsw.edu.au.

Yours sincerely

Dr Robert Stevens
Manager, Quality Assurance/Research
19 March 2015

NB. All ethics approvals were renewed annually as required.

Appendix 2: Letters Sent to Schools - Samples

2.1 Letter of Introduction to the Principals

<div align="right">
4 Adelong Place
WAHROONGA NSW 2076
01 March 2013
</div>

Dear Principal's name

Thank you for allowing your school and selected staff to participate in my PhD research project entitled "The use of information and communication technology-based Science resources by NSW Stage 3 Primary school teachers" which I am running throughout the 2013 academic year.

Accompanying this letter are the Phase I surveys. One survey is for completion by either the Principal or a representative Executive Staff Member. The second survey is for completion by the participating teacher(s) of Stage 3 students. All identification on surveys, which is just there for tracking purposes, will be removed after receipt.

Please return the completed surveys at your earliest convenience. Being a teacher myself, I realise that schools are very busy environments and that teachers are also very busy. Therefore, I am happy to receive the completed surveys sometime before the end of Semester I.

The surveys can either be returned by mail to the above address or by email to galvinsresearch@gmail.com

Once again, thank you for your assistance and I look forward to your participation in the project.

Kind regards,

Signature here

Anne Galvin

2.2   Letter to Principals Accompanying Phase I Survey

<div align="right">
4 Adelong Place
WAHROONGA NSW 2076
01 March 2013
</div>

Dear Principal's name

Thank you for allowing your school and selected staff to participate in my PhD research project entitled "The use of information and communication technology-based Science resources by NSW Stage 3 Primary school teachers" which I am running throughout the 2013 academic year.

Accompanying this letter are the Phase I surveys. One survey is for completion by either the Principal or a representative Executive Staff Member. The second survey is for completion by the participating teacher(s) of Stage 3 students. All identification on surveys, which is just there for tracking purposes, will be removed after receipt.

Please return the completed surveys at your earliest convenience. Being a teacher myself, I realise that schools are very busy environments and that teachers are also very busy. Therefore, I am happy to receive the completed surveys sometime before the end of Semester I.

The surveys can either be returned by mail to the above address or by email to galvinsresearch@gmail.com

Once again, thank you for your assistance and I look forward to your participation in the project.

Kind regards,

Signature here
Anne Galvin

2.3 Information Sheet for Principals

The use of Information and Communication Technology-based Science resources by New South Wales Stage 3 Primary School teachers.

Information sheet for Principals.

Purpose of research

The purpose of this research is to investigate the use of Information and Communication Technology-based Science resources by New South Wales Stage 3 Primary School teachers.

The research will be carried out in two phases.

- Phase I: I will gain an overview of the culture of teaching science to Stage 3 students in NSW primary schools and the factors which are perceived to affect this. Principals (or an Executive representative) and one or two Stage 3 teachers from each school will be invited to participate in completing separate, brief and easy-to-complete surveys. **Approximate time commitment Semester 1 – 10 minutes (principal), maximum 15 minutes (teachers)**

- Phase II: Will involve only half the number of schools from Phase I. I will investigate the uses of ICT resources by Stage 3 teachers to enhance their Science content knowledge and to discern any difference in the frequency of this usage between teachers in metropolitan and provincial schools. Ideally, these participating teachers will be selected from the schools which participate in Phase I.

- Phase II will consist of participants initially completing two easy-to-complete electronic surveys. These will be followed-up by a brief written questionnaire and the keeping of a log of ICT usage. The log format will be kept as simple as possible so that it is quick to fill-out. **Approximate time commitment for teachers Semester II – 2 x 30 minute surveys plus 1 x 10 minute survey plus log which will take a couple of minutes per entry.**

- **Consent to participate**

  Your own involvement in the research and that of your school is entirely voluntary. You have the right to withdraw your own involvement and/or that of the school and its staff at any stage without it affecting your rights or responsibilities. At the conclusion of the study you will be given a brief summary of the findings and a comprehensive list of ICT Science resources resulting from this study to be made available to the school's staff.

  Confidentiality

  The information you provide will be kept confidential. No individual staff member, school name or identifying information will be used in any public presentation or published document. Pseudonyms will be used when presenting research findings.

  Further information

  This research has been reviewed and given approval by Curtin University Human Research Ethics Committee (Approval number SMEC-30-12). If you would like further information about the study, please feel free to contact me on 02 9489 1451 or by email galvinsresearch@gmail.com

Alternatively, you can contact the Curtin ethics officer (Ms. Linda Teasdale) on 08 9266 2784 or l.teasdale@curtin.edu.au

Thank you very much for your involvement in this research; your participation is greatly appreciated. A stamped, addressed envelope has been enclosed.

2.4 Information Sheet for Teachers

Curtin University

The use of Information and Communication Technology-based Science resources by New South Wales Stage 3 Primary School teachers.

Information sheet for Participating Teachers of Stage 3 Students.

Purpose of research

The purpose of this research is to investigate the use of Information and Communication Technology-based science resources by New South Wales Stage 3 Primary School teachers.
The research will be carried out in two phases.

- Phase I: I will gain an overview of the culture of teaching science to Stage 3 students in NSW primary schools and the factors which are perceived to affect this. Principals (or an Executive representative) and one or two Stage 3 teachers from each school will be invited to participate in completing separate, brief and easy-to-complete surveys. **Approximate time commitment Semester 1 – maximum of about 15 minutes**

- Phase II: Will involve only half the number of schools from Phase I. I will investigate the uses of ICT resources by Stage 3 teachers to enhance their Science content knowledge and to discern any difference in the frequency of this usage between teachers in metropolitan and provincial schools. Ideally, these participating teachers will be selected from the schools which participate in Phase I.

- Phase II will consist of participants initially completing two easy-to-complete electronic surveys. These will be followed-up by a brief written questionnaire and the keeping of a log of ICT usage. The log format will be kept as simple as possible so that it is quick to fill-out. **Approximate time commitment Semester II – 2 x 30 minute surveys plus 1 x 10 minute survey plus log which will take a couple of minutes per entry.**

Consent to participate

Your involvement in the research is entirely voluntary. You have the right to withdraw your own involvement at any stage without it affecting your rights or responsibilities. At the conclusion of the study the Principal will be given a brief summary of the findings and a comprehensive list of ICT Science resources as a resulting from this study to be made available to the staff of your school.

Confidentiality

The information you provide will be kept confidential. No individual staff member or identifying information will be used in any public presentation or published document. Pseudonyms will be used when presenting research findings.

Further information

This research has been reviewed and given approval by Curtin University Human Research Ethics Committee (Approval number SMEC-30-12). If you would like further information about the study, please feel free to contact me on 02 9489 1451 or by email galvinsresearch@gmail.com Alternatively, you can contact the Curtin ethics officer (Ms. Linda Teasdale) on 08 9266 2784 or l.teasdale@curtin.edu.au**.**
Thank you very much for your involvement in this research; your participation is greatly appreciated. Your principal has been supplied with a stamped, addressed envelope for consent returns.

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2.5 Consent Form for Principals

CONSENT FORM FOR PRINCIPALS PHASE I
(Alternatively, this is to be completed by an executive staff member representing the principal)

_____

• I understand the purpose and procedures of the study.

• I consent to allow staff members of this school to participate in Phases I and II of this study if they wish to do so.

• I have been provided with the participation information sheet.

• I understand that the procedure itself may not benefit me.

• I understand that my involvement is voluntary and I can withdraw at any time without problem.

• I understand that no personal identifying information like my name and address will be used in any published materials.

• I understand that all information will be securely stored for at least 5 years before a decision is made as to whether it should be destroyed.

• I have been given the opportunity to ask questions about this research.

• I agree to participate in the study outlined to me.

_____

Please indicate whether one or two teachers of stage 3 will be participating so that I can send the correct number of surveys.   _____

Name: _____ (Please Print)

Signature: _____

School: _____

Date: _____

2.6 Consent Form for Teachers

Curtin University

CONSENT FORM FOR TEACHERS OF STAGE 3 - PHASES I and II

_____

• I understand the purpose and procedures of the study.

• I have been provided with the participation information sheet.

• I understand that the procedure itself may not benefit me.

• I understand that my involvement is voluntary and I can withdraw at any time without problem.

• I will initially agree to participate in Phases I and II. I do not have to participate in Phase II if I
   change my mind.

• I understand that no personal identifying information like my name and address will be used in any
published materials.

• I understand that all information will be securely stored for at least 5 years before a decision is made
as to whether it should be destroyed.

• I have been given the opportunity to ask questions about this research.

• I agree to participate in the study outlined to me.

_____

Name: _____ (Please Print)

Signature: _____

Date: _____

Appendix 3: Phase I and II Surveys

NB: Spacing for answers has been changed with reformatting for resizing of surveys.

3.1 Phase I Principals' or Executive Staff Members' Survey

PHASE I QUESTIONS: Principal or Executive Staff Member

PHASE I: These questions to be answered by the Principal or Executive Staff member.
 (Note: "SECTION"'s are for the researcher's reference only)

Name of school (this is only for purposes of initial record-keeping and will be removed before data analysis is undertaken)

_____

_____

School's postcode: _____

How is your school classified by the "MySchool" website? [   ] Metropolitan
 [   ] Provincial

Number of students:
[   ] <100   [   ] 100-200   [   ] 200 – 500   [   ] 500 – 800
[   ] 800+

Your school is: [   ] State   [   ] Catholic   [   ] Independent

SECTION 1:
1.a.i Please briefly state the school's policy relating to the teaching of science.

_____

_____

_____

_____

If there is no specific policy is there a reason for this? Briefly explain why this is the case.

_____

_____

_____

_____

b.i Does the teaching of some subject areas in your school have higher priority than others? For example, does the teaching of English and Mathematics have a higher priority than other subjects? Please outline these priorities - with particular reference to Science if it features in these priorities.

_____

_____

_____

_____

ii. Is there are particular reason for the setting of these priorities in your school? For example, the school might have a particular focus on improving Literacy and Numeracy and these are, therefore, given very high priority.

_____

_____

_____

_____

_____

iii. Does the school employ specialist science teachers? [   ] Yes [   ]   No

    IF YES: does the teacher teach Stage 3 students?

                                        [   ] Yes – all stage 3 students

                OR   [   ] Only some Stage 3students

                OR   [   ] No Stage 3 students

    IF YES: The Science specialist employed on a: [   ] Full time   [   ]   PPT basis?

    IF YES : How many? _____

  Additional comments (optional) on the teaching of science in your school

_____

_____

_____

_____

THANK YOU

3.2 Phase I Teachers' Survey

PHASE I QUESTIONS: Teachers of Stage 3 Students

PHASE I: These questions to be answered by at least one staff member who is teaching Science and Technology to Stage 3 students.

Name of school (this is only for purposes of initial record-keeping and will be removed before data analysis is undertaken)

_____

Name of stage 3 teacher (also only for purposes of initial record-keeping and will be removed before data) analysis is undertaken:

_____

School's postcode: _____

SECTION 2: (Note: "SECTION"s are for the researcher's reference only)

2. i. Are you a: [ ] Generalist-trained Primary Teacher ? [ ] Specialist Science or Science and Technology teacher?

ii. Approximately how much time do you spend teaching the Science and Technology KLA to each Stage 3 class per week?
[   ] <0.5h   [   ] 0.5h[   ]   0.5 – 1h   [   ] 1 – 2h   [   ]>2h iii.

Are the Science and Technology resources available to you at school:
[ ] good   [ ] OK   [ ] poor

iv. Please list as many factors as possible which you consider to affect the teaching of Science and Technology in your school. These factors can be extrinsic (e.g. the school's policy/teaching priorities; community/parental expectations; school budget/resources; time allocated to teaching subjects; availability of a specialist Science and Technology teacher or presence of teachers who have some Science and Technology expertise; etc..) or intrinsic (e.g. your own expertise/interests, subject teaching priorities, beliefs about the students you teach, etc..). Please explain if you feel this is necessary.

_____

_____

_____

_____

_____

_____

_____

v. Do you perceive that your school places more emphasis on any subjects other than Science and Technology? If so, please name them:

_____

_____

_____

SECTION 3:

3. Do you feel that your knowledge of Science content needs to be supplemented to enhance your ability to teach Science and Technology effectively? [ ] Yes [ ] No

IF YES: do you access resources to achieve this?   [   ] Yes [   ] No

Please identify any resources by name, author or URL (where applicable), etc. that you use to supplement your Science content knowledge (e.g., Science or Science and Technology text books, hard-copy/soft-copy resources provided by the school, internet sites, twitter, working with a mentor, team teaching, etc.).

_____

_____

_____

_____

_____

_____

If you team-teach and/or work with a mentor please briefly describe these

partnerships.

_____

_____

_____

_____

Please list any Professional Learning courses that you have attended in the last two years including the course names, course provider and course duration. If you are unable to recall all of the details please identify as much as you can.

_____

_____

_____

_____

_____

_____

IF NO:

Do you spend less time teaching Science and Technology than you think you should spend?
[   ] Yes [   ] No

OR

Do you avoid teaching Science and Technology whenever possible?
[   ] Yes [   ] No

OR

Do you just try to teach Science and Technology based on the knowledge that you feel is probably inadequate? [   ] Yes [   ] No

If you don't use resources to supplement your Science content knowledge please briefly explain why (e.g., lack of access to resources, no time, no interest, etc.)

_____

_____

_____

_____

_____

Computers in your school.
How many computers are available to you for everyday use at your school to research Science content if you wish to do so? _____

List the factors which affect your access to these computers. This might include too many staff sharing the same computer(s), lack of time, location of computer(s), other staff using a computer as if it were their own, computers often not working, etc..

_____

_____

_____

_____

_____

_____

_____

_____ Do you prefer searching for information to enhance your Science

content knowledge at home? [   ] Yes [   ] No

Why is this your preference?

_____

_____

Approximately how much time would you spend at home each week searching for
this information?
[   ] None   [   ]<0.5h   [   ]   0.5 – 1h   [   ] 1-2h   [   ] 2 -3
h
[   ] >3h

THANK YOU FOR YOUR TIME

3.3 Phase II Online Teachers' Survey

This survey was administered using "Survey Monkey Gold" software and has been downloaded from that site.

<div style="border:1px solid black;">

Phase II Questions: The Use of ICT Science Resources by NSW Stage

Science Teaching Efficacy Belief Instrument

*5. 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

	SA	A	UN	D	SD
When a student does better than usual in Science it is often because the teacher exerted a little extra effort.	○	○	○	○	○
I am continually finding better ways to teach Science.	○	○	○	○	○
Even when I try very hard I don't teach Science as well as I do most subjects.	○	○	○	○	○
When the Science grades of students improve it is most often due to their teacher having found a more effective teaching approach.	○	○	○	○	○
I know the steps necessary to teach Science concepts effectively.	○	○	○	○	○
I am not very effective in monitoring Science experiments.	○	○	○	○	○
If students are underachieving in Science it is most likely due to ineffective Science teaching.	○	○	○	○	○
I generally teach Science ineffectively.	○	○	○	○	○
The inadequacy of a student's Science background can be overcome by good teaching.	○	○	○	○	○
The low Science achievement of some students cannot generally be blamed on their teachers.	○	○	○	○	○
When a low achieving student progresses in Science it is usually due to extra attention given by the teacher.	○	○	○	○	○
I understand Science concepts well enough to be effective in teaching elementary Science.	○	○	○	○	○
Increased effort in Science and teaching produces little change in some students' Science achievement.	○	○	○	○	○
The teacher is generally responsible for the achievement of students in Science.	○	○	○	○	○
Students' achievement in Science is directly related to their teacher's effectiveness in Science teaching.	○	○	○	○	○
If parents comment that their child is showing more interest in Science at school it is probably due to the performance of the student's teacher.	○	○	○	○	○
I find it difficult to explain to students why Science experiments work.	○	○	○	○	○
I am typically able to answer students' Science questions.	○	○	○	○	○
I wonder if I have the necessary skills to teach Science.	○	○	○	○	○
Effectiveness in Science teaching has little influence on the achievement of students with low motivation.	○	○	○	○	○
Given a choice I would not invite the principal to evaluate my Science teaching.	○	○	○	○	○
When a student has difficulty understanding a Science concept I am usually at a loss as to how to help the student understand it better.	○	○	○	○	○
When teaching Science I usually welcome student questions.	○	○	○	○	○
I don't know what to do to turn students on to Science.	○	○	○	○	○
Even teachers with good Science teaching abilities cannot help some students learn Science.	○	○	○	○	○

Page 2

</div>

Phase II Questions: The Use of ICT Science Resources by NSW Stage

General Education Background

*6. What is your gender?

○ Male   ○ Female

*7. In what year were you born?

[   ]

*8. What is the highest level of education you have completed?

○ Diploma

○ Graduate Diploma

○ Bachelor's Degree

○ At least one year of course work beyond a Bachelor's degree but not a post-graduate degree

○ Master's Degree

○ Education specialist or professional diploma based on at least one year of course work past a Master's degree level

○ Doctorate

*9. What is the highest level of Science which you studied at school?

○ NSW School Certificate (or equivalent)

○ NSW Higher School Certificate (or equivalent)

*10. Please tick the subject(s) studied:

☐ Physics

☐ Chemistry

☐ Biology

☐ Geology

☐ Senior Science

☐ First Level Science (pre-1975)

☐ 2S Science (pre-1975)

☐ 2F Science (pre-1975)

Other(s), please name:

[   ]

Tertiary Education Background

＊11. Did you have a major, minor, or special emphasis in any of the following subjects as part of your undergraduate coursework?

MARK ONE ON EACH ROW

	Yes, a major	Yes, a minor or special emphasis	No
(a) Biology or other life science	○	○	○
(b) Physics, chemistry or other physical Science	○	○	○
(c) Earth or Space Science	○	○	○
(d) Mathematics or mathematics education or engineering	○	○	○
(e) Primary education	○	○	○
(f) Secondary education	○	○	○

12. ONLY TEACHERS WITH POST-GRADUATE COURSEWORK.

If not applicable go to question 13

Did you have a major, minor, or special emphasis in any of the following subjects as part of your post-graduate coursework?

MARK ONE ON EACH ROW

	Yes, a major	Yes, a minor or special emphasis	No
(a) Biology or other life science	○	○	○
(b) Physics, chemistry or other physical Science	○	○	○
(c) Earth or Space Science	○	○	○
(d) Information and Communication Technologies or Computing	○	○	○
(e) Primary or secondary education	○	○	○

13. Counting this school year, how many years have you been teaching in a primary school? Please include part time teaching.

*A 12-month period of part time teaching counts as 1 year, not a part thereof.

14. Counting this school year, how many years have you taught Stage 3 students? Please include part time teaching.

*A 12-month period of part time teaching counts as 1 year, not a part thereof.

Page 4

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15. Counting this school year, how many years have you taught at your current school? Please include part time teaching.

*A 12-month period of part time teaching counts as 1 year, not a part thereof.

Professional Learning

In this survey "professional learning" is defined as activities that develop an individual's skills, knowledge, expertise and other characteristics as a teacher.

Please only consider professional learning that you have taken after your initial teacher training/education.

*16. During the last 18 months, did you participate in any of the following kinds of professional learning activities, and what was the impact of these activities on your Science and Technology knowledge?

For each question below, please mark one choice in (A). If you answer 'Yes' in (A) then please mark one choice in (B) to indicate how much impact it had upon your development as a teacher.

	(A) Participation: Yes	No	(B) Impact: No impact	A small impact	A moderate impact	A large impact
(a) Courses/workshops on Science and Technology Subject Matter	☐	☐	☐	☐	☐	☐
(b) Education conferences or seminars (where teachers and/or researchers present their Science and Technology research results and discuss educational problems related to Science and Technology)	☐	☐	☐	☐	☐	☐
(c) Qualification program (e.g. a degree program)	☐	☐	☐	☐	☐	☐
(d) Observation visits to other schools	☐	☐	☐	☐	☐	☐
(e) Participation in a network of teachers formed specifically for the professional learning in the area of teaching Science and Technology	☐	☐	☐	☐	☐	☐
(f) Individual or collaborative research on a Science and Technology KLA topic	☐	☐	☐	☐	☐	☐
(g) Mentoring in the Science and Technology KLA, as part of a formal or informal school arrangement	☐	☐	☐	☐	☐	☐
(h) Being mentored in the teaching of Science and Technology as part of a formal or informal school arrangement	☐	☐	☐	☐	☐	☐

*17. In all, how many days of professional learning related to Science and Technology teaching did you attend during the last 18 months?

If your answer is 0, please go to Question 21.

18. Of these, how many days were compulsory for you to attend as part of your job as a teacher?

19. For the professional learning in which you have participated in the last 18 months, how much did you personally have to pay?

○ None   ○ Some   ○ All

20. For the professional learning in which you participated in the last 18 months, did you receive release time for undertaking the professional learning that took place during regular work hours?

○ Yes   ○ No   ○ Did not take place during regular work hours

＊21. Thinking about less formal professional learning, during the last 18 months, did you participate in any of the following activities, and what was the impact of these activities on your development as a teacher?

For each question below, please mark one choice in (A). If you answer 'Yes' in (A) then please mark one choice in (B) to indicate how much impact it had upon your development as a teacher.

	(A) Participation: Yes	No	(B) Impact: No impact	A small impact	A moderate impact	A large impact
(a) Reading professional literature (e.g. Science or Science and Technology journals, evidence-based papers, thesis papers)	☐	☐	☐	☐	☐	☐
(b) Engaging in informal dialogue with your colleagues on how to improve your Science and Technology teaching	☐	☐	☐	☐	☐	☐

＊22. Thinking of your own professional learning needs related to teaching the Science content of the Science and Technology KLA, please indicate the extent to which you have such needs in the areas listed.

	No need at all	Low level of need	Moderate level of need	High level of need
(a) Knowledge and understanding of Science content for the Science and Technology KLA for teaching Stage 3	○	○	○	○
(b) ICT skills to assist my own learning of the Science content of the Science and Technology KLA	○	○	○	○

＊23. In the last 18 months, did you want to participate in more professional learning than you did?

○ Yes

○ No

24. If you answered Yes to Question 23, which of the following reasons best explain what prevented you from participating in more professional learning for the Science and Technology KLA than you did?

Please mark as many choices as appropriate.

☐ I did not have the pre-requisites (e.g. qualifications, experience, seniority)

☐ Professional learning was too expensive - I could not afford it

☐ Professional learning was too expensive - my school could not afford it

☐ There was a lack of employer support

☐ Professional learning conflicted with my work schedule

☐ I didn't have the time because of family responsibilities

☐ There was no suitable professional learning offered

Other(s) (please specify)

[   ]

The Use of Science Resources by Teachers to Enhance their Science Teaching.

If you are a GENERALIST teacher of Stage 3 students - PLEASE ANSWER QUESTIONS 25 to 35.

If you are a SPECIALIST Science teacher of Stage 3 students - PLEASE ANSWER QUESTIONS 36 to 38.

∗25. Approximately how much time on average do you spend teaching Science and Technology to each Stage 3 class per week?

○ <0.5h   ○ 1 to 2h

○ 0.5h   ○ >2h

○ 0.5 to 1h

∗26. Do you consider the Science and Technology resources available to you at school:

○ Good   ○ OK   ○ Poor

∗27. Do you perceive that your school places more emphasis on any subject(s) other than Science and Technology. If so, please name:

[   ]

∗28. Do you feel that your knowledge of Science content needs to be supplemented to enhance your ability to teach the Science and Technology KLA effectively?

○ Yes

○ No

29. Do you access resources to supplement your content needs?

○ Yes

○ No

30. On average, approximately how much time per week would you typically spend reviewing/using these resources to supplement your Science content knowledge?

○ <0.5h

○ 0.5 to 1h

○ 1 to 2h

○ >2h

31. Please list the broad types of resources that you use to supplement your Science content knowledge (e.g. Science and/or Science Technology text books, hard-copy/soft-copy resources provided by the school or external sources, Internet sites, Twitter, mentors, team teaching, Professional Learning courses, etc.). This list can include sites such as "Primary Connections" used for programming, planning and general Science information.

If you answered that there is "No Level of Need" in Question 22 on the previous page:

32. Is the time spent teaching the Science and Technology KLA shortened?

○ Yes   ○ No

OR

33. Do you avoid teaching the Science and Technology KLA whenever possible?

○ Yes   ○ No

OR

34. Do you do your best to teach the Science and Technology curriculum unassisted?

○ Yes   ○ No

35. If you do not use resources to supplement your Science content knowledge please briefly explain why (e.g. lack of access to resources, no time, no interest, etc.)

If you are a SPECIALIST Science teacher please answer Questions 36 and 37.

36. QUESTIONS 36 TO 38 ARE FOR SPECIALIST SCIENCE TEACHERS.

Do you continue to use ICT resources to further enhance your Science content knowledge?

○ Yes

○ No

37. On average, approximately how much time per week would you typically spend reviewing/using these resources?

○ < 0.5h

○ 0.5 to 1h

○ 1 to 2h

○ > 2h

38. Please list the ICT resources that you use most frequently (e.g. soft-copy resources provided by the school or external sources, Internet sites, Twitter, etc.). This list can include sites such as "Primary Connections" used for programming, planning and general Science information.

39. In the table provided, please list as many ICT resources that you are aware of even if you don't necessarily use them. Wherever possible/applicable include the URL.

1.

2.

3.

4.

5.

THIS IS THE END OF THE SURVEY. PLEASE READ THE FOLLOWING CAREFULLY.

THANK YOU very much for completing the survey. I would be very appreciative if you would complete the interactive log of your use of ICTs.

Make sure you press the Done button to submit this survey AFTER you have read the following instructions and COPIED the link:

INSTRUCTIONS:

To access the interactive log, please use this link:

https://www.dropbox.com/s/x2whz7my7wjqglv/Log%20of%20ICT%20Usage.doc

Highlight the link and copy and paste it into a new browser window.

Press Download at the top right, and then click Direct Download to save it to your computer. Add more rows as required.

When you have completed the log, please email it to me at:

galvinsresearch@gmail.com

Thank you,

Anne Galvin

3.4 Phase II Interactive Log of ICT Use

NB: This is the interactive Log table referred to in the online survey - see Page 12 above. It has been slightly re-sized to fit the prescribed margins.

LOG OF ICT USAGE:

Thank you for your further participation in Phase II of my Research. The completion of this log will provide some valuable insight into ICTs used by teachers. A comprehensive list of these resources will be provided to your school after completion of the research.

There is a great variety of resources available to teachers to supplement their Science content knowledge. Many of these are available through forms of Information Communication Technologies (ICTs). Broad examples of these forms of ICT are: purpose-made web-based resources (available through education companies, government agencies the DEC, the World Wide Web), purpose-designed twitter accounts, video conferences and general resources online.

Over a minimum of 4 weeks, please record any use of ICT resources used to supplement your Science content knowledge. Record repeat uses of each ICT re-visited. If these resources are used when planning over school holidays please also include them!

Circle which is applicable: I am a generalist primary /specialist Science teacher.

Date	Resource Name	URL, Site Author and Institution responsible for resource. For sites accessed more than once please write "see above" and the date of the first	Where site was accessed (e.g. at school, at home)	Time spent at site (minutes)	*Rank

*Please rank each site you use according to how well it meets your needs:
  3 = very useful; 2 = moderately useful; 1 = of little use

Appendix 4: Information Related to the Interviews

Phase III Interview Protocol and Questions

The use of Information and Communication Technology-based Science resources by New South Wales Stage 3 Primary School teachers.

Interview Protocol:

Date:
Time:
Method: Telephone interview
Interviewer: Anne Galvin
Interviewee (not real name):
Classification of interviewee's school: Metropolitan / Provincial. (Adapted from Creswell, 2008, p. 234)

All interviewees are teachers of Stage 3 Students in NSW Primary Schools

Establish rapport with interviewee through general conversation for several minutes.

Remind him/her of the intent of the research and that the interview aims to establish data related to teaching the science component of the Science and Technology KLA. Explain that the interview is designed to provide data which can be used as a cross-reference for other data collected in the Phase I and II surveys. That is, as a method of triangulation for the study.

Thank the interviewee for consenting to take part in the interview process. Explain that the interview will take approximately 15 minutes, is being digitally recorded and will later be transcribed by the interviewer. In accordance with ethics principles, the participant can withdraw from the interview at any time. Offer the interviewee the opportunity to receive a copy of the transcript of their interview (via email) to give them the opportunity to check the details that what they have said has been accurately transcribed and that their intent has not been misinterpreted. Remind them that the data will remain confidential and that neither they nor their school can be identified from it in any way. The only identification of their school will be as a metropolitan or provincial school – based according to the school's classification on the "My School" website.

INTERVIEW QUESTIONS:

1. For how many years have you been teaching at primary school?

2. Please describe any formal science training that you have completed at tertiary level.

3. a. Do you think that any subjects have priority at your current school?

      b.   Why do you think this is the case? *This might lead into a discussion of Literacy and Numeracy/ Primary Connections/ overcrowded curriculum/ etc. which can be discussed.*

4. a.   Do you attend or take part in any Professional Learning (professional development) that would enhance your science content knowledge?

   b.   Please outline what Professional Learning you have attended in the last year or so and what was the content and structure of the courses.

5. Do you feel confident that you have enough science background to teach the current curriculum? *discuss this.*

6. Do you access any ICT-based science resources to help you to understand curriculum science topics before you teach them? This can be web-based resources, twitter, TED talks, etc.. *Discuss which ones and how often this might be the case*

7.   a.   Would you say that most of this research to enhance your science content knowledge is done at home or at school?

   b.   Please explain why this is the case?

8. Are there any other comments you would like to make in relation to the teaching of science at primary school level?

At the conclusion of interview: Thank the interviewee for their time and allowing me to interview them and that their co-operation is greatly appreciated. Offer, again, the opportunity for them to receive a copy of the transcript via email and arrange for this to occur. Remind them that all data collected is completely confidential – as above.

Appendix 5: Additional Resource Information from Phases I To III

5.1 Online Resources

Table A5.1. Summary of Online Science-based Resources cited by participants as used for Enhancing Science Content Knowledge:

Site – as identified by the teachers	Teacher's ranking of how well the site met their needs
METROPOLITAN TEACHERS:	
www.bppsresources.weebly.com	3
CSIRO email	2*
Steve Spranger site	3#
ABC (Australia) plash	3*
www.promethian.com/en/resources	3*
www.khan academy.org	3*
www.science.org.au/primaryconnections/	3*
www.fi.edu	3*
undsci.berkeley.edu	3*
kidshealth.org/kid/	3#
www.microscope.edu.au/index.aspx	1*
"various"	2
Queensland Museum	3*
www.antarcticstation.org	3*
http://museumvictoria.com.au/scienceworks/	2*
www.bbc.co.uk/bitesize/ks2/science	3*
www.primaryconnections.org.au/science-background-resource/data/index.html/	3*
http://encyclopedia.kids.net.au/page/bu/Bouyancy	3#
BrainPOP	3#
www.youtube.com/watch?v=EAEmseXr_JM	3^
http://science.howstuffworks.com/transport/engines-equipment/submarine1.htm	3#
PROVINCIAL TEACHERS:	
http://www.globalelectricity.org/en/	2#
http://home.cc.umanitoba.ca/~stinner/stinner/pdfs/2007-alessandro.pdf	1*
http://www.energyquest.ca.gov/story/chapter02.html	3*
http://www.andythelwell.com/blobz/	3*
http://observatoryhilleec.nsw.edu.au/special-projects/watch-our-watts/	3
http://www.curriculumsupport.education.nsw.gov.au/env_ed/teaching/focus/energy.htm	3*
http://www.amysenergysave.com.au/index.html	2*
http://www.livinggreener.gov.au/	3*
http://primaryconnections.org.au/curriculum-resources/its-electrifying.html	2*
http://www.bbc.co.uk/schools/scienceclips/ages/10_11/changing_circuits.shtml	3*
http://www.hyperstaffs.info/work/physics/child/main.html	3*
http://observatoryhilleec.nsw.edu.au/special-projects/watch-our-watts/	3*
http://56fwow.wikispaces.com/	2^
http://www.environment.nsw.gov.au/sustainableschools/	3*
http://learnelectricity.ausgrid.com.au/	3*
www.sciencekids.co.nz	2*
www.sciencebob.com	2#
www.Scientistsinschools.edu.au	3*
www.kidzone.ws/science	2^

Table A5.1 Cont'd

http://au.tv.yahoo.co/staurday-disney/experiments	3^
Various YouTube videos on experiment demonstrations	2
www.neok12.com/Electricity.htm	3
Various YouTube videos on Electricity	2^ and 3^
www.scienceweb.asta.edu.au/	2*
www.coolaustralia.org	3*
www.curriculumsupport.education.nsw.gov.au	3*
www.coolaustralia.org	3*
www.earthsky.org	2^
www.getsmarts.weebly.com	3*
http://primaryconnections.org.au/curriculum-resources/its-electrifying.html	3*

Sites which can be considered to be reliable such as those which are administered by government and Non-Government Organisations(NGOs) (such as Universities, BBC, ABC (Australia), etc.). All of the NGO-sites have a government or university body in partnership with or supported by them. See * above

A number of the sites are administered by private companies# and a small number fall outside of both of the above categories ^ – such as YouTube videos, Web2 sites, etc..

5.2   Pamphlet for Participating Schools and Teachers - Sites Identified as Useful to Stage 3 Teachers to Assist With Enhancing their Science Content Knowledge

The colour pamphlet is to be printed, double-sided, onto A4-size paper and folded in the center.

5.2.1 Pages 1 and 4 of pamphlet

Teaching the NSW Science &Technology KLA to primary school students?....

Need to brush-up your science content knowledge? ...

... here are some ICT-based resources you might like to check out to help you enhance your science content knowledge.

Some other sites you might like to try out ...

➢ www.kidszone.ws/science
➢ www.sciencekids.co.nz
➢ www.khanacademy.org
➢ www.qm.qld.gov.au
➢ www.sophia.org/subjects/basic-science
➢ www.encyclopedia.kids.net.au
➢ www.brainpop.com/science
➢ undsci.berkeley.edu
➢ www.bbc.co.uk/education
➢ www.getsmarts.weebly.com
➢ www.sciencelearn.org.nz/Primary-Science
➢ www.deakin.edu.au/arts-ed/education/sci-enviro-ed/early-years/
➢ www.scienceweb.asta.edu.au
➢ www.edutopia.org/blog/websites-for-science-teachers-eric-brunsell
➢ www.skwirk.com.au/
➢ sciencelearn.org.nz/
➢ splash.abc.net.au/
➢ mashable.com/2010/05/11/science-websites
➢ www.learningscience.org

➢ TaLE – Available to NSW Department of education teachers
➢ Scootle – Available to teachers in a number of education sectors

➢ www.aussieeducator.org.au/resources/teaching/scienceresources.htm
   l - this site lists many Australian online resources some of which are great for enhancing science content knowledge

© Compiled by A T Galvin

400

5.2.2 Pages 2 and 3 of pamphlet

There are many ICT-based science resources available to you help explain the science concepts that you have to teach.

Check out some of these ...

Do you know about ...

"TED-Ed: Lessons worth sharing"?

"Bill Nye the Science Guy" videos?

"Science Alert" and "Science is Amazing" websites? (also follow these on Fb)

"Crash Course" science video series?

ABC "Splash" videos? Find them at:
www.splash.abc.net.au

Explore these sites and more to help you brush-up on your science knowledge!

Let SOCIAL MEDIA help you! ...

Pinterest ... search for your topic and you'll find lots of information to explain the science concepts you teach!

Twitter & Facebook... there are lots of teachers out there tweeting and running Fb groups on topics of interest to you. Just search for Science and you'll find lots of reliable sources of information.

Why not start your own group with other primary teachers. Have a look at "I F*****g Love Science" and "Amazing Science" on Fb, too!

Social media forums are also great places to find other resources such as activities, posters and other ideas. Give them a go!

1. "Know the content and how to teach it" – Standard 2.
Australian Professional Standards for Teachers (NSW BOSTES, 2011).
www.nswteachers.nsw.edu.au/DownloadDocument.ashx?DocumentID=1122

Appendix 6   Copyright permission letters

6.1   Pro-forma to Request Copyright Permission from Author/Organisation

(Date)

(Copyright Owner/Publisher Address)

Dear **(Copyright Owner/Publisher)**

It is my understanding that you/your organisation are the copyright holder for the following material:
Description of the material – e.g., journal article (journal number, edition, volume, month, year); book (title, author, ISBN number); diagram/illustration/photograph (title or description of image, name of publication), etc.
I would like to reproduce an extract of this work in a doctoral/Master's thesis which I am currently undertaking at Curtin University in Perth, Western Australia. The subject of my research is **[Specify]**. I am carrying out this research in my own right and have no association with any commercial organisation or sponsor.
The specific material / extract that I would like to use for the purposes of the thesis is **[Specify]**
Once completed, the thesis will be made available in online form via Curtin University's Institutional Repository espace@Curtin (http://espace.library.curtin.edu.au). The material will be provided strictly for educational purposes and on a non-commercial basis.
I would be most grateful for your consent to the copying and communication of the work as proposed. If you are willing to grant this consent, please complete and sign the attached approval slip and return it to me at the address shown. Full acknowledgement of the ownership of the copyright and the source of the material will be provided with the material.
If you are not the copyright owner of the material in question, I would be grateful for any information you can provide as to who is likely to hold the copyright.
I look forward to hearing from you and thank you in advance for your consideration of my request.

Yours sincerely

(Name)

PERMISSION TO USE COPYRIGHT MATERIAL AS SPECIFIED BELOW:
[Specify material and source, as per cover letter]
I hereby give permission for **[Insert name of research student]** to include the abovementioned material(s) in his/her higher degree thesis for Curtin University, and to communicate this material via the espace@Curtin institutional repository. This permission is granted on a non-exclusive basis and for an indefinite period. I confirm that I am the copyright owner of the specified material.

Signed:

Name:

Position:

Date:

Please return signed form to **[Insert name and address of research student]**

6.2 Permission to Use a Figure from a Paper by Grindrod, Klindworth, Martin, and Tytler (1991)

PERMISSION TO USE COPYRIGHT MATERIAL AS SPECIFIED BELOW:

Figure 1a, Feelings about science brought to C&M science by third year pre-service primary teachers as found in:

A survey of Pre-Service Primary Teachers' Experiences of Science in Schools. by Grindrod,A., Klindworth,A. Martin, M-D. & Tytler, R. Published in RISE in 1991.

I hereby give permission for **Anne T Galvin** to include the abovementioned material(s) in his/her higher degree thesis for Curtin University, and to communicate this material via the espace@Curtin institutional repository. This permission is granted on a non-exclusive basis and for an indefinite period.

I confirm that I am the copyright owner of the specified material.
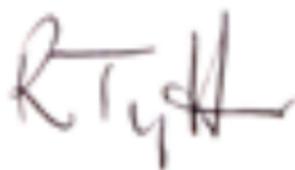
Signed:

Name: Russell Tytler

Position: Professor of Science Education, Deakin University.

Date: Sept 3, 2016

Please return signed form to Anne T Galvin - an5galvos@gmail.com

6.3 Permission to Use a Figure from a Paper by Fensham (1988)

PERMISSION TO USE COPYRIGHT MATERIAL AS SPECIFIED BELOW:

Figure 1: A model of the competing societal demands on school science education (from Fensham 1988) as used in "The Future Curriculum for School Science: What Can be Learnt from the Past?" published in RISE (2016) 46: 165 – 185.

I hereby give permission for **Anne T Galvin** to include the abovementioned material(s) in his/her higher degree thesis for Curtin University, and to communicate this material via the espace@Curtin institutional repository. This permission is granted on a non-exclusive basis and for an indefinite period.

I confirm that I am the copyright owner of the specified material.

Signed:Peter J Fensham

Name:P.J.Fensham

Position:Emeritus Professor Monash University

Date:12 Sep 2016

Dear Anne, I trust this will suffice for your purpose or do I actually have to sign by hand writing. If so, I will print this permission statement out sign it and then scan it to send to you. Hope this simpler way is OK. Let me know. Peter

6.4 Permission to Use Combined Graph/Photograph from *The Financial Review* (2012)

6.4.1 Email Requesting Permission to Use Graph/Photograph

14 September 2016
Fairfax Media Syndication Team

Dear **Peter,**

Thank you for your assistance this morning. It is my understanding that your organisation is the copyright holder for the following material:

"NAPLAN Dominates Teaching". *The Financial Review* (2012, November 26)*, by J Mather.*

Retrieved from the address below.

I would like to reproduce an extract of this work in a doctoral thesis which I am currently undertaking at Curtin University in Perth, Western Australia. The subject of my research is .**The use of Information and Communication Technology-based Science resources by NSW Stage 3 Primary School Teachers to enhance their science content knowledge to enhance their science content knowledge.** I am carrying out this research in my own right and have no association with any commercial organisation or sponsor.

The specific material / extract that I would like to use for the purposes of the thesis is **the combined graph /photograph featured in the article. Please see the attachment for the figure. The article is available online at:** http://www.afr.com/news/policy/education/naplan-dominates-teaching-20121125-j1fdw. Once completed, the thesis will be made available in online form via Curtin University's Institutional Repository espace@Curtin (http://espace.library.curtin.edu.au). The material will be provided strictly for educational purposes and on a non-commercial basis.

I would be most grateful for your consent to the copying and communication of the work as proposed. If you are willing to grant this consent, please complete and sign the attached approval slip and return it to me at the address shown. Full acknowledgement of the ownership of the copyright and the source of the material will be provided with the material.

If you are not the copyright owner of the material in question, I would be grateful for any information you can provide as to who is likely to hold the copyright.

I look forward to hearing from you and thank you in advance for your consideration of my request.

Yours sincerely

Anne T Galvin

6.4.2 Response to the Above Email Request

Hi Anne

I have confirmed the graphic is our copyright.

You can use that in your Higher degree thesis for Curtin University, and to communicate this material via the espace@Curtin institutional repository.

That is all approved.

I can not sign any paperwork so take this as confirmation. You can credit the graphic to "Fairfax Syndication"

All the best

Kind regards
Peter

Peter Lindeman

Business Development Manager | Fairfax Syndication

1 Darling Island Road
Pyrmont NSW 2009

t 02 9282 3631
plindeman@fairfaxmedia.com.au | www.fairfaxsyndication.com

6.5 Permission to use Data from Victorian Auditor-General's Office Report (2012).

6.5.1 Email Requesting Permission to Use the Data

From: Anne Galvin <an5galvos@gmail.com>
Subject: Seeking Copyright permission
Date: 14 September 2016 at 10:27:35 AM AEST
To: policy.infomngt@det.qld.gov.au

The Victorian Auditor General's Office

Dear Stephanie,

Thank you for you call this afternoon. It is my understanding that your organisation is the copyright holder for the following material:

The Science and Mathematics participation rates and initiatives Report (2012). Retrieved from *http://www.audit.vic.gov.au/publications.aspx*

I would like to reproduce an extract of this work in a doctoral/Master's thesis which I am currently undertaking at Curtin University in Perth, Western Australia. The subject of my research is The use of Information and Communication Technology-based Science resources by NSW Stage 3 Primary School Teachers to enhance their science content knowledge. I am carrying out this research in my own right and have no association with any commercial organisation or sponsor.

The specific data that I would like to use for the purposes of the thesis are in Figure 3D on p. 29 (a table of "Teachers stating that their knowledge of science and Mathematics is good or very good"). I wish to use only the data relating to primary teachers and their science knowledge.

Once completed, the thesis will be made available in online form via Curtin University's Institutional Repository espace@Curtin (http://espace.library.curtin.edu.au). The material will be provided strictly for educational purposes and on a non-commercial basis.

I would be most grateful for your consent to the copying and communication of the work as proposed. If you are willing to grant this consent, please complete and sign the attached approval slip and return it to me at the address shown. Full acknowledgement of the ownership of the copyright and the source of the material will be provided with the material.

I look forward to hearing from you and thank you in advance for your consideration of my request. An email will suffice in lieu of a signature. Am email to acknowledge receipt of this request would be appreciated. Thank you.

Yours sincerely,
Anne Galvin
0414 509 880

6.5.2   Response to the Above Email Request

Hi Anne

Thanks for seeking permission to use the content as specified in your email.

I have not filled in the form as it is not fit for our office, however I can confirm that VAGO will provide you with permission if you provide the following wording in your acknowledgement : "Used with permission from the Victorian Auditor-General's Office" and providing you include the report in your bibliography.

Kind regards

Stephanie

Stephanie Briskin
Manager, Legislation and Policy
Governance, Legal and Strategy Group
Victorian Auditor-General's Office
(03) 8601 7033
stephanie.briskin@audit.vic.gov.au
I work every day except Wednesday pm and Fridays

6.6 Permission to use Data from Report by Masters (2009)

6.6.1   Email Requesting Permission to Use the Data

On 05/09/2016, at 11:35 AM, <ssq-enquiries@smartservice.qld.gov.au> <ssq-enquiries@smartservice.qld.gov.au> wrote:

Dear Anne,

Thank you for contacting the Queensland Government regarding the use of copyrighted materials.

Your email has been forwarded to the Department of Education and Training who will respond to your inquiry.

If you require further information you can phone 13 QGOV (13 74 68) or visit the Queensland Government website (www.qld.gov.au).

Regards,

Tegan
Customer Service Advisor
Queensland Government
Internet: www.qld.gov.au
Phone: 13 QGOV (13 74 68)

This information has been collected and distributed by the Queensland Government. The Queensland Government has not checked the accuracy or completeness of any information which should therefore not be construed as a recommendation. Responsibility for the selection of any service or item rests with the enquirer.

Destination Message : This message is from: State Government contact form
name : Anne Galvin
email : an5galvos@gmail.com
phone : 0414 509 880
organisation : HDR Student at Curtin University, WA
additional-comments : 03 September 2016

The State of Queensland
Dept. of Education and Training

Dear Sir/Madam,

It is my understanding that your organisation is the copyright holder for the following material:
A Shared Challenge: Improving Literacy, Numeracy and Science Learning in Queensland Primary Schools. by G Masters, 2009.

I would like to reproduce an extract of this work in a doctoral/Master's thesis which I am currently undertaking at Curtin University in Perth, Western Australia. The subject of my research is The use of Information and Communication Technology-based Science resources by NSW Stage 3 Primary School Teachers to enhance their science content knowledge. I am carrying out this research in my own right and have no association with any commercial organisation or sponsor.

The specific Figure that I would like to use for the purposes of the thesis is Figure 9.1 on p. 93 - a graph of hours of Science teaching time at Year 4 - which was derived from the TIMSS data (2007) for the purpose of the report.

Once completed, the thesis will be made available in online form via Curtin University's Institutional Repository espace@Curtin (http://espace.library.curtin.edu.au). The material will be provided strictly for educational purposes and on a non-commercial basis.

I would be most grateful for your consent to the copying and communication of the work as proposed. If you are willing to grant this consent, please complete and sign the attached approval slip and return it to me at the address shown. Full acknowledgement of the ownership of the copyright and the source of the material will be provided with the material.

If you are not the copyright owner of the material in question, I would be grateful for any information you can provide as to who is likely to hold the copyright.
I look forward to hearing from you and thank you in advance for your consideration of my request.

Yours sincerely,

Anne Galvin
0414 509 880

PERMISSION TO USE COPYRIGHT MATERIAL AS SPECIFIED BELOW:
[Specify material and source, as per cover letter]
I hereby give permission for [Insert name of research student] to include the abovementioned material(s) in his/her higher degree thesis for Curtin University, and to communicate this material via the espace@Curtin institutional repository. This permission is granted on a non-exclusive basis and for an indefinite period.
I confirm that I am the copyright owner of the specified material.
Signed:
Name:
Position:
Date:
Please return signed form to [Insert name and address of research student]

6.6.2   Response to the Above Email Requests

Dear Anne,

Thank you for your email dated 3 September 2016 to the Department of Education and Training regarding the use of material from A Shared Challenge: Improving Literacy, Numeracy and Science Learning in Queensland Primary Schools, by Geoff Masters, ACER, 2009, for your Curtin University thesis.

Permission has been granted for use of the requested resource. Please ensure you reference the original author in your publication.

Kind regards,

Kylie Gill

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