COLLABORATIVE PARTNERSHIPS: A MODEL OF PROFESSIONAL LEARNING IN PRIMARY SCIENCE FOR PRACTISING AND PRESERVICE TEACHERS

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STATEMENT OF AUTHORSHIP AND SOURCES

This thesis contains no material published elsewhere or extracted in whole or in part from a thesis by which I have qualified for or been awarded another degree or diploma.

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This thesis has not been submitted for the award of any degree or diploma in any other tertiary institution.

All research procedures reported in the thesis received the approval of the relevant Ethics/Safety Committee (where required).

Mellita M. Jones
June, 2010.

ABSTRACT

This study explores collaborative partnerships between practising and preservice teachers as a model of primary science teacher professional learning. Thirteen volunteer preservice teacher participants from a 3rd year core Science Education unit in a Bachelor of Education course from a regional university were partnered with eight practising teacher volunteers from primary schools in the regional centre in which the university was situated. Partners planned, implemented and reflected on a series of science lessons using the 5Es framework (Australian Academy of Science, 2009) adapted from Bybee (1997). Partners were encouraged to integrate other areas of the curriculum into their science lessons where appropriate.

A model of reflective practice informed by Korthagen's (2001) Action, Looking back on the action, Awareness of essential aspects, Creation of alternative actions, and Trialling of the new action (ALACT) model was used to guide partners' reflection and subsequent planning of lessons. Data collection was achieved through a variety of methods including round table and online discussions with and between preservice teachers throughout the partnership period; semi-structured interviews with practising teachers after the partnership period; a variety of qualitative data collected at initial and final partnership workshops; and quantitative data collected through initial and final participant questionnaires which included the STEBI-A and STEBI-B instruments developed by Enochs and Riggs (1990).

Findings revealed that six out of eight partnerships achieved medium to strong collaboration, while two partnerships had little to no collaboration between preservice and practising teachers. Where collaboration was achieved, the experience was effective in building preservice teacher efficacy and confidence to teach science. These partnerships also provided valuable experience for preservice teachers to observe and teach science which was lacking in their previous professional experience teaching rounds. Some content and pedagogical knowledge development was also evident, particularly from those preservice teachers who were involved in collaborative partnerships. Guided reflection in expert facilitated round table discussions also appeared essential in forming the theory-practice nexus that helped preservice teachers develop knowledge of science teaching. Practising

teachers who lacked confidence in their knowledge of science and belief in their ability to teach it also experienced growth in efficacy and knowledge of science and its teaching. Teachers who already had strong science knowledge and teaching efficacy did not appear to experience knowledge growth, but did gain enhanced ideas and approaches to teaching science. The more formal the reflection conducted between partners, the more practising teachers appeared to benefit overall. It was also identified through the findings that time for organisation and accessing appropriate resources were significant issues in teachers' sense of their ability to teach science more often. Confidence and background knowledge were also identified as barriers for increased science teaching in schools. In spite of this all preservice teachers indicated a strong desire to include science in their teaching frequently as a result of their experience in this project.

These findings suggest that professional learning in science education can be achieved for both practising and preservice teachers when they work together in collaborative partnerships to plan and reflect on a series of science lessons that are implemented in an authentic classroom setting.

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CHAPTER 1: FRAMING THE RESEARCH

1.1 Introduction

This study seeks to explore collaborative partnerships between practising and preservice teachers as a model for primary science teacher education and professional learning. Several factors have shaped the formation of this study, my own passion for science being one of the strongest. I have a firm belief that science is one of the most important areas of education and there needs to be strong consideration of how it is effectively achieved at all levels of education. This view is supported by a range of literature sources from government reports to science education research.

The Australian Government through the Department of Education, Science and Training (DEST) (2002) discusses the importance of science education as a key link to the development of the Australian nation. They argue that as the Australian economy moves towards an information or knowledge based economy, the importance of a scientifically literate society becomes increasingly important. Others recognise the urgent need for sustainable living (Hodson, 2003) as the world struggles with the worsening effects of climate change and with addressing the role science education has in informing people on sustainability issues and ways to deal with them. In addition to this, a number of bodies recognise the growth of technological society (e.g. DEST, 2002; Hodson, 2003) in developed and developing nations and highlight the relationship this has with science education in helping citizens manage, use and consider the ethics behind the ever-developing technology in their lives.

The focus on science education in research and government reporting stems from a concern that although there is a recognised growing need for science education, retention of students studying post-compulsory science is in decline (Batterham, 2000, Dobson, 2003; Fensham, 2004). This raises a concern as it sets in motion a potential spiralling decline in the quality of science education. Studies around the turn of the century (e.g. Batterham, 2000, Dobson, 2003) have found fewer students are studying post-compulsory science, and of those who do, only in less than 0.9% of cases do they go on to pursue science education (McInnis, Hartley & Anderson, 2000). This leaves those charged with educating future citizens about science often under-qualified, and/or with relatively low levels of interest and ability in science themselves (Lyons, Cooksey, Panizzon, Parnell & Pegg, 2006; Sanders, 2004). Low teacher interest and depth of knowledge in science in turn impacts on the next generation of science teachers, and the downward spiral continues.

The question of the quality of science education has been the focus of a number of research projects around the world (for example Dobson, 2003; Dobson & Calderon 1999; Goodrum, Hackling & Rennie, 2001; Lyons et al., 2006; McInnis et al., 2000). These studies consistently report that students are 'turned off' science by the early years of secondary schooling, and in the primary years, science is approached in a disconnected fashion or not at all (Appleton, 2003; Goodrum et al., 2001; Keys, 2005). In particular, the relevance of science to young people's lives and the particular pedagogies being adopted by teachers of science, along with the science professional learning opportunities available and accessed by teachers, have been questioned. There are indications that a large proportion of teachers have low levels of confidence and background knowledge in science, impacting both their willingness and ability to teach science effectively, particularly in the primary years. These are critical areas of concern when other studies show that the development of children's understandings is fundamentally tied to their teacher's abilities (Darling-Hammond, 2000a; DEST, 2003). This highlights the need for significant development in current and future teachers' attitudes, personal efficacy and ability to teach science effectively.

This literature highlighted to me that areas of science education that might address these issues are: the quality of science teaching and learning; teachers' self-efficacy towards teaching science; and the science professional learning opportunities available and accessed. Of particular relevance to me, the literature highlighted the need for professional learning for practising teachers, and my own experience as a science teacher educator fuelled my desire to improve preservice teacher science education learning. Consequently these framed the context of my own study: professional learning about science education.

1.2 Context of the Study

I entered teacher education nine years ago as a sessional lecturer in a core science education unit in a Bachelor of Education course preparing primary teachers. I recall being sceptical when the lecturer whom I was succeeding warned me that 'you'll find they all hate science, so the primary aim is to shift their attitude'. I was somewhat aghast at how true his words turned out to be. A short poll at the beginning of Lecture One, asking students to move to an area of the room that best represented their feelings about science, saw at least three quarters of the approximately 120 students stand up and move to the 'Absolutely hate science' side of the room. This left about one quarter who were divided between 'It's ok' and 'I love science' with only about three in the 'I love science' zone. Until that moment I had no idea how poor the general attitude of people could be towards science and I had to begin seriously considering the impact this was going to have on my role as a science teacher educator.

Since then I have moved into a permanent lecturing position at a different university. At the beginning of each year I always begin the first science unit in the Bachelor of Education (primary) course with the same 'pop' poll. I am always disappointed, but no longer surprised, by the same sort of results. Anecdotally, most of the preservice teachers I encounter really 'hate' science. Many studies indicate a similar problem on a national and international level (e.g. Goodrum et al., 2001; Hackling & Prain, 2005; Sanders, 2004). My personal concern stemming from this is, how can these preservice teachers ever go on to be effective teachers of science when they themselves, generally speaking, 'hate' science? I do not see how it is possible for anyone to communicate awe, wonder, curiosity and excitement about something they claim to hate. Yet these are the very feelings I have about science and, as a science educator, want everyone to share.

Exploring anecdotally the reasons for my preservice teachers' dislike of science revealed their dislike of what they see as a subject where they believe they have to memorise a large body of 'facts' for which they see no relevance in their personal, daily lives. The periodic table is a classic example they quote when I ask 'such as what…?' They reported loving practical work but hating the subsequent, 'laborious' practical report, so much so that they came to dread the practical work as well. They reported spending time reading and answering questions out of text books and the boredom of learning in this way for period after period of science. All comments centred on their secondary school experience of science and few, if any, could even recall science in primary school.

This type of feedback, year after year, creates a number of challenges for me in my role of a passionate, awe and wonder-filled science teacher educator. Firstly, I saw a need to improve attitudes and enjoyment of science for my preservice teachers so they would at least begin to appreciate the need for science and want to experience it positively. Secondly, and in relation to the first challenge, I saw a need for my preservice teachers to experience the nature of science, as I believe this is where awe and wonder for science are nurtured. It was my belief that if their interest, awe and wonder could be stimulated, and that they could have a positive 'nature of science' experience of learning, they might be more inclined to teach science using similar strategies supporting a 'nature of science' experience for their own students.

As a result, in order to address these challenges, the subsequent preservice teacher science education I delivered was social constructivist in approach and heavily laden with personal experiences of science processes and science thinking. I asked my preservice teachers to become the questioners, thinkers, investigators, analysts, reporters, and theorists. I dispelled the notion of 'facts' and encouraged the notion of 'theories'; theories waiting to be explored, tested and adapted as technology and culture provide us with new and different ways of viewing the world around us. I provided examples of this having occurred in the past, such as 'world is flat – world is round' thinking, and 'geo-centric versus helio-centric' thinking and the tenacity with which these views were held at the time they were first challenged. I attempted to involve the affective domain alongside the cognitive domain and often used De Bono's Thinking Hats (1992) to encourage different types of thinking to achieve this.

Overall, my approach to science teacher education appeared to be quite successful. Unit evaluations reported significant shifts in student attitudes towards science. My approach also provided an experiential framework through which I could relate pedagogies of teaching and learning with the experiences preservice teachers had in tutorials, thus ensuring an academic rigour existed within the framework adopted. I still held concerns in regard to gaps in preservice teachers' science content knowledge, but at least they had experienced the types of pedagogical approaches supported by current literature, that hopefully influenced the way they go on to teach science.

It was important to me to build in these types of experiential approaches to the experiences in the present study. I wanted to enhance preservice teacher attitudes, use a social constructivist approach, expose and encourage the use of science processes that reflect the nature of science and build scientific literacy. I also wanted my preservice teachers to experience teaching science in this manner themselves. Initially I used micro-teaching as a strategy for this, where in pairs, preservice teachers planned and delivered a science lesson adopting scientific process principles to their peers in tutorial sessions. Whilst this appeared to help preservice teachers experience the process of planning and organising a science lesson, it was not able to convey the impact the reaction children can have when they experience an interesting and challenging science lesson; the kind of mastery experience Bandura (1977) discusses as so important in building efficacy. Indeed, over the years, a number of preservice teachers have conveyed their belief that ‘kids’ would not enjoy science, a response that always featured in De Bono’s Black hat thinking along with ‘how can we make children enjoy science?’ Their own dislike of science was so strong they were unable to consider that primary children might actually enjoy it. This was a key aspect of my desire to create a more authentic experience where they planned and implemented science in the classroom, with ‘real’ children.

A way of achieving this experience presented itself through another study I was involved in. In 2005-2006 I was engaged in a professional learning research project that aimed to enhance pedagogical approaches and attitudes towards Information and Communications Technology (ICT) in the primary classroom, through university and primary school partnerships. The focus included teachers’ lack of confidence in their own ICT skills, their lack of ability to use ICT in their teaching and their desire for ICT professional learning (see McNamara, Jones & McLean, 2006). The Australian national project, known as Partnerships in ICT Learning (PICTL) (Pegg, Reading & Williams, 2007) was divided into a number of state-based research projects. I was part of the research team based in the state of Victoria.

The national PICTL project required the states and territories involved to adopt a partnership approach between schools and universities to carry out the research, and in the Victorian project this was viewed as an opportunity to involve preservice and practising teachers working together. Preservice teachers targeted for the project were in their final year of their Bachelor of Education primary degree, and as they were approaching transition into the profession, a model for their involvement was sought where they could take on a role of equality or even leadership, with their practising teacher partners. From this the notion of a collaborative partnership between practising and preservice teachers emerged. However, it was not realised at the time how important this notion of collaboration was going to be in the findings.

In the Victorian PICTL project, collaborative partners were required to plan, implement and reflect on the use of ICT in their teaching over a period of 5-6 cycles or lessons. Findings indicated that the experience increased both practising and preservice teacher participants' confidence to use ICT. One of the unexpected findings was that preservice teachers reported their experience as one of the first opportunities they had to engage with 'real' teaching (i.e. with children in the classroom) without feeling the pressure of having their teaching supervised and assessed. One participant in particular indicated that because of this, she had been far more willing to take risks and experiment with the ICT in ways she would not have done if she knew her teaching was being monitored and reported on (see McNamara et al., 2007; Jones & McLean, 2006). This was significant in framing the present study.

As I began to frame the research design for the present study, grappling with my desire to incorporate an experience of the nature of science and to create an authentic experience of teaching science for my preservice teachers, the findings of the PICTL project appeared very relevant. I was faced with the challenge of shifting attitudes towards science, developing sound pedagogical approaches to science teaching, enhancing science content knowledge and convincing my preservice teachers that primary school children do not necessarily hold the same negative attitudes towards science that they did. PICTL showed that a collaborative partnership with practising teachers provided preservice teachers with a classroom for authentic teaching practice. It also provided classroom support from their practising teacher partner for planning, teaching and reflecting on the teaching and learning processes that freed the preservice teachers from the apprehension associated with assessed, supervised teaching. In addition, PICTL showed that the collaborative partnerships' cycles of teaching with ICT developed confidence and ability for both preservice and practising teachers. The significance of preservice and practising teachers' experiences in PICTL suggested that a similar model might be successful in building confidence and developing pedagogies for effective teaching in a science education context. It suggested that the model could actually target both preservice science teacher education and practising teacher science professional learning. In this way, the PICTL research project served as a pilot study and impetus for the present study and inspired the ideas for research into collaborative partnerships as a model for practising and preservice teachers' science professional learning.

1.3 Purpose of the Study

The purpose of this study was to examine whether a collaborative partnership model could impact the science education professional learning needs of practicing and preservice primary teachers. In recognition of key concerns raised in the literature, the confidence levels, attitudes and knowledge of practising and preservice teachers were the particular foci for exploration.

Following the model used in the PICTL project, the collaborative partnerships were required to plan and reflect on a series of science lessons which were implemented in the practising teacher partners' classrooms. This experience formed an assessment requirement for preservice teachers in their science education unit, which was a part of their third year curriculum in a four year Bachelor of Education course. Practising teachers were involved in professional learning workshops alongside their preservice teacher partners.

The pedagogical framework adopted for the study was taken from the Australian Academy of Science (2006) 5Es inquiry framework associated with their Primary Connections resources. The Primary Connections model uses an adapted version of Bybee's (1997) 5Es inquiry framework as a process for the delivery of primary science education. Hackling and Prain's (2005) research evaluating the 5Es model was also considered in its selection for this project. The Primary Connections resources make explicit links between science and literacy outcomes to encourage greater curriculum integration and more holistic approaches to primary science education. Implicit links with other curriculum areas, particularly numeracy, are also evident.

The research was qualitative in design and focused on questions of deep transformation through critical reflections; exploring how practising teachers and preservice teachers' attitudes towards and perception of science education, both as learners and teachers, might be developed and, where needed, changed. This holistic model emphasised the empowerment of practising teachers and preservice teachers as individuals and as members of an equal partnership. The model was viewed as fundamental to the deeper learning and on-going motivation of teachers to continue to explore and develop science teaching and learning strategies beyond the timeframe of the study.

Specifically, the focus of the research was to explore the effect this partnership model of professional learning had on the attitudes, self-efficacy beliefs and knowledge of preservice and practising teachers towards science, and to ascertain whether their involvement in teaching science in an authentic classroom setting increased their intention to incorporate science as a high priority in their teaching repertoire. Both general content knowledge (GCK) to do with the development of scientific background knowledge and pedagogical content knowledge (PCK) to do with the strategies and approaches used to effectively teach science concepts were targeted, with a greater emphasis on the latter of these since the science education unit is predominantly concerned with how to teach science rather than learning of science. A search of the literature generated insights into expected attitudes, self-efficacy, content and pedagogical knowledge, and from this a number of aims emerge for the study.

1.4 Statement of Aims

1. Establish the attitudes and self-efficacy beliefs towards science of preservice primary school teachers in a third year undergraduate Bachelor of Education Science Education unit.
2. Establish the attitudes and self-efficacy beliefs of practicing primary school teachers towards science, and the level of priority science has in their teaching repertoire.
3. Establish whether involvement in collaborative partnerships with preservice teachers enhances the knowledge, attitudes, and self-efficacy beliefs of practicing primary school teachers towards science, and the level of priority science has in their teaching repertoire.
4. Establish perceived barriers to increasing the profile of science in primary school classrooms.

These aims led to the overarching research question:

What is the impact of collaborative partnerships between preservice and practising teachers, using a model of critical reflection for action, on the knowledge, self-efficacy beliefs, and attitudes of teachers towards teaching and learning of science in primary schools?

This was broken into a set of smaller, sub-questions which serve as the key research questions to be investigated in order to answer the overarching research question. These are:

1. What attitudes and levels of self-efficacy beliefs do preservice teachers have towards science before and after the partnership experience?

2. What attitudes and levels of self-efficacy beliefs do practicing primary school teachers have towards science before and after the partnership experience?

3. What are the effects of action-reflection in collaborative partnerships between practising and preservice teachers on knowledge, attitudes and self-efficacy beliefs of preservice teachers towards science education?

4. What barriers are perceived to exist to increasing the priority of science in primary school classrooms?

1.5 Significance of the Study

The significance of the study is linked to the importance of science education and the questions surrounding the quality and quantity of its delivery in Australian primary schools. These issues appear to be linked to teachers' confidence to teach science and the pedagogical approaches they adopt when they do teach it. Similarly, preservice teachers' attitudes, confidence and knowledge of science have been established to be fairly poor. If the model adopted in this study can affect practising and preservice teachers' attitudes, confidence, their general content knowledge (GCK) and pedagogical content knowledge (PCK) of science, then it becomes significant for science teacher educators and professional learning facilitators around the nation and further afield.

The model has already been trialled in the field of ICT education and if similar success is found with science education through this study then it may also provide a model of preservice teacher education and practising teacher professional learning that can be used more generally, across other areas of education.

For these reasons, the study has significance for government bodies that help support and shape the nature of education and professional learning opportunities across different sectors of education. It is also of particular significance for those involved in education in the tertiary sector who are continually searching for effective ways to establish partnerships with their stakeholder bodies including education offices, and the schools they help service.

1.6 Writing Style

I have elected to write this thesis using the first person wherever possible. This approach aligns with the closeness I have with the research design and my involvement as the expert facilitator of the science education unit and professional learning workshops in which participants are involved for the purposes of the study. It also aligns with the ontological perspectives of constructivism, phronèsis and hermeneutical phenomenology which underpin the theoretical and methodological framework of the study. The subjective, social constructivist epistemology adopted also supports such a stance.

1.7 Structure of the Thesis

This research has been informed by personal experiences and a range of literature about the importance and quality of science education. These experiences and some of the literature have been outlined in this first chapter to help frame the research project and show the development of the research aims and questions.

In Chapter 2, I present a more extensive review of the literature that provides additional detail on why science education is viewed as important, both in Australia and internationally. Literature concerned with the status and quality of science in Australian schools is also reviewed in more detail. Next, some of the best-practice approaches to science education, tertiary education and teacher professional development are considered because of their impact on how the research project was shaped. The nature and impact of preservice teachers' professional experiences in schools are considered due to the feature of the authentic school-based teaching that formed part of the research design. Within this, a number of models of partnerships between preservice and practising teachers are reviewed from other studies. Finally, the importance of teacher efficacy is reviewed as this was an issue identified as a significant one for current primary teachers, practicing and preservice, with respect to science and the prevalence of its teaching in primary schools across Australia.

Chapter 3 outlines the theoretical and methodological framework for the study and reviews a range of literature associated with qualitative research design. Subsequent limitations of the methodological design and strategies for minimising them are also considered from the literature to help demonstrate how they are applied to build reliability and trustworthiness in the present study design. The participant workshops and partnership formation are also detailed in Chapter 3 along with a description of the data collection techniques adopted. Data analysis techniques are also described and associated literature reviewed.

The results of the study are presented in Chapter 4. This chapter is divided into a number of sections to sequence logically the rich and non-linear data generated through the study. These sections cover: results of participants' self-efficacy beliefs before and after the project; the development of participants' knowledge as a result of their involvement in the project; the benefits and weaknesses of the partnership model as perceived by the participants; their recommendations for improving the model; and their intention to teach science more often as a result of their experience in this study.

The discussion of results and implications of the findings are considered in Chapter 5. In this chapter I draw together the findings from practising and preservice teachers and consider the overarching implications of these findings. Finally, in Chapter 6 I begin by answering the research questions and then go on to consider the broader implications of the findings for teacher education and further research by discussing future recommendations emerging from the study.

CHAPTER 2: REVIEW OF THE LITERATURE

> *Learning takes place through the active behaviour of the student: it is what he does that he learns, not what the teacher does.*
>
> Tyler, 1949, p. 63

2.1 Introduction

This chapter reviews some of the 'big picture' ideas revealed by previous science education research. This assists in building a picture of the issues that underpin the thesis which emerge in more detail as the chapter progresses. With this in mind, I begin this chapter by outlining outline the literature that informed the research design and consider other studies that have examined science professional learning for practicing and preservice educators. To further the argument around the importance of the study, the importance of science education is considered in more detail than it was in Chapter 1. Ideas around the purpose of science education are also considered from current perspectives leading to the notion of science literacy. From here some examples of best-practice in science education as informed by research are discussed and some of the barriers and issues surrounding the achievement of best practice in science education are presented.

Following this, the notion of reflective practice is introduced as an increasingly important component of effective education at all levels, including preservice teacher education and practising teacher professional learning. This component of the literature review was important in the development of the structure collaborative partnerships and led to the two sections of the literature review dealing with teacher professional learning and preservice teacher education.

Issues surrounding effective teacher professional learning and strategies for achieving effective teacher professional learning are then presented. This literature was important in informing the design of the teacher professional learning component of the present study. Also important to the design of the study was the review of literature concerned with effective teacher education, particularly in relation to professional experience, which formed a key aspect of the research conducted in the present study. Within this, research into different types of partnerships between practising and preservice teachers is examined to determine how the present study offers something new in the approach to partnerships for practising and preservice teacher learning.

Finally, the importance of self-efficacy is established through a short review of self-efficacy research. This component of the literature review establishes why self-efficacy is such an important component of professional learning in an area of the curriculum where practising and preservice teachers are reported to have low efficacy beliefs which impact on their teaching practice.

The importance of this study is closely linked to the importance of science education in Australia. If education in the sciences is taken as important for society then examination of the effectiveness of science teacher preparation, professional development and science teaching and learning become critical issues. The literature explored here provides firstly, a summary of different perspectives of why science education is important for children and secondly, why science teacher education and professional development are critical issues for science today. In light of this discussion, current issues and innovations associated with the science education of young people is examined with a view to considering how to best prepare current and future science educators through effective preservice teacher education and professional learning, especially through models of collaboration and partnership.

2.2 The Importance of Science Education

Science education is important to the future of Australian society (DEST, 2002). Scientific knowledge and understanding underpins growth and development of a nation: economically, technologically and for sustainability. The future of any emerging information economy and knowledge-based society such as Australia requires that a proportion of the population has expert knowledge and ability in the sciences (DEST, 2002). Sustainable living and ethics are also essential emerging facets of scientific progress and technological development (Hodson, 2003). These require not only the preparation of scientific experts who are able to find ways to protect and repair the environment and to further the economy of the nation, but also scientifically literate citizens who can make informed decisions about the environment, their health, the way science and technology develops, and the future of the world (DEST, 2002; Hodson, 2003; NSTA, 2003; Rennie, Goodrum & Hackling, 2001).

Scientific literacy is commonly thought to be the overarching purpose of science education (De Boer, 2000; Goodrum, 2004) but in spite of this there is no consensus on its definition (Bybee, 1997; De Boer, 2000; Fensham, 2004; Goodrum, 2004; Roberts, 2007). De Boer (2000) tells us that as a concept, the breadth of the meaning of scientific literacy has been established from a range of shifting historically significant themes in education which reflect its political influences. Fensham (2004) indicates that scientific literacy is not understood well as it has no historical context, particularly in primary schools. Since the 1970s, scientific literacy has embraced a social context alongside its discipline-based framework (De Boer, 2000). For a number of years now, it has been generally accepted as the level of science understanding held by the general public that enables their effective decision making and participation in science related discourses relevant to active citizenship (De Boer, 2000; Goodrum, 2004).

Roberts (2007) reminds us of the two significant themes competing for precedence in how scientific literacy is viewed. The first deals with the discipline of science itself and the other embraces science-related situations that could be encountered in everyday life. Roberts views these themes as two extremes which are important to consider when it comes to thinking about science education. One theme encourages content based approaches to teaching that deal with the products and processes of science. This is characteristic of science teaching of the past (Aikenhead, 2006; De Boer, 2000) where the tendency has been to teach abstract concepts. The other encourages a contextualised approach, where abstract science ideas are taught in relation to situations that students can relate to everyday life, and this is encouraged to be the driver in current Australian science education. In fact Goodrum (2004), in line with this view, proposes five attributes for scientific literate people as those who:

- are interested in and understand the world around them;
- can identify and investigate questions and draw evidence-based conclusions;
- are able to engage in discussions of and about science matters;
- are sceptical and questioning of claims made by others;
- can make informed decisions about the environment and their own health and wellbeing.

(p. 56)

Achieving scientific literacy of this nature would clearly require both some knowledge of science content matter and an understanding of its social implications. This requires a balance between the two extremes discussed by Roberts (2007) and an overall approach where the study of science content is introduced through contextualised, science related issues. This contextualised approach supports that of Fensham (2005) who indicates a view of scientific literacy that includes:

- an individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues;
- understanding of the characteristic features of science as a form of human knowledge and enquiry;
- awareness of how science and technology shape our material, intellectual and cultural environments; and
- willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen.

(pp. 44-45)

Which is also similar to that of the Organisation for Economic CoOperation and Development's [OECD] Programme for International Student Assessment [PISA] (2003) which states that:

> [s]cientific literacy is the capacity to use scientific 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 thorough human activity. (p. 133)

The primary aim of this approach to science education is linked to what De Boer (2000) describes as the need to engage and retain interest in science to encourage a population who is interested enough to remain informed throughout their lifetime, also a key goal also according to Fensham (2005). Capturing and retaining this interest is also acknowledged as important by Goodrum (2004), who recognises that science experts will emerge from those who pursue post-compulsory science education rather than from those who experience a general, scientific literacy based curriculum couched in a social context. However, this approach makes science more accessible to all school students rather than just those who are to follow it into further study and a career, which is a relatively small proportion (Aikenhead, 2006). Fensham (2005) though, does list the need for school science curricula to inform students of the "great range of exciting careers that tertiary science study can enable" (p. 42).

Batterham (2000), reporting in the Australian Chief Scientist's discussion paper, indicates that Australia has been producing an insufficient number of graduates with science, engineering and technology (SET) skills to support knowledge-based industries. The Australian Science Teachers'

Association [ASTA] (2005) supports this claim, and advocates that this shortfall of SET graduates needs to be acknowledged and met in all training and education sectors.

McInnis, Hartley and Anderson (2000) tell us that:

> The enabling sciences [physical sciences and mathematics] underpin and support the development of new sciences. They also contribute to science literacy and awareness amongst the general population, a necessary factor if innovation and high technology enterprises are to be supported and used in socially responsible and effective ways. (p. 1)

The Australian Department of Education, Science and Training [DEST] (2003) also acknowledges the place of scientific and technological capability for “future growth and prosperity in a competitive global economy” (p. 1). It reports on the need for strategies to improve science and mathematics education and technological capability and recognises teachers as the “key to mobilising schools for innovation” (p. 1).

Science has often been seen as an elitist area, something for ‘smart kids’. DEST (2003) and Aikenhead (2006) purport is that science needs to be accessible to all people as it is an area that has become essential for work and citizenship; a human endeavour. This fits with the sort of scientific literacy outcomes of education described by Goodrum (2004), Roberts (2007) and De Boer (2000). This sentiment is was initially noted by Rennie, Goodrum and Hackling (2001) who remark that both the technological society we live in and the “ever-growing importance of scientific issues in our daily lives demands a populace who has sufficient knowledge and understanding to follow science and scientific debates with interest, and to engage with the issues science and technology poses – both for them individually, and for our society as a whole” (p. 456).

2.3 Student Engagement with Science

Concerns over the retention of students studying science subjects in secondary school and indeed at an undergraduate level have sparked a number of funded studies around and since the turn of the century (Dobson, 2003; Dobson & Calderon 1999; Goodrum, Hackling & Rennie, 2001; Lyons, et al., 2006; McInnis, et al., 2000). The Third International Mathematics and Science Study (TIMSS) reported by Martin, et al. (2001) revealed that Australian 13- and 14-year-olds’ (beginning secondary school students) attitudes towards science were quite poor, rating 19th out of 23 countries; the worst of all English speaking countries. They also found that half of the Australian science secondary school teachers and almost half (45%) of Australian primary school teachers in the study reported that they would like to leave the profession. These results are concerning. Student findings are concerning because relatively speaking, Australian students are not indicating an enjoyment of science that may lead to and encourage post-compulsory study that would help develop Australia's competitiveness in the world market as a knowledge economy. It is also concerning that so many teachers are looking to leave the profession, particularly secondary science teachers who, in Australia, generally have undergraduate science degrees to qualify for science teaching. As part of an already small minority of science graduates who pursue education as a career, if half are looking to leave the profession, the proportion of qualified science educators the Australian education system will be left with is alarming.

Another major project, commissioned by the Australian government, that reviewed the quality of school science education in Australia, confirms that the trends of falling numbers in science enrolment in both upper secondary and at the tertiary level, along with a perceived lack of awareness about science in the community, has been evident for at least twenty years. This major national project led by Goodrum, Hackling and Rennie (2001) along with Dobson's (2003) research into trends in university science, revealed concerns associated with the profile of science both in schools and in the community. These concerns centred on the lack of relevance of science education for young people; on the pedagogy used in the delivery of science; and on the resources and professional development opportunities afforded to teachers of science in the primary, secondary and tertiary sectors.

The consequences of students being 'turned off' science, essentially in the early years of secondary schooling (Goodrum et al., 2001), are that there are fewer students electing to pursue higher study in the sciences and ultimately a further decline in the number of people studying science education. Students who do pursue post-compulsory science rarely pursue science education after their degree (less than 0.9%, reported by McInnis et al., 2000). McInnis et al. also note that on average, science education employment is renumerated in the bottom of all science related employment categories, as reported by the 1150 respondents in their research. This does not make science education an attractive alternative for those with the knowledge and interest in the field. Consider then, what this means for students entering undergraduate preservice primary education: if those students with the interest and ability in the sciences tend to pursue post-compulsory science (Dobson, 2003), then students entering undergraduate, preservice primary education are less likely to have that same level of interest and ability in the sciences. Skamp (1997) indicates in one research project, that two thirds of students entering a primary graduate diploma had completed science only to Year 10, the end of compulsory science in Australian schools. Schibeci and Hickey (2004) report a higher figure in Western Australian schools (in a study of 28 teachers) where most participants had completed at least one science subject in Year 11 or 12, but in 75% of those cases the subject was biology. A number of studies also indicate a general negative attitude exits towards science in teachers at the primary level (Skamp & Mueller, 2001; McDuffie, 2001; Fensham, 2004).

The repercussions of this are that we have a decreasing number of teachers qualifying in the sciences, especially physics and chemistry, and consequently, a decreasing number of teachers generally who have a thorough understanding of and appreciation for science in both secondary and primary education, having experienced relatively low levels of attainment in their own science studies (DEST, 2003). In addition to this are Martin et al.'s (2001) findings that half of the already qualified primary and secondary science teachers are looking to leave the profession. This has an impact in the secondary sector by schools needing to employ more often, teachers who are not qualified in science to teach in science subjects (Sanders, 2004; Lyons et al., 2006). In the primary sector, as Goodrum, et al. (2001), Appleton (2003) and Keys (2005) have all found, science is approached in a disconnected fashion or not at all.

The Quality of Science Teachers

This lack of qualified and scientifically literate teachers is of significant concern given the level of impact high quality teachers can have on their students (DEST, 2003). Darling-Hammond (2000a) reports on the significance of the relationship between the quality of teachers and the quality of student learning outcomes. If science teachers are not of this 'high quality' in the sciences, then what sort of impression and effect can science education have? High quality teachers are essential for significant and lasting contributions to the education in the lives of young people (DEST, 2003). However, as these reports reveal, educators are generally not well equipped to guide students into a scientifically literate view of the world (DEST, 2002; DEST, 2003; Goodrum, et al., 2001; Hackling & Prain, 2005; Lyons, et al., 2006). This is of particular concern in regional, rural and remote areas of Australia where it is about twice as likely in regional areas and more than three times as likely in remote areas for teachers to be required to teach in an area in which they lack expertise (Lyons et al., 2006).

Many teachers themselves report having low confidence and ability in the sciences and that they feel under-supported in professional development and resources in this area (Rennie et al., 2001; Appelton, 2003). Goodrum et al. (2001) indicate that teachers themselves are calling for increased opportunities for professional development which would help to address the problem. This suggests to me that teacher preparation courses and the effective delivery of science within them should be helping the situation, but science education is already a part of preservice teacher education and yet science teaching continues to be reported at low levels of quality and quantity. This implies that, to date, the presence and/or approach to science teacher education is having little lasting effect on teachers' ability and confidence to teach it. A view to improving the level of knowledge in science, personal efficacy beliefs about teaching science, and attitudes towards the importance of including it in the curriculum need to be more meaningful and longer lasting in both preservice teacher education and professional learning programs. This would better ensure its profile is raised so that school students' learning opportunities in science are subsequently improved.

The long term effects of an educational climate with under-qualified and low scientific literacy amongst primary and secondary teachers is that many children in the education system have a poor experience of science, which perpetuates the problem. As discussed earlier, this has significant implications for the future of Australian society economically, technologically, ethically and for sustainability. These are critical issues in a milieu where the Western World is experiencing increasing levels of technology for living and is held largely responsible for an environmental climate that is becoming critical for sustaining life on Earth. It has never been more essential that children, as caretakers of the planet, have a good understanding of science, its issues and ethics.

Improving the Quality of Science Teaching

There is some debate as to whether it should be preservice or practising teachers who are targeted in an effort to improve the quality of science teaching and consequently students' science experiences and outcomes. Sanders (2004) asserts that a responsibility to change teaching in order to improve science competency and understanding lies with preservice teacher education. As reported from personal experience in Chapter 1, an increasing number of preservice teachers report dissatisfaction and even dislike of science, stemming from the way they themselves were taught – in a curriculum that is “laden with content which is decontextualised from, and irrelevant to, the lives and experiences of the students” (Rennie et al., 2001, p. 468). Also as previously mentioned, issues lie in the general view of science of being for the elite (Goodrum et al., 2001; Aikenhead, 2006). One solution to this may lie in the way that science is approached in the classroom, its connection with students’ lives, and an increase in the teaching of science in the primary years to foster the enjoyment and wonder of science for students so they are more likely to follow it as a course of study and a career path.

With this in mind there has been a number of initiatives over the past decade targeting professional development for teachers in the effective teaching of science. These include the science in Schools Initiative (SiS) (Tytler, 2002a) and more recently, the Primary Connections project that links science outcomes with literacy (Hackling & Prain, 2005).

Each of these projects has, to date, targeted practising teachers in on-going professional development on delivering and assessing science outcomes. Whilst these projects have reported good success, only in recent times with Primary Connections, has the next step into targeting teacher education been considered as a component of a holistic approach.

Anderson and Michener (1994) contest the idea of directing change-programs at preservice teachers and argue that it is current practising teachers who need to be targeted. They also argue that teacher professional learning needs to take place within the school context. However, there are issues in targeting practising teachers alone. Jones and Carter (2007) indicate that teachers’ epistemological beliefs tend to be resistant to change, and that this is particularly the case for experienced teachers. This would make the targeting of practising teachers alone somewhat futile if significant change in science teaching is to take place only through the means of professional development. However, the importance of practising teachers on change can not be over-looked. Hewson (2007) highlights that practising teachers are in much larger proportion than new beginning teachers, and that practising teachers tend to hold the power balance over teachers who are just entering the profession. This emphasises how targeting preservice teacher education alone is likely to have limited effect and any reform would take a long time to be widely implemented.

In addition to this, most attempts at reform have already targeted practising teachers rather than preservice teacher education (Appleton & Kindt, 1999). Given the ongoing issues reported in the literature, this appears to be having limited effect. This adds to the argument that alternate approaches are needed to supplement practising teacher professional learning. Preservice teacher education courses need to be targeted to ensure sufficient effective teaching of science and science experiences so that future generations of educators are well-equipped to break the cycle of perpetual dislike and lack of confidence and understanding in the sciences. This could combat concerns associated with sustaining the outcomes of projects and extending them across all schools once funding is withdrawn, something highlighted by the Science in Schools (SiS) project team (Beeth, Duit, Prenzel, Ostermeier, Tytler & Wickman, 2002).

Hackling and Prain (2005) indicate that “new teachers to the profession can have a large impact if properly prepared” (p. 7). They have worked closely with the Australian Academy of Science in teacher professional learning using the Primary Connections resources. Encouragingly, the Academy has recently secured government funding to induct university science teacher educators into the Primary Connections model. This could be a way forward, especially given so many attempts to change the nature of science teaching through professional development of practising teachers, dating back to Hurd’s writings in 1958 (Goodrum et al., 2001), and still research is producing the same findings about science teaching and learning that has limited effect, is disconnected and approached haphazardly in schools across Australia (Appleton, 2003; DEST, 2003; Fensham, 2004; Goodrum et al., 2001; Lyons et al., 2006).

In acknowledging all of these ideas, this study offers a different model: to examine the effect of professional development and preservice teacher education being tackled together, in the school context, using a collaborative partnership model of professional learning in science.

2.4 The Status and Quality of Science Education in Australian Primary Schools

Science education is important for many reasons as previously discussed, and in spite of it being rated as the third most important subject in the primary school curriculum [behind English and mathematics (ASTEC, 1997; Fensham, 2004)] Goodrum, et al. (2001) report that on average, around 59 minutes per week is spent on science teaching (although they believe even this figure might be inflated), with significant variation present between teachers and between schools. More recently, Tytler and Griffiths (2003) found that the majority of Australian primary schools were "spending in the range of 30 – 90 minutes per week on science with a mean time somewhat less than one hour" (p. 12), although acknowledgement is made of the fact that it can be difficult to measure the amount of time spent on science teaching since it is often approached as a part of an integrated study (Goodrum et al., 2001; Tytler & Griffiths, 2003).

Factors such as an overcrowded curriculum and an increasing focus on literacy and numeracy mean that other curriculum areas suffer (ASTA, 2005; Goodrum et al., 2001; Appleton, 2003). The most significant aspect of this, as acknowledged by ASTA (2005), is that educators seem to associate the delivery of literacy and numeracy with the teaching of English and mathematics and fail to recognise the opportunities that other curriculum areas offer to deliver literacy and numeracy outcomes and standards, particularly science. This is a significant problem when a one hour block for each of literacy and numeracy has been introduced into Australian primary school classrooms every day in the state of Victoria. This impacts on the time available for other areas of the curriculum, including science. Alongside this, teachers' lack of confidence, training, background knowledge and access to resources to teach science and technology to young students has a significant impact on the profile of science in the primary classroom (Goodrum et al., 2001; Appleton, 2003).

The most significant issue with primary science as reported by Goodrum et al. (2001) is not so much on the teaching pedagogy, but whether in fact it is taught at all, a concern also expressed by Tytler and Griffiths (2003). Akerson (2005) also conveys this anxiety and goes on to indicate that teachers in primary schools tend to have incomplete knowledge in the field of science and thus look for ways to compensate for this incomplete understanding. One of the main strategies for this compensation is to teach as little science as possible (Appleton, 2003; Akerson, 2005). However, when science is taught, it is often it is very content focused and not always made relevant to the lives of young people (Aikenhead, 2006; Fensham, 2004; Goodrum et al., 2001; Tytler, 2003).

Other issues with the delivery of primary school science include that while students are often involved in investigation, it is usually teacher directed rather than student led; that science is limited to indoor classroom activities rather than outdoor activities and excursions; science speakers rarely visit classrooms; and computers and the internet are used infrequently for science work or not at all

(Appleton, 2005; Goodrum et al., 2001). Appleton and Kindt (1999) also indicate the tendency of beginning teachers to rely on writing and reading-based approaches to science teaching, if it is incorporated at all, due to the prevalence of these approaches in other curriculum areas, in conjunction with other aspects of the initial teaching experience which can be overwhelming as they embark on their teaching careers. Akerson (2005) adds that when science is taught it is more often biology than physical science, another strategy she says that teachers use to compensate for incomplete knowledge, supporting earlier discussions about the impact of concerns about students opting out of physical/chemical science in upper levels of schooling.

Indeed, Speedy, Annice and Fensham (as cited in Schibeci and Hickey, 2004) report on concerns that primary science is in such a poor state that it might even be better if it is not offered in the primary years at all. All of this evidence points to the strong conclusion that significant concerns around the teaching of primary school science have been present for decades and that targeting either practicing or preservice teachers alone is insufficient. This further highlights the need for a new approach that might help improve on science teaching and learning outcomes. Such an approach is investigated in this study: that is, the use of collaborative partnerships targeting science professional learning for both preservice and practising teachers together. It is important however, that any new approach is informed by best practice research that has already been established. Some examples of this best practice in science are explored in the next section.

2.5 Best Practice in Science Education

Goodrum et al. (2001) highlight a number of themes that describe the ideal teaching and learning of science. They indicate that science teaching and learning should be:

1. Relevant to the needs, concerns and personal experiences of students;
2. Centred on inquiry where students investigate, construct and test ideas and explanation about the natural world;
3. Assessed to serve the purpose of learning, consistent with and complementary to good teaching;
4. Characterised by enjoyment, fulfilment, ownership of and engagement in learning, and mutual respect between the teacher and students.

(Goodrum et al., 2001, p. 175)

They also highlight themes associated with teaching as a profession, resources for teaching and learning and the value placed on science education. These themes have informed the development of the Primary Connections project and are linked to the pedagogical practices central to the Science Innovation in Schools (SIS) project outlined below.

The SIS Components of Effective Teaching and Learning in Science

1. Encouraging students to actively engage with ideas and evidence;
2. Challenging students to develop meaningful understandings;
3. Linking science with students' lives and interests;
4. Catering for individual students' learning needs;
5. Embedding assessment within the science learning strategy;
6. Representing the nature of science in its different aspects;
7. Linking science with the broader community;
8. Exploiting learning technologies for their learning potentialities.

(Tytler, 2002a, p. 9)

One of the most significant changes that Goodrum et al. (2001) identify is to de-emphasise the teacher controlled, recall of facts approach to teaching science and turn rather to an inquiry-based, hands-on approach where students can "plan and carry out worthwhile, extended and meaningful investigations through which they can develop understanding of science and scientific ways of thinking" (Rennie et al., 2001, p. 486). As shown above, this has been an ongoing concern for decades, where Goodrum et al. (2001) tell us that Hurd first questioned the 'traditional' approaches to science teaching in the 1970s. The United States' National Science Education Standards produced by the National Research Council [NRC] (1996) also called for a change to an active, student-centred, inquiry based approach to science teaching that meets the interests, knowledge, understanding, abilities and experiences of students. The goals in both of the SiS project and Goodrum et al.'s themes on quality teaching and learning in science identify these same elements for science education in Australian schools.

Goodrum et al. (2001) acknowledge the variety of approaches and ideas held by a range of science educators. What they do report as a common goal however, is an experience that will develop scientific literacy:

> helping (students) to be interested in and understand the world around them, to engage in the discourses of and about science, to be sceptical and questioning of claims made by others about scientific matters, to be able to identify questions, investigate and draw evidence-based conclusions, and to make informed decisions about the environment and their own health and wellbeing.
>
> (p. 466)

This, linked with the idea of science teaching being more about the active development of concepts (Skamp, 2004) or, as Levitt (2001) puts it, “altering prior conceptions rather than giving explanations where none existed before” (p. 3), was a major theme coming through in the national professional standards for highly accomplished teachers of science, released by the Australian Science Teachers’ Association (ASTA) in 2002 and 2009. Jones and Carter (2007) report on studies that have found that teachers who hold constructivist beliefs have a larger repertoire of teaching strategies and select strategies that promote conceptual change.

These ideas are consistent with Vygotsky’s (1978) ideas of social constructivism: learning as a social and collaborative process with respect for alternative conceptions and students’ prior learning. One of the essential messages emerging here is that there is a number of authors and departments associated with the development of teaching and learning in science that appear to be in agreement with the main processes and elements that reform should incorporate. This in turn lends support to Rennie et al.’s (2001) assertion that “current science syllabuses and curriculum frameworks provide an appropriate, modern and progressive vision of the intended science curriculum” (p. 473). The key issue then, appears tied to the implementation of reform ideas and national professional standards. The theory underpinning the recommendations coming out of major reports and studies in science education is that of constructivist learning.

Constructivism: A Theory of Teaching and Learning

Constructivist pedagogies originated in Piaget’s work on a learner’s personal construction of meaning through his or her experiences and Vygotsky’s (1978) social constructivism that acknowledges the broader social environment and its influence in the construction of knowledge and understanding. There are many interpretations of constructivism depending on the school of thought from which they originate. Generally speaking however, constructivist methodologies “focus on deep understanding of knowledge rather than on reproduction and recall and require the development of meta-cognitive skills to ‘work’ successfully with knowledge” (Cuttance, 2001, p. xiii). Constructivism “assumes a dynamic and interactionist conception of human learning” (Bybee, 1997, p. 167) where students bring their current beliefs, understandings, attitudes and skills to the learning environment (i.e. their prior knowledge), and these are recognised, developed, challenged and redefined in the learning process (Bybee). Constructivism has expanded approaches to teaching and learning in science to include a broader range of ideas on how to work scientifically, which includes critical thinking and drawing inferences using scientific ideas.

Emerging from constructivist ideas in science education are concerns with concept development (Skamp, 2004) which tie to ideas on how we construct knowledge. Students form conceptions to explain phenomena that they encounter from their experiences with these phenomena, or from well-intentioned peers, family and media who also operate within what has been termed an 'alternative conception' framework (Hewson & Hewson, 1983). Alternative conceptions are essentially a conceptual understanding of phenomena that is based on explanations and ideas that are not accepted as fully consistent with the current thinking of the scientific community (Hewson & Hewson, 1983; Skamp, 2004; Tytler, 2002b).

To have any hope of altering these alternative conceptions to form more scientifically accepted conceptions, Skamp (2004) argues that "knowledge of students' alternative conceptions is critical" (p. 4). This requires strategies to be put in place where teachers can identify what students already know and what logic constructs have been built around this 'knowing'. This has been recognised in a number of learning programs, not necessarily linked to science, which have been endorsed and even been made compulsory in primary classrooms e.g. Early Numeracy Research Project [ENRP] (DEECD, 2006); Children's Literacy Success Strategy [CLaSS] (Crevola & Hill, 2005). Interviews, concept maps and pre-tests are common tools for identifying children's prior knowledge which can then hopefully be built on. This tapping into prior knowledge is a fundamental aspect of constructivist learning, and critical for conceptual change (Hewson & Hewson, 1983).

Creating opportunities for students to explore their initial scientific ideas and challenge their constructions is a critical issue (Hewson & Hewson, 1983; Skamp, 2004; Tytler, 2002b). Duit and Treagust (2003) help to explain why by recognising that:

> students do not come into science instruction without any pre-instructional knowledge of beliefs about the phenomena and concepts to be taught. Rather, students already hold deeply rooted conceptions and ideas that are not in harmony with the science views or are even in stark contrast to them. (p. 671)

The tenacity with which students hold onto their conceptions makes the pedagogy selected to challenge their constructions crucial if teachers are to successfully engage students in challenging their constructions and moving towards a conception that aligns with current accepted scientific views. Hewson and Hewson (1983) argue that any attempt to achieve conceptual change must be intelligible, plausible and fruitful. For the new concept to be intelligible it must be understood by the individual (Hewson & Hewson). For it to be plausible, the individual “must also believe it to be true” (Hewson & Hewson, p. 732). For it to be fruitful, in that the individual must be able to use it to resolve an issue or problem, and for this to occur, interaction with the individual’s prior knowledge is essential (Hewson & Hewson). The 5Es model (Bybee, 1997), based on principles of constructivism and conceptual change, is one such model shown to be effective through Hackling and Prain’s (2005) Primary Connections research.

The 5Es Inquiry Framework

The 5Es model uses inquiry and investigation for students to question subject matter in order to form explanations for the phenomena and concepts they explore. Students move through five stages of instruction: Engagement, Exploration, Explanation, Elaboration and Evaluation (Bybee, 1997). Each of these stages takes a student through a process of relatively unstructured experiences through to more formal learning instruction. Bybee (1997) explains that this enables students to experience assimilation, accommodation and equilibrium; different phases of learning as described by Piaget more than four decades ago.

Through reading Bybee’s work on the 5Es model, it can be surmised that the Engage and Explore phase focus students on the task as they begin to explore the ideas they already have on the topic, a process of assimilation. Following the guidelines from the Australian Academy of Science (2006) who developed the Primary Connections resources, it is in the Engage phase that teachers can assess students’ prior knowledge, and the source(s) and depth of any alternative conceptions can be identified. Then as students spend more time in the Explore phase, teachers can provide activities and stimulate discussion that helps children confront their alternative conceptions and begin to form intuitive understandings of more scientifically accepted conceptual frameworks.

The Explain phase is where the teacher begins to formalise the learning and help students explain their developing understandings of scientific concepts. Thus it is in this phase that they accommodate new and old understandings by examining the experiences from their explorations.

Formative assessment takes place in this phase to ensure that students' alternative conceptions are moving towards explanations that are consistent with current views of science.

In the Elaborate phase students are required to participate in group discussion and apply their new understandings to new situations with an aim to begin generalising concepts learned. Evaluation is an opportunity for students and teachers to review the learning that has taken place. Consolidation of new concepts in this phase helps students retain new knowledge and understanding. Hence it is in this phase that students are provided with an opportunity to reflect on their overall learning and express this in a manner such that teachers can use summative assessment practices to assess conceptual outcomes.

The 5Es model has reportedly been successful in the Primary Connections project (Hackling & Prain, 2005) where it "supported the progressive development of understandings (and) facilitated changes to teachers' practice" (p. 2), two essential components of the changes needed in science teaching and learning. It is also consistent with constructivist theory. Hackling and Prain (2205) explain how:

> The model is based on an inquiry and investigative approach in which students work from questions to undertake investigations and construct explanations. It is therefore consistent with contemporary constructivist learning theory which suggests that learners actively construct knowledge and make personal meaning from their experiences. (p. 2)

Parallels can also be drawn between the 5Es model and other examples of best practice in science education research, in particular with a number of Tytler's (2002a) SIS components. Each of the phases of the 5Es model align with Tytler's first SIS component: encouraging students to actively engage with ideas and evidence. This is achieved in the Engage phase where activities are selected to "engage students' interest in the topic and elicit their existing beliefs and experiences about the topic" (Hackling & Prain, 2005, p. 25). In the Explore phase it is achieved through the hands-on experiences of science that are integral to this phase. These approaches encourage active engagement in the learning process. In the Explain phase students are encouraged to identify patterns and relationships from their observations of science phenomena and thus are actively engaged with ideas and evidence for which they begin to form scientific explanations.

Similarly in the Elaborate phase, where students "test and extend their new conceptual understandings in a new context" (Hackling & Prain, 2005, p. 26), active engagement with ideas and evidence is used to consolidate and extend learning. These phases also address Goodrum et al.'s (2001) call for science teaching and learning to be 'relevant to the … personal experiences of students (p. 175) and 'centred on inquiry where students investigate, construct and test ideas and explanations (p. 175) as this would require both active engagement with ideas and learning materials (SIS component 1) as well as maintaining links with the lives and interests of students (SIS component 3).

Tytler (2002a) indicates through the second SIS component that effective teaching and learning of science requires teachers to challenge students to develop meaningful understandings. This is achieved by connecting science learning across lessons and across contexts. Using the 5Es model for a topic of work encourages the development of meaningful learning across lessons, and the Elaborate phase encourages application of new ideas to different contexts which helps achieve the across contexts element of this SIS component.

The Australian Academy of Science's (2009) adaptation of Bybee's original 5Es model explicitly builds in opportunities for embedded assessment. This includes diagnostic assessment in the Engage phase, formative assessment in the Explain phase, and summative assessment in the Elaborate and Evaluate phases. This helps their 5Es model address Tytler's (2002a) SIS component five which calls for embedded assessment within the science learning strategy. The embedded assessment approach also helps meet Goodrum et al.'s (2001) recommendation for science teaching and learning to be "assessed to serve the purpose of learning" (p. 175). The 5Es model is shown in Table 2.5.1.

Table 2.5.1: 5Es Model of teaching and learning

PHASE	DEFINITION
ENGAGE	Engage student and elicit prior knowledge. *Diagnostic assessment.*
EXPLORE	Provide hands-on experiences of the phenomenon. *Formative assessment*
EXPLAIN	Develop science explanations for observations and represent developing conceptual understandings. Consider current scientific explanations. *Formative assessment.*
ELABORATE	Extend understandings to a new context or make connections to additional concepts through student-planned investigations. *Summative assessment of the investigating outcomes.*
EVALUATE	Students represent their understanding and reflect on their learning journey and teachers collect evidence about the achievement of outcomes. *Summative assessment of conceptual outcomes.*

Australian Academy of Science, 2009, p. 9

The 5Es model was also used as the basis for the writing and delivery of the earlier Primary Investigations project (Aubusson & Steele, 2002). This project saw the production of teacher resource books, with activities and lessons written to the 5Es principles of constructivism being delivered in association with teacher professional development that highlighted the theoretical underpinnings in using the activities. 5Es was reported to be highly successful as a model for teachers who undertook the associated professional development. However, for those teachers who used the resources without attending the associated professional development workshops, the pedagogical approach underpinning the development of the resources was treated in a dismissive manner (Aubusson & Steele, 2002).

This is significant in demonstrating the power of being overt with the theoretical models that inform particular initiatives in science teaching and learning. Teachers used the Primary Investigations resources and reported favourably on them but unless they participated in associated professional development they were not conscious of the associated pedagogies, and in fact, adapted the activities to cater to their own established approaches. As Aubusson and Steele (2002) show, activities on their own can be useful and fun in the classroom, but they can also be adopted to fit any particular existing approach to teaching and learning in the teacher's repertoire. These findings suggest that it is through professional development and opportunities to engage teachers in reflection on their practice that changes in pedagogical approaches used in primary science teaching can be addressed. Otherwise, significant gaps may continue to exist between the intended and actual delivery of science. This may encompass both the curriculum intended by science education researchers when they produce curriculum materials as highlighted above and/or the gap between what teachers themselves intend to achieve with what they ultimately deliver. The next section explores this idea further.

Intended and Actual Delivery of Science

Rennie et al. (2001) report that there is a gap between the intended and actual science curriculum delivered in Australian schools. Teachers seem to support ideas behind achieving scientific literacy through a thinking curriculum and hands on learning in their rhetoric, but as noted by Keys (2005), these expressed beliefs do not always translate into practice. Content driven, transmission approaches to teaching are easier to prepare and deliver and the preparation and delivery of more student-centred approaches are considered too time-consuming for many teachers to contend with on an on-going, regular basis (Appleton and Kindt, 1999; Keys, 2005; Goodrum et al., 2001; Lumpe et al., 2000).

Levitt (2001) reports on an American study that found that teachers do believe in a student-centred, hands-on approach to teaching science, but her findings also indicate that belief does not always translate into practice. When this notion was discussed with participants in Levitt's study, one participant responded that the reason teachers do not pursue the hands-on, student-centred teaching and learning associated with their rhetoric is because of the "time, money and effort" (p. 12) it takes. This reasoning is also revealed by Appleton and Kindt (1999), Keys (2005) and Rennie et al. (2001) where primary school teachers indicate that insufficient resources and inadequate time for preparing are the main factors that frequently limit the quality and quantity of science teaching and learning in the classroom. Appleton and Kindt also found that collegial support was a key factor in determining whether beginning teachers incorporated science in their teaching programs.

However, Keys' (2005) study goes on to reveal that even when resources are provided, this does not necessarily translate into improved practice or more student-centred/hands-on approaches being adopted. This was evident when only three out of 43 teachers studied in Queensland schools who were provided with science kits, actually used them. Aikenhead (2006) reported a similar finding where teachers pointed to other barriers to implementing student-centred approaches to science teaching once resources were provided. In Levitt's (2001) American study, kits provided to teachers in the research schools were incorporated in a more hands-on approach to teaching, but these teachers were supported with a professional development program to go with the kits. The Queensland teachers of Keys' research had kits made available but were given no real support structure to encourage their use. One of the participants in Levitt's study did report that she believed it was internal motivation more than provision of resources or time that influenced teaching of science. If "the teacher believed enough in teaching science through hands-on activities [then] they would put in the time, money, and effort because it helped kids learn" (Levitt, p. 12).

Appleton and Kindt (1999) report a similar finding in their research into beginning teachers' influences on science teaching practices. They found that beginning teachers found it difficult to access resources, even if they were available in the school. If the resources were poorly organised, this was also an inhibiting factor, unless the individual teacher was particularly committed to science teaching. They also reported that the extent and organisation of available resources was a determining factor as to which topics were taught, how topics were taught, and what particular activities were included in the program.

The findings from Levitt (2001) and Keys (2005) indicate that teachers generally do believe (in rhetoric at least) in the inquiry-based models of teaching and learning science. The fact that few follow through with actions that would support these claims raises the question of whether it is really teachers' self-efficacy beliefs and lack of science background – both content and pedagogical knowledge, that impact on their ability to identify and select appropriate resources for a given topic or lesson. This is perhaps why one of the other overarching claims made by teachers is related to the need for professional development and on-going support in delivering science education (Keys, 2005; Levitt, 2001; Rennie et al., 2001; Sanders, 2004).

If we want teachers to implement constructivist approaches to learning in science, it is appropriate that their own learning is achieved through these approaches. A number of studies have shown that teachers' concepts of teaching are strongly influenced by the way they themselves were taught (Dunn & Dunn, 1979; Stofflett & Stoddart, 1994). It has been established that school science is geared away from constructivist approaches, leaving only the short period of teacher education to model more appropriate approaches. Indeed, the application of constructivist approaches has been found to have "a profound effect on science teacher education" (Koballa & Tippins, 2001, p. 223). This means that science teacher education not only needs to provide strategies and resources to promote constructivist approaches to science teaching and learning in schools, but must also model these teaching and learning approaches in their courses. Teacher professional learning is one of the key ways in which this can be addressed. This is considered in the next section along with the literature examining the components required for professional learning to be effective.

2.6 Teacher Professional Learning in Primary School Science

The studies of Keys (2005), Goodrum et al. (2001), Lumpe et al. (2000) and Levitt (2001) highlight that the issue of on-going professional development is a critical one. We can resource schools and staff, but to actually improve teaching and learning in science and change pedagogy, support structures in selecting and using these resources is also necessary. There is a growing need for primary school teachers to strengthen both their knowledge of science content (general content knowledge (GCK) and pedagogical content knowledge (PCK) for the teaching of science. As demonstrated earlier, primary teachers are uncertain about how best to teach science, have relatively low levels of interest in science and have relatively low academic attainment in their past science and mathematical pursuits (DEST, 2003). Akerson (2005) and Appleton (2003) tell us that the lack of confidence these teachers have in teaching science could come from incomplete understandings they hold of scientific concepts. Findings in the SIS project demonstrate that with on-going support, improvement in quantity and quality of science in primary schools is achievable (Tytler & Griffiths, 2003).

Professional development 'is now recognised as a vital component of policies to enhance the quality of teaching and learning in our schools (Ingvarson, Meiers & Beavis, 2005, p. 2), an idea supported by Darling-Hammond (2000a) and Hewson (2007), both of whom also indicate that professional development can have a substantial impact on improving the quality of teaching and learning. This becomes a key goal in primary science where it has been recognised that teaching and learning are not receiving the time allocation or ideal approaches needed (Appleton & Kindt, 1999; Keys, 2005; Rennie et al., 2001). It has also been recognised that professional development can reduce stress and improve low morale (Senate Employment, Education and Training References Committee Inquiry, 1998); key issues in an area where confidence and self-efficacy have been demonstrated to be critical (Goodrum et al., 2001; Hackling & Prain, 2005), and where teachers are shying away from science to compensate for incomplete knowledge (Keys, 2005).

Effective Professional Learning

Loughran (1999) highlights a growing concern that teacher professional development is not as effective as it might be due to the tendency of approaching it as 'a way of "doing things to teachers', rather than 'doing things with teachers" (p. 271). Loughran encourages a more constructivist approach to teachers' in-service learning by "tapping into teachers' professional knowledge" (p. 271) and using this as a basis for developing learning suitable "to their individual teaching context" (p. 271). Posnanski (2002) further promotes the notion of a constructivist approach to teacher professional development and characterises such an approach as one where teachers are able to "develop the knowledge base to effectively analyse their teaching situation and choose from a variety of strategies to enhance teaching behaviours and student learning" (p. 190).

Ingvarson et al. (2005) identified a number of components that characterise effective professional development from their study of over 3000 teachers participating in a range of 80 different professional development programs. These included:

- content focus;
- follow up;
- active learning;
- feedback;
- collaborative examination of student work.

Ingvarson et al., 2005, p. 8

These components align with findings from Garet, Porter, Desimone, Birman and Yoon (2001) who highlight that:

> professional development that focuses on academic subject matter (content), gives teachers opportunities for "hands-on" work (active learning), and is integrated into the daily life of school (coherence), is more likely to produce enhanced knowledge and skills. (p. 935)

Garet et al. (2001) go on to indicate that enhanced knowledge and skills are more likely to translate into changed teaching practice. The coherence they refer to as a component in effective professional development is connected to a number of factors. These include the extent to which a given professional learning experience is linked to other professional development experiences; is aligned with state/district/territory curriculum standards and assessments, and promotes professional communication. Posnanski (2002) recognises a similar range of factors to consider in effective professional development programs and highlights in particular the need for "sufficient duration" (p. 192), theory-practice integration and reflection.

The Focus on General Content Knowledge versus Pedagogical Content Knowledge

Ingvarson et al. (2005) also report on the need for professional development program content to "increase teachers' understanding of the content they teach, how students learn that content and how to represent and convey that content in meaningful ways" (p. 8), a notion also recognised by Cohen & Hill, (2000). Abell (2007) discusses the tension between the focus on general content knowledge (GCK) at the exclusion of pedagogical content knowledge (PCK) in science professional learning.

She highlights that whilst some incorporation of GCK is necessary, it is the development of PCK that makes for effective teaching. Posnanski (2002) also indicates that effective science professional learning programs incorporate both PCK and GCK as this assists in increasing teachers' self-efficacy beliefs and in lowering their anxiety about science teaching.

The notion of ongoing, as an alternative to one-off, injection type approaches to professional development, has been recognised for a number of decades as an important feature of effective professional learning programs (Fullan, 1982; Garet et al., 2001; Hewson, 2007; Posnanski, 2002; Tytler, 2003). Goodrum et al. (2001) also discuss the importance of "the provision of ongoing structured professional development (as) most important so that teachers' science and pedagogical knowledge is current and relevant" (p. 132). Supporting this idea, Hewson (2007) discusses how essential continuing support during planning, implementing and reflecting phases of new ideas for science teaching are in determining substantial and lasting change in teachers' practices. This relates to Ingvarson et al.'s (2005) report on the importance of follow-up as a component of effective professional development. Teachers report a need for on-going support in addition to initial professional development activities in order to assist them with issues that emerge once they have had the opportunity to practice new ideas and strategies (Garet et al., 2001; Goodrum et al., 2001; Hackling & Prain, 2005; Ingvarson et al., 2005). This is in line with concepts associated with reflective practice which "draws from experiential learning" (Osterman & Kottkamp, 2004, p. xii).

The current success of a combined focus on content and pedagogy is evident in the research on Primary Connections (Hackling & Prain, 2005). The Primary Connections teacher resource books and accompanying professional development program had a significant impact on "teachers' practice, students' learning and the status of science" (Hackling & Prain, p. 1) in trial schools. Primary Connections uses a lesson-by-lesson approach to different units in science (e.g. Marvellous Micro-organisms) that adopts a focussed 5Es model of teaching and learning. Teachers in trial schools could deliver each lesson and thus a whole unit, by following the steps and activities outlined in the resource books. Where teacher confidence, experience and initiative were present, individual teachers had the potential to add their own elements, thus taking away from the otherwise recipe-like delivery. The strength of this model is that a sequential, research-based structure is provided for teachers who have low confidence, self-efficacy and background knowledge whilst the capacity for more confident, experienced and knowledgeable teachers to use the resources and model flexibly to explore complementary initiatives is still present. The model is in accordance with Ingvarson et al.'s (2005) assertion of the importance of content focus, and Posnanski's (2002) and Hewson's (2007) recognition for blended programs targeting both content and pedagogy.

Active learning was another component Ingvarson et al. (2005) and Garet et al. (2001) reported on as important in the delivery of effective professional development. Garet et al. describe active learning occurring through peer observation and obtaining feedback; planning classroom implementation of new strategies/ideas introduced in a professional learning program; reviewing student work, and presenting, leading discussion and producing written work. Osterman and Kottkamp (2004) extend this, stating that "reflection must be integrally linked with action" (p. 24). In this case, active learning is characterised by the need for teachers to reflect on their own practice "in relation to professional standards for good practice" (Ingvarson et al., 2005, p. 8) and is discussed in the next section.

2.7 Reflective Practice

Reflective practice as a key process in active learning is considered by most educators as "a generic component of good teaching" (Korthagen, 2001, p. 51). The concept of reflective practice has had increasing attention in research since the mid-seventies and it is now well established as a characteristic of 'good' teachers (Schon, 1983; Brookfield, 1995; Korthagen, 2001; DEST, 2003). This is recognised in Australian literature about effective practices, in government teacher registration bodies (Victorian Institute of Teaching (VIT), 2003; NSW Institute of Teachers, 2003) and by teachers themselves who contributed to the development of teaching standards for registration. What is not well established, however, is a definition of what reflective practice is, or what exactly it entails.

Schon's (1983) model of reflection-in-action, reflection-on-action, appears to be one of the most widely adopted and adapted models of reflection where a key feature includes that of identifying a problem. It has been the basis for much action research and is informed by experiential learning theories. It is primarily concerned with the identification of a problem which can then be considered in relation to some sort of action for improvement. Criticism of Schon's approach is that "he acts as an objective observer [of problematic situations] and is therefore only able to record observable behaviour" (Clandinin, 1986 (cited in Parsons and Stephenson, 2005), p. 96).

Kreber and Cranton (2000) distinguish between three components of reflection: content, process and premise. Content reflection focuses on describing the problem, for example, what were the problematic teaching and/or teaching processes used? They relate this component of reflection to instructional knowledge. Process reflection seeks to uncover the theoretical underpinnings of the actions being reflected upon; such as reflection on the instructional processes informing the teaching/teaching strategies used. Kreber and Cranton relate this form of reflection to pedagogical knowledge. In premise reflection, the focus turns to consideration of the importance of the problem. Why was the teaching approached in a certain way, what is the rationale behind the actions taken and the alternative actions? Kreber and Cranton link this component of reflection to curricular knowledge and argue that this is where reflection on practice becomes critical.

Grushka, McLeod and Reynolds (2005) also distinguish between three areas for reflection. They term these the technical, practical and critical components. Technical reflection links with Kreber and Cranton's (2000) content reflection, practical reflection with process reflection, and critical reflection with premise reflection. Grushka et al. also identify three stages of reflection for each of these components that relate to a 'before, during and after' notion. They discuss reflection before a lesson as 'Reflection for Action' which involves the technical, practical and critical reflections associated with planning a particular activity or lesson. Their reflection during a lesson, 'Reflection in Action', relates to Schon's (1983) ideas on the ability to reflect on personal performance based on the experiences occurring at the time – 'during' the event. Finally, their post-lesson reflection, termed 'Reflection on Action', involves the review and evaluation of what has happened, why it has happened and what might be changed in the future.

Loughran (2002) discusses how reflection is viewed as "thinking about something" (p. 33) by some, "whereas for others, it is a well-defined and crafted practice that carries very specific meaning and associated action" (p. 33). He purports that however reflection is considered, its common notion is that it concerns "a problem (a puzzling, curious, or perplexing situation)" (p. 33). Reflective practice is distinguished by its emphasis on personal experience, and specifically, data regarding an issue or problem in the professional setting that an individual seeks to change (Osterman & Kottkamp, 2004; Korthagen, 2001). Loughran (2010) also states that reflective practice “is about examining, learning and responding” (p. 164). This notion of examining is one of the significant components of reflective practice as it requires the study of the theories underpinning actions and practices (Brookfield, 1995; Korthagen, 2001; Osterman & Kottkamp, 2004), something that can be “difficult and uncomfortable if the data does not support our own framing” (Loughran, 2010, p. 164).

Reflective Practice for Professional Learning

The idea of reflective practice for professional learning has had significant growth in the past decade and has already been linked implicitly with other components of effective professional development on which Ingvarson et al. (2005) have reported. In education, ‘professional standards’ can encompass a range of issues from theory about teaching pedagogies to standards written by a variety of teaching organisations and associations e.g. National Standards (MCEETYA, 2003); Victorian Institute of Teaching Professional Standards (VIT, 2003); National Science Teaching Standards (NSTA, 2003).

Opportunities to practice new ideas and strategies and receive feedback on performance have also been identified as vital components in effective professional development (Ingvarson et al., 2005; Posnanski, 2002). This feedback can come from a mentor or a supporting teacher (Ingvarson et al.) and links to elements of Brookfield’s ‘lenses’ used in critical reflection (Brookfield, 1995). Brookfield discusses reflection through the use of “four critical lenses” (p. 29) through which individuals can view their teaching in order to achieve critical reflection. These lenses include Autobiographical, Students’ Eyes, Colleagues’ Experiences and Theoretical Literature. These cover respectively, personal perspectives on practice, looking at practice through the eyes of students, peer review and discussion with colleagues, and researching the literature to help explain the assumptions that influence practice and ways to change them.

Brookfield’s (1995) argument for using the four lenses is linked to the notion of critical reflection. He argues that through the examination of practice from a variety of sources, critical reflection is achieved where individuals can identify and consider the appropriateness of the assumptions that guide their behaviours. The links made to reflective practice from Ingvarson et al.’s (2005) follow up and active learning align with Brookfield’s (1995) Autobiographical, Students’ Eyes and Theoretical Literature lenses. The student and colleague lenses discussed by Brookfield (1995) are tied to the notion of feedback. Utilising students and colleagues as sources of feedback help teachers view their practice through the eyes of external observers.

Kreber and Cranton (2000) discuss their view of reflective practice and how it is achieved. They state that “the scholarship of teaching includes the acquisition of knowledge about teaching through reflection on practice and research” (p. 478). They go on to say that reflective practice is “developed through a combination of reflection on theory and research and experience-based knowledge on teaching” (p. 478) and may include issues such as success and difficulties in a particular lesson, selection of content, questioning, selection of teaching and organisational strategies, classroom management and behavioural modification techniques, assessment tasks and selection and use of resources. However, this remains a model of experiential reflection and does not become critical until it is linked with research and literature, and action on the reflection is taken. Brookfield (1995) would also argue that to be critical, the reflection must also address the pedagogical assumptions informing the teaching behaviours and selection of activities/resources and incorporate external feedback from students and colleagues. The notion of external feedback for reflection can be linked to the idea of collaboration, which is discussed next.

Collaboration in Reflective Practice

Collaboration is a strong element in achieving feedback from colleagues, a component of critical reflection as purported by Brookfield (1995). It is also the factor that separates reflective practice from reflection according to Osterman and Kottkamp (2004):

> While reflective practice clearly involves analysis, it is distinctly different from reflection. In contrast, reflective practice involves a systematic and comprehensive data-gathering process, not simply a recollection of events. Similarly, while reflection often relies solely on personal resources, dialogue and collaborative effort enrich reflective practice.
>
> Osterman & Kottkamp, 2004, p. 65

One of the reasons current and future activities need to focus on collaborative approaches to professional development, as highlighted by Goodrum et al. (2001), is that teachers report lacking “the time and opportunity to share ideas, collaborate, reflect, evaluate, adequately prepare and participate in ongoing learning/professional development” (p. 87). Other reasons are tied to the nature of collaboration in reflective practice which has been argued as an effective form of professional development in its own right (Korthagen, 2001; Osterman & Kottkamp, 2005), and the implicit and explicit links it has with the elements of effective professional development reported generally by Ingvarson et al. (2005), and specifically to science teacher professional development by Goodrum et al. (2001) and Hackling and Prain (2005). Berry and Milroy (2002) relate how “it is difficult to ‘see’ your practice when working alone” (p. 214) in highlighting why collaboration was such a cornerstone for growth and development in a research project about their practice.

The discussion around collaboration is related to the final component of effective professional development reported by Ingvarson et al. (2005); this being collaborative examination of student work. Osterman and Kottkamp (2005) espouse that “analysis in a collaborative environment is likely to lead to greater learning” (p. 65). This includes collaboration on student work where teachers can gain a “deeper understanding of student learning outcomes and greater discrimination about what counts as meeting those objectives” (Ingvarson et al., p. 9). Brookfield’s (1995) ‘lens’ of Colleagues’ Eyes as explained above, can quite naturally extend to this aspect of collaboration with one’s peers, thus highlighting once again the power of reflective practice as a means of effective professional development. This applies not only to teacher professional development however, but also to effective preservice teacher education, as is discussed next.

Reflective Practice in Preservice Teacher Education

Reflective practice needs to be a critical component of preservice teacher education. Parsons and Stephenson (2005) indicate that new teachers in their very first appointment are expected to be reflective practitioners. It is highlighted by Corley and Eades (2004) that in fact any profession that expects continuous professional development, as does the teaching profession, would be concerned with reflective practice. It is essential then, that teacher education courses build in experiences of reflection and strategies for being critically reflective in order to equip students with the skills required by their profession.

This approach is evident in Korthagen’s (2001) work where he developed the Action, Looking back on the action, Awareness of essential aspects, Creation of alternative actions, and Trialling of the new action (ALACT) model as an approach to preservice teacher education. The ALACT model highlights “an alternation between action and reflection” (Korthagen, p. 43) where problems are identified in a particular action. 'Looking back on the action' enables critical thinking, research and problem solving approaches to be developed to address improvement in the new action that is consequently planned (Creation and Trialling of alternative actions). This model was applied in Brandenburg's (2004) research with first year mathematics education students where theory and experience were linked in 'round table' discussion tutorial sessions that looked back on experiences of teaching mathematics in the one day a week school experience (teaching round) that the students were involved in.

Parsons and Stephenson (2005) also report on their research with preservice teachers where reflection was built into school experience. One of the critical points that they make is that the teaching round is usually so pressured and time hungry that students spend most of their time thinking about "what should I do next" rather than on "why am I doing it" (p. 103). It becomes critical then, that the time and need for reflection is formally built into the experience in some way.

Brandenburg (2004), Korthagen (2001) and Parsons and Stephenson (2005) all report on research that involved students in a social construction of reflective practice. Critical to this approach is the collegial nature of the reflective practice. This can occur in a number of ways. As a whole group, students might share their teaching experiences/identification of problems they have made and discuss their case with the whole group in a 'round table' situation (Brandenburg, 2004). Alternatively, a mentoring partnership might be created where the teacher supervisor or perhaps the academic work in a one-on-one manner with the preservice teacher to scaffold the reflective process and contribute to the generation of new ideas.

Loughran (2002) discusses effective reflective practice as the consideration of "teacher knowledge through particular concrete examples" (p. 39) which can lead to a bridging of the theory-practice gap. He purports a constructivist approach to reflective practice, arguing for the importance of "positioning the student teacher as a learner in a curriculum constructed as a result of real experiences and reconstructed through interaction between learners" (p. 41). Darling-Hammond (2006) also offers the view that the integration of course-work and field-work help preservice teachers to better "understand theory, to apply concepts they are learning in their course work, and to better support student learning" (p. 307), something she reports as being supported by a number of other researchers. This integration of theory and practice through the key role of reflection helps to connect preservice teachers in a manner in which they are better able to “handle the problems of everyday teaching through theory-guided action” (Korthagen et al., 2006, p. 1021).

Loughran (2002) also discusses how sharing experiences in practice-focussed discussions can enhance meaningful learning for preservice teachers, particularly if they are required to “develop assertions about their practice as a result of this sharing” (p. 38). He argues that meaningful learning occurs due to the developing understanding stemming from preservice teachers reconsidering their own and their peers’ experiences and articulating these within practice-based assertions forged from common understandings through sharing and discussion. This development of higher-order synthesis of experience into assertions would have to involve thinking and talking about theory, thus drawing on a number of Brookfield’s (1995) lenses as reflection moves from personal experience to collegial experience, and articulated through theoretical notions associated with the course of study. Loughran (2002) believes that:

> This ability to recognise, develop, and articulate a knowledge about practice is crucial as it gives real purpose for, and value in, effective reflective practice; it is a powerful way of informing practice as it makes the tacit explicit, meaningful, and useful. (p. 38)

Korthagen et al. (2006) highlight reflection as being an “essential tool” (p. 1024) for bridging the theory-practice gap in preservice teacher education. The process outlined above by Loughran (2002) describes one approach that could achieve this using reflection as its basis. Korthagen et al. go on to discuss how learning does not occur through experience, but rather through reflection on experience and interaction with others. They also highlight the need for the theoretical underpinnings of practice to be “tailored to the specific situation under consideration” (p. 1025). This helps to achieve two things: firstly, it brings relevance of learning to the learner and best accesses learning through constructivist means by building on what the learner already knows or believes he/she knows; and secondly, it reinforces ideas that are being connected through theory and practice which Darling-Hammond (2006) tells us produces more effective learning.

Other examples of collegial reflection in preservice teacher education are evident in the literature. Parsons and Stephenson (2005) report on a critical partner model where students completed their school placement in pairs, and acted as supportive, critical observers of one another to enhance the reflective process. McNamara, Jones and McLean (2007) adopt another model where practising and preservice teachers worked in a collaborative relationship, where neither acted as a mentor, but rather, shared ideas and reflect together as equals in the partnership. Any one of these, or combinations of them all, help develop skills to reflect critically on practice and avoid the 'solitary nature' that placements can sometimes have (Parsons & Stephenson) which in turn can have negative implications in the development of skills for reflection. This notion is supported by Roth (2007) who reports on "the importance and value of collaboration between teacher researchers (which) challenges the prevailing norm of teaching as an isolated activity" (p. 1235).

Providing a structure that helps scaffold the reflective process is also of critical importance for beginning reflective practitioners, a claim supported by Russell (2005) who purports that reflection needs to be explicitly taught. Parsons and Stephenson (2005) report that most students, in providing reflections on their school experiences, treat reflection as a descriptive task, reporting on events, rather than as an analytical task where they identify reasons for successes and difficulties for which they can then construct approaches for improvement. A structure such as a set of guided questions can help provide the scaffold that promotes the development of independent monitoring by helping students learn the areas to focus on and the sorts of questions they need to consider.

As already recognised in discussing reflective practice in teacher professional learning, the notion of collaboration is important here also, as partners can help with the scaffolding for one another's thinking in the reflective process (Parsons & Stephenson, 2005). In the case of Jones and McLean's study (2006), there was great benefit also in the preservice teachers witnessing the types of thinking and questions established teachers asked themselves during the reflective phase. This modelling of reflective practice further developed the preservice teachers' abilities to engage in their own reflection. This links to Corley and Eades' (2004) premise that to best support reflection in education students, academics also need to be prepared to undertake the questioning of their own practice.

Loughran (2006) offers a summary set of points he sees as essential underpinning assumptions for effective reflective practice in preservice teacher education:

- a problem is unlikely to be acted on if it is not viewed as a problem;
- rationalisation may masquerade as reflection;
- experience alone does not lead to learning – reflection on experiences is essential;
- other ways of seeing problems must be developed;

- articulation matters;
- developing professional knowledge is an important outcome of reflection.

(p. 131)

So it is critical in the endeavour of teacher education that the development of these abilities occurs in preservice teachers – the educators of tomorrow. It seems that this will occur best when theory and practice are closely linked and students are provided with scaffolded opportunities to engage in different levels of reflection. Working in a collaborative partnership should enhance this process, as would incorporating it throughout their teacher education program with increasing demands and complexity. This should ultimately help to produce teachers, across all sectors of education, who are aware of and able to monitor their own thinking, understanding and knowledge about teaching and who are aware of the assumptions that influence their practice.

In addition to the notion of reflective practice in teacher educational pedagogy as discussed above, some further factors need to be considered, as a number of bodies have called for wider reform in teacher education around the world. Some of the issues they raise about effective teacher education are considered in the next section.

2.8 Preservice Teacher Education

There has been mounting criticism in the last few decades (Korthagen, 2001; Srikanthan & Dalrymple, 2002) about the ability of teacher education to have any significant influence on teachers and the improvement of education, and that “traditional approaches to teacher education do not function well” (Korthagen, 2001, p. 4). Darling-Hammond (2000b) also acknowledges criticisms of teacher education but contends that there is a body of evidence that “indicates that teachers who have had more preparation for teaching are more confident and successful with students than those who have had little or none” (p. 166).

Concerns about the quality of teacher education coupled with the perception that teachers are a key determinant of the quality of schooling and student learning (DEST, 2002) led the previous Australian Prime Minister John Howard, in conjunction with state and territory governments, to launch a review into teaching and teacher education (DEST, 2002; DEST; 2003). Given the central role universities have in preparing teachers (DEST, 2003); it must be considered how preservice teacher education within tertiary institutions can be best achieved.

Biggs (2003) reports that even in higher education, "learning is the result of the constructive activity of the student" (p. 11) a notion supported by Ramsden (2003), and yet most university level courses apply a transmission approach to learning, a consequence no doubt of the large numbers of students who are situated in a lecture-style environment. Ramsden (2003) reveals that poor learning is often encouraged in universities through the use of "teaching methods that foster passivity and ignore the individual differences between students" (p. 98). This would describe lectures delivered in the traditional format which have also been found to be ineffective because they fail to stimulate higher order thinking skills (Biggs, 2003).

Ramsden (2003) indicates that the quality of students' understanding in higher education is "intimately related to the quality of their engagement with learning tasks" (p. 40). While it could be argued that the university educator is always careful and thoughtful about planning the content for teaching, learning and assessment activities, it is the approach that is the most crucial element to effective teaching (Ramsden, 2003; Biggs, 2003). This is revealed in Lord's (1997) study that demonstrated significantly higher scores in knowledge, understanding and enjoyment of biology for non-majors where a constructivist approach based on Bybee's (1997) 5Es was compared with a traditional approach to teaching. Ramsden proposes that the concept of approach is qualitative in nature and is concerned with the 'what' and 'how' students learn rather than how much they remember. In addressing this idea, two main approaches appear in the literature as promoting or inhibiting the effectiveness of teaching and learning, these being 'deep' and 'surface' approaches (Biggs, 2003; Ramsden, 2003). Table 2.8.1 illustrates the difference between these.

While it could be argued that most preservice teacher educators are aware of the need for deep approaches to learning and teaching, the tendency to draw on more surface types of approaches stems from a response to what was a relatively quick expansion, restructuring and refinancing of the tertiary sector in the 1990s (Biggs, 2003). Biggs indicates that this resulted in significantly larger class sizes and a greater range in student diversity with respect to ability, motivation and cultural background. He also points out that financial constraints often resulted in fewer permanent staff and reduced autonomy among teachers as policy and general decision-making became more centrally controlled. Ultimately these changes in conditions and the teaching environment left tertiary educators struggling to cope and maintain standards (Biggs). He states quite simply that that tertiary educators were left feeling stressed.

Table 2.8.1: Deep and Surface Teaching and Learning Approaches

	TEACHING APPROACHES ADOPTED BY THE TEACHER	LEARNING APPROACHES ADOPTED BY THE STUDENT
SURFACE APPROACHES	• Teaching piecemeal by bullet lists; not bringing out the intrinsic structure of the topic or subject • Assessing for independent facts, inevitably the case when using short-answer and multiple-choice tests • Teaching, and especially assessing, in a way that encourages cynicism • Providing insufficient time to engage the tasks; emphasising coverage at the expense of depth • Creating undue anxiety or low expectations of success	• An intention only to achieve a minimal pass • Non-academic priorities exceeding academic ones • Insufficient time; too high workload • Misunderstanding requirements (thinking factual recall is adequate) • A cynical view of education • High anxiety • A genuine inability to understand particular content at a deep level
DEEP APPROACHES	• Explicitly bringing out the structure of the topic or subject • Eliciting an active response from students (questioning, presenting problems), rather than trying to expound information • Building on what students already know • Confronting and eradicating students' misconceptions • Assessing for structure rather than independent facts • Teaching and assessing to encourage a positive working atmosphere, so students can make mistakes and learn from them • Emphasising depth of learning, rather than breadth of coverage • Using teaching and assessment methods that support explicit aims and objectives of the course. This is known as 'practice what you preach'	• An intention to engage the task meaningfully and appropriately. • Appropriate background knowledge • Ability to focus at a high conceptual level, working from first principles • A genuine preference, and ability, for working conceptually rather than with unrelated detail

(Biggs, 2003, pp. 15-16)

Over a decade has passed since this change occurred and those in the tertiary sector, still faced with the same issues, need to consider how to better manage the teaching of the large, diversified student bodies they have inherited from a system that operates from an economic rationalist framework. Biggs (2003) and Ramsden (2003) are two authors who suggest a range of strategies to assist tertiary educators maintain and improve standards that help them cater better for the large, diversified student populations whose education they are now charged with.

One of the critical elements that can be construed from the deep versus surface approaches is that “student-based factors are not independent of teaching” (Biggs, 2003, p. 17). The approaches taken by teachers can have an impact on the approaches a student consequently adopts. This links to Biggs’ notion that “motivation is a product of good teaching, not its prerequisite” (p. 13). It is also evident from the deep learning model, that appropriate assessment is a critical component of effective learning.

Ramsden (2003) reports on the tendency, that he indicates is almost universal, that “the longer most undergraduate students stay in tertiary institutions, the less deep and the more surface-oriented they become, and the more their understanding is assessment related” (p. 35). He reveals that students generally display excellent ideas about what understanding means in real life, an idea that would be considered fundamental for preservice teachers, but in the university environment, their practical notion of understanding becomes whatever they see will meet assessment requirements. This is inextricably linked to the nature of the assessment to which they are exposed, which students generally regard “as an addition to teaching rather than an essential part of it” (Ramsden, 2003, p. 177). Ramsden proposes that if students perceive that their learning will be measured in terms of reproducing facts, they will adopt approaches that reflect this, no matter how effective and student-centred the teaching and learning activities selected. The assessment methods must be aligned with the teaching and learning activities.

Biggs (2003), emphasising a notion introduced almost sixty years previously by Tyler (1949), proposes that effective teaching and learning is a result of constructive alignment. The premise of this is that the curriculum, teaching methods, assessment procedures and methods of reporting, as well as the institutional climate, are critical components that must be in alignment for effective teaching and deep learning to occur. Alignment is characterised when each of these components support each other, pushing, if you like, in a common direction, towards a common goal; that of deep learning: “[I]n aligned teaching there is maximum consistency throughout the system” (Biggs, 2003, p. 27).

What students learn is not only connected to how they learn it and how it is assessed, but is also linked to satisfaction and enjoyment. Deep approaches to learning promote understanding and retention (Biggs, 2003; Ramsden, 2003). Biggs reports that students describe the experience of understanding as satisfying. It relates to confidence, self-efficacy and self-esteem. Deep approaches also promote personalised meaning of learning to be constructed (Ramsden, 2003). So, if learning is the result of constructive activity as purported by Biggs (2003), a deep approach to teaching, learning and assessment where constructive alignment is evident, would seem to be critical to achieve. Lord (1997) supports this thinking with the findings from his study where students who experienced a constructivist approach to biology became more interested in the subject and more immersed in the learning process. They complained that the summative testing was unfair as it did not allow them to demonstrate the extent of their understanding where as students from the traditionally delivered cohort complained that the same tests were too hard and covered things they had not dealt with explicitly in lectures and tutorials.

A significant aspect of effective teaching and learning and personal meaning-making appears to be linked to the extent of opportunity students have to interact with their peers (Lord, 1997; Biggs, 2003). This can be seen as an extension of the constructivist model where Vygotsky's (1978) social constructivist ideas come into play. Vygotsky considered learning to have a significant social dimension, where "individuals develop personal meanings through being engaged in social practices" (van Huizen, van Oers & Wubbels, 2005, p. 280). This forms a crucial component of Bybee's (1997) 5Es constructivist model where students 'Explore' together and share their understandings of these explorations in the 'Explain' stage of the model.

Loughran (2006) discusses this peer collaboration and also highlights its significance in learning about teaching:

> When students of teaching meet to discuss their knowledge and understanding of teaching and learning they share, and identify with, one another's concerns and readily respond to each other's ideas. In sharing their experiences and teaching approaches they gain confidence and trust in each other and risk introducing episodes that demonstrate their own difficulties and "failures". In so doing, they also create situations through which, together, they can freely brainstorm reasons for limited progress in their classes without the judgement that often accompanies working with more experienced others (e.g. supervising teachers and teacher educators). In discussing with one another – their particular issues, concerns and situations – students of teaching begin to generalise about their practice and test these generalisations with others in similar positions. (p. 139)

In spite of the difficulties faced in modern university settings, these ideas need to be incorporated more widely in preservice teacher education learning programs. It is particularly important to consider these tenets of learning in science teacher education, given the lack of impact it has appeared to have on effective teaching of science to date. New and revised science teacher education programs need to consider how to best achieve deep and aligned learning that optimises the opportunities preservice teachers have to appreciate and understand science content and its effective teaching in schools. They need significant, guided opportunities to share experiences and ideas, identify problems and develop theories about effective practice that are urgently required in primary science education.

Deep and aligned approaches to learning also need to be extended to the professional experience environment where preservice teachers gain their practical teaching experience and apply their developing theoretical knowledge about effective teaching. This is discussed further in the next section in conjunction with other issues associated with the professional experience component of preservice teacher education.

2.9 Professional Experience: The Teaching Practicum

Professional experience, also known by a range of other terms including the teaching practicum, teaching rounds, teaching placement and internship, is associated with all teacher education programs and is arguably one of the most critical aspects of a teacher's preparation (Grundy, 2007; McBurney-Fry, 2002; SCTP, 1995; Zeichner, 2002). This makes this aspect of teacher education of significant import; one worthy of much attention and research into 'getting it right'. In spite of this, the teaching supervision experience is often treated with a level of disdain by university lecturers, mainly due to being coupled with a full teaching load and pressures for other academic pursuits that are more financially fruitful for, and thus encouraged by, the university (e.g. research and publications) (Zeichner, 2002; Paris & Gespass, 2001).

Some of the criticisms of professional experience lie in the nature of the supervision and its assessment. Usually, it is a classroom teacher who is charged with the supervision and assessment of preservice teachers on professional experience, often with a single visit from a university supervisor who may or may not witness the preservice teachers' teaching. Paris and Gespass (2001) argue against each of these teacher supervisor's teacher-centred nature of judgements of observable behaviours which "grant authority to the perceptions of the supervisor/teacher over the experiences of the student teacher/learner" (p. 398). They promote the idea that in an environment that focuses largely on teaching with constructivist approaches to learning, the assessment and evaluation attached to the supervisor's role ought to reflect assessment practices that also acknowledge the preservice teacher as a constructivist learner.

Korthagen (2001) and Darling-Hammond (2006) discuss the importance of the nexus between theory and practice: "both practice on its own, and theory alone are incomplete. I believe one can only really understand the former if one knows about the latter and vice versa" (Korthagen, p. xi). This is important if what Zeichner (2002) and Darling-Hammond (2006) tell us is true, as they criticise the lack of knowledge and understanding that university lecturers and the co-operating teachers in schools have of one another's programs and their underlying philosophies and principles. This lack of knowledge leaves the preservice teacher to try to make sense of the theory they experience at university and the experience they have in the classroom with little real support from someone who understands what is occurring in each of these environments.

With preservice teachers left to forge their own understanding of how their theoretical experiences relate to practice, it is little wonder that they eventually "begin to view the placement as an assessment task in which they have to adopt particular types of behaviour that signal competence and will please the supervising tutor" (i.e. the classroom teacher and/or university supervisor) (Maynard, 2001, p. 40), rather than establish their own identities and trial some of the practical applications of the theories covered in order to understand and apply them better. One student in a study conducted by Maynard commented in particular: "I use the teacher's ideas - there's no time to think of your own and you know their ideas are going to work" (p. 45). Maynard discusses some of the positive associations mimicking the teacher can have, however overall this approach seems limited in its ability to support the nexus between theory and practice advocated by Korthagen (2001) and Darling-Hammond (2006).

Loughran (2006) indicates the need for preservice teachers to experiment with their own practice "in situations in which judgement and assessment are minimised in order to encourage risk taking so that strong personal learning might be experienced" (p. 161). This is supported by Jones and McLean (2007) who found that preservice teachers working in non-assessed collaborative partnerships with classroom teachers indicated their willingness to take more risks because the threat of assessment had been removed. Loughran encourages the notion that preservice teachers become researchers of their own practice as a form of teacher education. He argues that through this method, preservice teachers become "more sensitive to, and better informed about practice as they learn through their experiences of, and responses in, their particular pedagogical contexts" (p. 147). In this approach to teacher education, Loughran argues that the teacher educator, in place of transmitting information, becomes a facilitator of learning, "helping their learners to see, and respond to, the teaching and learning opportunities they experience" (p. 145).

This notion is supported by Darling-Hammond (2006) who discusses the powerful learning associated with programs that encourage and allow for preservice teachers to turn analysis of what are otherwise abstract ideas, into application through curriculum planning, teaching and other performance assessments of the theoretical components of their course. She points to the difficulty preservice teachers have in doing this in traditional courses due to the impossibility of teaching "people how to teach powerfully by asking them to imagine what they have never seen or to suggest they "do the opposite" of what they have observed in the classroom" (p. 308). She highlights how "no amount of course work can counteract the powerful experiential lessons that shape what teachers actually do" (p. 308). Rather, teacher education programs need to provide opportunities for preservice teachers to analyse and apply theory, reflect on their subsequent practice and have further opportunities to retry and improve (Darling-Hammond, 2006). Better collaboration between universities and schools is one of the suggested ways this could be achieved and forms the focus of this study. Some of the approaches that have already been trialled to achieve this are explored in the next section.

2.10 Collaborative Partnerships between Universities and Schools

There are a number of stakeholders involved in partnership experiences between university-based teacher educators and school-based personnel (SCTP, 1995). The university-based partners may include the lecturers, and sometimes, as Zeichner (2002) points out, temporary staff who are employed solely to carry out professional experience supervision and "have little other connection to or authority in the rest of the teacher education program" (p. 60). The teaching profession can include principals and teachers (SCTP) and may extend to a preservice teacher coordinator as well as the classroom teacher. The preservice teacher is the partner who connects these two. The nature of the partnerships between these entities suggested by SCTP (1995) and Zeichner (2002) needs to be one of collaboration if the preservice teacher and his/her learning are to be supported sufficiently.

The Standards Council of the Teaching Profession (SCTP) (1995) indicates that the nature of the partnership between university and school bodies needs to be “deeply collaborative (where) school based elements of the program need to be well integrated with the university-based elements” (p. 11). This notion has since been supported by Darling-Hammond (2000b), who highlights evidence that the more tightly integrated extended practical experiences are with university coursework, the more effective the teachers experiencing this system will be, and hence the more likely they are to enter and stay in teaching.

Kirschner, Dickinson and Blosser (1996) refer to the number of years that schools and universities have worked co-operatively on staff professional development and preservice teacher education, work that has continued to be trialled and researched in different ways to date. They quote the American Heritage Dictionary to define school-university partnerships as ‘co-operative’ or ‘collaborative’, where co-operative relationships are those where partners work “together toward a common end or purpose” and collaborative as working “in joint intellectual effort” (p. 206). They discuss their efforts in moving from co-operative to collaborative relationships and report on how those efforts have resulted in enhanced “quality of schooling through research and development and the preparation of career professionals in teaching” (p. 212). Thus they present collaborative partnerships as the more powerful approach for preservice teacher learning.

The notion of transforming co-operative efforts to collaborative ones appears to have gained momentum in the 1990s with examples such as those from Friesen (1994), Catelli (1995) and Kirschner et al. (1996). This is in part due to the emergence of Professional Development Schools (PDS) in the US in the early 1990s where a focus on collaborative work between educators was established. These early studies in collaborative partnerships between experienced and preservice teachers were not context-specific. They saw preservice teachers working in PDS alongside an experienced mentor “collaboratively to develop and demonstrate” (Kirschner et al., p. 212) a range of general characteristics and attributes of effective and productive educators. They highlight a number of benefits and challenges of collaborative partnerships.

Benefits and Challenges of Collaborative Partnerships

Using the PDS context, Levin and Rock (2003) studied the impact of action research projects on the collaboration between preservice teachers and what they refer to as 'on-site teacher educators' who are actually teacher mentors in the school base. They were able to identify a number of benefits and challenges for both participant pairs and made a number of useful recommendations for establishing effective collaborative experiences between preservice and experienced practising teachers. Levin and Rock's findings indicate that collaborative action research allowed practising and preservice teachers more opportunities to work together; opportunities to identify and understand the pedagogical philosophies underpinning their partner's practice; an opportunity to develop communication skills; and valuable time for the preservice teachers to establish themselves before a formal teaching round experience. There were also a number of emergent issues associated with the collaborative partnerships in Levin and Rock's study. Participants identified the limitations of time impeding collaborative processes as preservice teachers were only on-site for 10 hours per week. They recognised the level of persistence and commitment successful collaboration requires and how depending on another person can be frustrating. Darling-Hammond (2006) also reminds us that research has shown that enacting these partnerships is quite difficult.

From the themes emerging from the practising teachers in Levin and Rock's (2003) study, teachers appeared to envisage themselves in the role of experienced mentor rather than an equal partner in a learning exercise where they may benefit as much as their inexperienced preservice partner. Only two of the five teacher participants in their case study were reported to have re-defined their role to more of an equal collaborator than expert mentor, which did result in additional learning for them (Levin & Rock).

Koballa and Tippins (2001) share some insights into collaborative models of professional development and teacher education that are specific to science. They discuss three collaborative research projects where preservice teachers work with veteran scientists in their laboratories; where preservice teachers co-teach alongside a 'master teacher' in their classroom; and where preservice teachers are engaged in theoretical teaching by examining classroom case studies in peer groups. Of these three approaches, Koballa and Tippins indicate that the co-teaching model is the most appealing as "learning to teach is embedded in the act of teaching" (p. 216). However, they do warn that there are risks inherent in the partnering of preservice teachers with an appropriate ‘master’ teacher on whom the model relies to be both a “skilled teacher of students (and) a skilled teacher of teachers” (p. 216). They also indicate that such a model may not be sustainable without external resources, as the example they considered drew on university expertise and was funded by an external grant. This adds to the argument for a professional learning model that targets practising and preservice teachers equally. This would mean that preservice teachers are placed in a practice situation as a part of their science education course work and university expertise for both preservice and practising teachers involved is arrived at through the teaching the lecturer would have undertaken in a science education unit anyway, thus negating the need for external funding.

Koballa and Tippins (2001) further discuss the need for preservice teachers to be exposed to a range of perspectives as their attitudes towards and practices of teaching are being shaped and that a partnership with a ‘master’ teacher may limit this. Loughran (2006) also emphasises the need for multiple perspectives in shaping preservice teachers’ learning as it is “in a professional community there is value in clarifying or sharing new insights and in developing and adjusting practice in response to evidence” (p. 142). It is only through the sharing and considering of multiple perspectives that reflection moves beyond the individual’s thinking and creates an opportunity for teachers to consider their practice from a variety of viewpoints, as encouraged by Loughran (2002). This emphasises the importance of making the partnership experience closely integrated with the science education coursework where opportunities for reporting, sharing and analysing each others’ situations are important components in the learning process, and important aspects of helping to promote the theory-practice nexus.

In discussing the nature of ‘collaborative’ when it comes to partnerships, the work of Rogoff, Matusov and White (1996) is of interest. They discuss the roles of teachers and children in learning, describing the learning process as one that “involves the transformation of participation” (Rogoff et al., p. 388), where there is “a mutual process of collaboration between active participants” (p. 389). Such a model can also be applied to the processes between preservice and practising teachers, where learning for preservice teachers is going to be stronger if they are active participants in a shared inquiry, rather than one where the preservice teacher enters the ‘real’ teacher’s world and learns how to adapt to it, rather than how to shape and influence it. This issue is highlighted well in Maynard’s

(2001) revelation of how the preservice teachers place importance on "fitting in' with the class teacher's 'style" (p. 45).

Levin and Rock (2003) indicate that:

> [p]articipation in collaborative action research projects provide(d) opportunities for deliberate, focused dialogue about teaching and learning. (p. 145)

and enabled:

> preservice teacher pairs to have discussions about their thinking related to the classroom without the discussion being centred on the preservice teacher's performance in the classroom. Consequently, the discussions were centred more on students and the topic of inquiry rather than the preservice teacher's ability. (p. 147)

This demonstrates the potential for collaborative partnerships to develop thinking about pedagogy, practice and children's learning which in turn help the preservice teacher to develop pedagogical skills, and practising teachers to reflect on and refine their practices. Subsequently it can be expected that the professional experience is viewed by preservice teachers less as an assessment task where the preservice teacher puzzles about how to fit the mould expected by the teacher, and more as a useful learning experience on what and how to teach.

The shared vision and joint intellectual work is the platform for trust, a necessary ingredient for successful collaboration (Kirschner et al. 1996). In traditional professional experience there is co-operation with the teacher's agenda, but this does not generally include the preservice teacher helping to shape the agenda or even necessarily understand it. Perhaps this is why, in Maynard's (2001) study, preservice teachers experienced difficulty in making use of the class teacher's suggestions for pupil activity. As Maynard points out: "content and pedagogy are inextricably linked in teacher's practice and activities will reflect the person as well as the teacher" (p. 45). This has potential to be reflected in preservice teachers' teaching if they are not part of the planning agenda from the outset. Instead of the traditional approach to 'partnership' between practising and preservice teachers, a more active and shared collaboration may help preservice teachers to overcome some of these difficulties.

Mutual Benefits of Collaborative Partnerships

Collaboration can support practicing as well as preservice teacher learning. Roth (2007) indicates that collaboration "plays a central role in helping teachers make sense of the particulars of their own classroom" and "provides insights into other teachers' practices" (p. 1236). Berry and

Milroy (2002) also report on teachers who have indicated the importance of collaboration in their development as a teacher. In a recent project, Kenny (2009) found that there were potential benefits for both practising and preservice teacher learning in the partnership approach to science he established in his science education elective unit. The teachers involved in his study reported that the partnership provided them with “an opportunity to reflect on their own attitudes to teaching science” (Kenny, p. 19).

Murphy and Beggs (2004; 2006) report on a collaborative project that emphasised equal sharing between practising and preservice teachers in planning, implementing and evaluating science lessons. They recognised the potential for this to allow ‘co-teachers’ the “opportunity to learn from each other and to improve their own practice” (Murphy & Beggs, 2006, para. 3) and the access this provided preservice teachers to what they recognised as “the greatest resource available” (para. 4) in the experienced classroom teacher. While their study focussed on the impact of these partnerships on the children’s attitudes towards science, they did also find that both practising and preservice teachers experienced gains in confidence to teach science (Murphy & Beggs, 2004). They also found that children involved in the project were significantly more positive than non-participating children about their science lesson.

Collaboration between practising and preservice teachers may also provide inroads towards overcoming other ideals put forward about “using compatibility as a criterion for determining student placements” (Zeichner, 2002, p. 61). Zeichner indicated the difficulty and improbability of finding “philosophically compatible student teaching placements” (p. 61) for the large number of student teachers in teacher education programs. Murphy and Beggs (2006) recognised this through their efforts to discuss potential co-teaching teams with school principals to avoid the sometimes less than ideal random pairing that otherwise took place. However, if Rogoff et al.’s (1996) notion of shared collaboration between teachers and children were adapted and applied to practising and preservice teachers, then the issue of ‘philosophical compatibility’ may be minimised. Kirschner et al.’s (1996) findings support this idea, indicating that interaction “build(s) trust, shared vision and common ways of talking necessary for joint intellectual work” (p. 206). The forging of common visions such as this would minimise the need for pre-determined compatibility of partners.

The real challenge then becomes, as Zeichner (2002) suggests, identifying classroom placements where the teachers in those classrooms also identify themselves as learners, "questioning and examining their practices, and continually seeking to improve their practice" (p. 62). These teachers will be more open to sharing ideas with and receiving ideas from the preservice teachers under their supervision, heightening the chances of shared inquiry and collaborative practice. This is supported by Levin and Rock's (2003) findings where the two teachers who did visualise themselves as learners and took on new and different roles, experienced additional learning. Zeichner (2002) tells us that the notion of teachers identifying as learners is likely to occur where there is a school culture that encourages inquiry and reflection about teaching, two aims that are also sought in teacher education programs.

Recommendations for achieving successful collaboration between practising and preservice teachers include a range of factors stemming from a number of research studies. These are best summarised by Levin and Rock (2003) who formed six guidelines for engaging preservice and experienced teachers in collaborative action research, presented in Figure 2.1.1.

1. Provide both preservice and experienced teachers adequate training, and, if possible, give preservice teachers prior experience with action research before they complete a collaborative action research project.
2. Increase ownership and accountability of experienced teachers by setting up informal group presentations and/or formal school presentations of action research projects. In other words, provide a wider audience for sharing and disseminating the results of action research.
3. Establish ways for experienced teachers to receive credit for their efforts by earning professional development or renewal credits from their district, or by earning university credit.
4. Allow action research questions to emerge from the interests and concerns of the experienced veteran teachers and the preservice teachers and not solely from the university's agenda.
5. Give adequate time and support to the question formulation period and to discussion and assessment of the value and practicality of the action research questions posed. The key is to identify an area of inquiry that assists all the participants to address their immediate needs and to work towards their long-term goals at the same time.
6. Encourage data collection strategies that include information gathered from students' perspectives. We say this because additional findings from this study (Rock, 1999) indicated that collecting data from students (e.g., individual interviews, class surveys, student work samples) provides valuable knowledge about students, which appears to help both preservice and experienced teachers focus (or refocus) on students' needs in the classroom.

(Levin & Rock, 2003, p. 148)

Figure 2.1.1: Guidelines for Engaging Preservice and Experienced Teachers in Collaborative Action Research

Levin and Rock (2003), along with a range of other researchers (e.g. Kenny, 2009; Murphy & Beggs, 2006), also acknowledge how classroom experience was found to contribute to improved teacher confidence or self-efficacy. This is particularly important in science where efficacy beliefs have been found to be so low that, as already discussed, many teachers avoid teaching science altogether. The next section discusses the importance of self-efficacy and outlines some of the strategies identified in the literature that can be used to enhance self-efficacy beliefs.

2.11 The Importance of Efficacy

Self-efficacy, a term that Palmer (2006a) indicates many researchers use interchangeably with self-confidence, is a measure of a person's belief in him/herself. It is defined by Bandura and Schunk (1981) as being "concerned with judgements about how well one can organise and execute courses of action required to deal with prospective situations that contain many ambiguous, unpredictable, and often stressful, elements" (p. 587). It can also be linked to constructs of attitude and belief, two further terms that are used interchangeably (Jones & Carter, 2007). Attitudes are linked to "larger belief systems that include self-efficacy, epistemologies, attitudes and expectations (Jones & Carter, 2007, p. 1070). The inter-changability of these terms stems from the relationship and bearing each one has on the other, where beliefs and attitudes influence efficacy and confidence, and vice versa.

Beliefs, attitudes, confidence and efficacy are all personal constructs that can be used to predict behaviour (Bandura, 1977; Jones & Carter, 2007). They are personal judgements of oneself which, in his seminal work, Bandura (1977) links to two defining factors: efficacy expectation - the belief in one's ability to successfully perform a particular behaviour; and response-outcome expectancy - one's expectation that a given behaviour will lead to a particular outcome.

Bandura (1977) postulates that the level of a person's efficacy expectation, or perceived self-efficacy, determines the types of activities and settings a person chooses to become involved in, and the likelihood of them expending effort and persisting in that activity/setting in the face of obstacles/challenges. This makes his idea of efficacy expectation of particular importance to this study as it implies that a teacher's self-efficacy with respect to science teaching is related to the science teaching they engage in and the effort and persistence they exhibit in overcoming any lack of confidence/knowledge they perceive they have about science. Goddard (2003) also relates high efficacy levels with the ability to overcome obstacles and links this resilience with innovative teaching practices and student learning when he reports on a number of studies that point to a link between teacher efficacy and student achievement.

These factors are important in the context of teaching generally and science teaching in particular. Teachers' personal efficacy beliefs "affect the types of learning environments they create and the level of academic progress their students make" (Bandura, 1993, p. 117). Levels of self-efficacy beliefs also influence the types of instructional strategies teachers implement in the classroom (Jones & Carter, 2007). Goddard (2003) supports this, telling us that "teacher efficacy is a significant predictor of productive teaching practices" (p. 183). This is important in science education if the inquiry and constructivist approaches to pedagogy advocated by many researchers in the field are to be attempted and achieved. In fact, Jones and Carter (2007) indicate that teacher beliefs can influence every aspect of the teaching role "including lesson planning; teaching; assessment; interactions with peers, parents and students; … professional development and the ways she [the teacher] will implement reform" (p. 1067).

Bandura (1977) presents four key components of self-efficacy that deal with both how levels of personal efficacy beliefs are formed, and consequently how they can be shaped and changed. He discusses performance accomplishments (later to become known as mastery experience); vicarious experience; verbal persuasion (sometimes referred to as social persuasion); and physiological states (also referred to as affective states). Bandura asserts that individuals' overall self-efficacy beliefs are determined by a combination of each of these sources of efficacy information. They are defined in the following discussion.

Mastery experience is the most influential source of efficacy information (Bandura, 1977). It is the experience of accomplishment, of having 'mastered' something, that informs individuals that they are capable and successful. "Success raises mastery expectations; repeated failures lower them" (Bandura, p. 195), although once strong efficacy is established, the impact of occasional failures is reduced. The strength of efficacy developed through mastery experience is also related to the complexity of the task undertaken, a premise that Stajkovic and Luthans (1998) tell us has been recognised by a number of self-efficacy researchers. If success is frequent and easy to achieve, failure is likely to have a more significant impact than if the success were considered to be achieved under more difficult circumstances (Goddard, 2003; Stajkovic & Luthans, 1998). This means tasks need to be considered challenging but achievable if they are going to have a positive and lasting effect on efficacy levels.

Mastery experience is linked to the notion of learning through the construction of knowledge. Tatto and Coupland (2003) discuss that "teacher change requires learning opportunities that support in-depth examination of theories and practices in light of teachers' *beliefs* and *experiences"* (p. 126) [authors' italics]. Jones and Carter (2007) suggest that "teachers believe a strategy can be successful only after they have seen it successfully work in their own classroom" (p. 1086). By aligning these premises, a mastery experience can be created to help teachers experience efficacy changes in their science teaching. They need a theoretical model that they interact with both practically, in their own classrooms, and reflectively to ensure they consider how any successes and challenges they experience can be attributed to theoretical underpinnings of their actions.

Vicarious experiences describe situations in which individuals witness others performing an activity that they themselves find threatening. This helps individuals observe the approaches and strategies that make a threatening experience successful, which in turn helps build their own confidence to replicate these strategies and thus reduces the level of perceived threat. The effect of vicarious experience is heightened if the person modelling the activity is a peer that the individual can identify with (Goddard, Hoy & Hoy, 2004), and if the individual observing has little previous experience with the activity being modelled (Palmer, 2006a). It is less dependable than the direct efficacy-building success that comes from personal accomplishment in mastery experiences (Bandura, 1977). Goddard et al. (2004) indicate that in teaching this can occur when teachers observe successful colleagues or other successful organisations that face similar circumstances and constraints as their own.

Social persuasion is the effect of encouragement provided by others through suggestions or feedback on performances (von Frank, 2009). It occurs "when people are told that they have the capability to handle a certain situation" (Palmer, 2006a, p. 656). Bandura (1977) indicates that again, this source of efficacy expectation is limited in its effect compared with authentic mastery experience. He warns too, that any form of disconfirming experience will quickly thwart any efficacy established through suggestion associated with social persuasion. However, verbal persuasion is quite useful in building efficacy when it is used as a reinforcer. Bandura has shown the success of verbal persuasion in situations where individuals can be persuaded that they possess the capability to manage difficult situations successfully when provided with provisional aids to do so, compared with individuals who receive the provisional tools without the verbal persuasion.

The final aspect of efficacy information presented by Bandura (1977) is the physiological/affective state. This is associated with the physiological and emotional responses of the body in stressful situations and the awareness individuals have of their body's response at these times. It includes aspects such as anxiety levels, nervousness and fear and can be detected physiologically. In situations where individuals distrust their capability, increases in heart rate and blood pressure are evident, stress hormones are released and immune function deteriorates (Bandura, 1993). When efficacy is strong, the same situations can be faced with behaviours determined by coping efficacy rather than anxiety and fear levels. Palmer (2006a) indicates the detrimental impact the affective state can have on efficacy if the individual relates these emotional and physiological responses to their inadequacy in the given situation. Bandura (1977) does maintain however, that some level of anxiety arousal is beneficial for performance.

In the context of science teaching, efficacy and attitudes are important issues. Findings that teachers and preservice teachers often experience poor attitudes and low confidence towards science have been identified in a range of studies (Fensham, 2004; McDuffie, 2001; Skamp &Mueller, 2001). As discussed earlier, there is a trend in which science is approached in a disconnected fashion or not at all in primary classrooms, and that this is believed to stem from teachers' lack of confidence and lack of background knowledge (Fensham, 2004; Goodrum, et al., 2001; Lyons et al., 2006). These factors all suggest that teachers' attitudes and efficacy towards science is very low, since those with low efficacy in a particular area tend to fear and avoid experiences they determine to be threatening (Bandura, 1977; Palmer, 2006a). The relationship between levels of efficacy and the selection of instructional strategies has also been established (Jones & Carter, 2007) which may help to explain the lack of constructivist, inquiry, hands-on, thinking approaches deemed to be necessary for effective science education raised in a number of the reports that have already been reviewed (Appleton, 2003; Bybee, 1997; Goodrum et al., 2001; NRC, 1996; Rennie, et al., 2001; Skamp, 2004; Tytler, 2002a).

As also discussed earlier, teachers themselves indicate lack of equipment and time as prevailing factors for not teaching science (Goodrum, et al., 2001; Jones & Carter, 2007; Keys, 2005; Levitt, 2001; Lumpe et al., 2000; Rennie, et al., 2001), but even this implies that teachers' efficacy towards science might be low, given that those with high levels of efficacy tend to overcome obstacles (Goddard, 2003; Jones & Carter, 2007). This reinforces the importance of building strong efficacy beliefs and good pedagogical practices in teachers of science so they can overcome the very real constraints of time and resource access. Some of the strategies for improving levels of self-efficacy from the literature are considered in the following section.

Strategies for Improving Self-efficacy Beliefs

Attempts to alter attitudes and efficacy beliefs have been a focus of research over many years (Cantrell, Young & Moore, 2003; Howitt, 2007; Morell & Carroll, 2003; Palmer, 2000b; Wingfield, Freeman & Ramsey, 2000). A number of factors have been found to be influential in changing attitudes and beliefs, both generally and in the science context. These essentially involve addressing Bandura's (1977) four sources of efficacy information: mastery experience, vicarious experience, social persuasion and physiological/affective states.

Howitt (2007) reports on her research findings which further support previously discussed evidence that science content courses have a significant lack of impact on effecting changes in attitudes and efficacy for teaching science compared with courses focusing on science pedagogy. Her findings help to show the importance of the place of science education units in teacher education courses as critical in any attempt at improving science attitudes and efficacy of preservice teachers. However, Richardson (2003) warns that "changes in beliefs during one academic class that are not accompanied by significant and structured involvement in a field experience do not happen" (p. 11), a notion supported by Cahill and Skamp (2003) and Jones and Carter (2007). This notion links to Bandura's (1977) mastery experience source of efficacy information that individuals draw on to impact levels of self-efficacy in a given area. The issue with this for preservice teachers lies in the difficulty in acquiring classroom teacher supervisors who include science in their classroom, those teachers' prevailing attitudes towards science, and the appropriateness of their role modelling, if they teach science at all (Skamp & Mueller, 2001).

Changing attitudes and efficacy beliefs towards science in practising teachers are similarly difficult. Practising teachers also require experiences of success, feedback, external validation of their efforts, and effective role models to help address Bandura's (1977) four sources of efficacy information through which changes in efficacy can be achieved (Jones & Carter, 2007). This can be difficult when the general status of science in primary schools is quite low and ineffective (Goodrum et al., 2001).

Bandura (1977) proposes that mastery experiences are the most influential in creating lasting increases in self-efficacy, but Palmer (2006b) indicates that this is yet to be corroborated in courses involving science education. In fact he found that the mastery experience opportunity he provided in a science education unit had little bearing on the increases in efficacy his students experienced. Instead, these students attributed their increased confidence to increased understanding of science content and pedagogy (Palmer, 2006b). The extent of the mastery experience these students had was somewhat limited however, as they taught a single hands-on science lesson to a single child rather than a series of lessons to a class. This is not highly representative of the 'real world' setting a classroom experience would provide, making it somewhat of a simulation of the 'real thing' which Stajkovic and Luthan (1998) warn does not always allow for all "relevant environmental elements" (p. 245) to be experienced.

Two separate studies performed by Morell and Carroll (2003) and Cantrell, Young and Moore (2003) each provide interesting data about the impact of science education units and associated professional experience dedicated to science teaching, on preservice teachers' efficacy. In Cantrell et al.'s study, preservice teachers demonstrated a significant gain in efficacy belief as measured by the Personal Science Teaching Efficacy (PSTE) scale of the Science Teacher Efficacy Belief Instrument (STEBI-B), which was designed by Enochs and Riggs (1990) to measure preservice teachers' personal efficacy beliefs towards teaching science. Cantrell et al. attributed this gain to the science teaching experience of those preservice teachers who taught science in a classroom for more than one hour per week during the three week science professional experience block associated with their science education unit. However, efficacy levels were largely unchanged after the general professional experience round in the course, and in fact a slight, but not significant, decrease in PSTE scores occurred. Cantrell et al. attribute this to the large variety of other factors that are often in play when a general professional experience round is undertaken compared with classroom experiences dedicated to particular areas of the curriculum.

A similar finding is presented by Morell and Carroll (2003) who report the PSTE scores for preservice teachers undertaking a science content unit, a science education unit and a professional experience round. Their findings indicated little to no impact of the science content course, except for those who started with efficacy scores below 50, suggesting that content courses can be beneficial for those who have low efficacy to begin with. Preservice teachers undertaking the science education unit showed significant increases in efficacy, but there were only slight and not significant increases after the professional experience round. Interestingly, there was also no correlation between STEBI scores and the number of science lessons taught on these rounds.

Morrell and Carroll (2003) attribute these findings to two possible factors. Firstly, they cite Roberts, Henson, Tharp and Moreno’s (2001) notion of the possibility of the ceiling effect impacting on the improbability of STEBI scores increasing due to an insufficient range in response options available for those participants who score relatively highly on the pre-test questionnaire. Secondly, they suggest that during the professional experience round, the level of vicarious experience and verbal persuasion would not be as high as it was in the science education unit, thus these reinforcers of efficacy information that complement mastery experience were not providing an all-encompassing effect on efficacy. Again this indicates that mastery experience associated with dedicated focus in a science education unit may be the optimum opportunity for impacting on science self-efficacy levels for preservice teachers. Another reason the student professional experience round may be demonstrating little impact could be related to Jones and Carter’s (2007) assertion that the socio-cultural environment may inhibit change in efficacy if the classroom teacher, or other school personnel, do not support the practices preservice teachers are encouraged to trial in their science teaching. Jones and Carter emphasise the importance of a shared vision of teaching and learning between co-operating and preservice teachers if changes in efficacy are to be achieved.

In a further study by Palmer (2006a), preservice teachers involved in a science education unit reported efficacy changes immediately after the unit which were sustained over a one year period. Palmer found that those who had the opportunity to teach science during a professional experience round in that interim had similar or further increased PSTE scores, while those who had not taught science all decreased in score. Similar findings occurred in Wingfield, Freeman and Ramsey's (2000) study where preservice teachers in a 'site-based' teacher education program appeared to experience greater opportunity for building mastery experiences. They found increases in self-efficacy using the STEBI instrument after the site based program, which were sustained one year into the participants' first year of teaching. These studies are important in two ways. They demonstrate that changes in science efficacy are durable over a period of time, and that the mastery experience in teaching science contributes to this durability.

Research into efficacy generally, and science efficacy in particular, indicates that mastery experiences are of the upmost importance in increasing self-efficacy beliefs in teachers and these can be further enhanced when reinforced with appropriate vicarious experiences and social persuasion. This is demonstrated clearly in Howitt's (2007) study where preservice teachers ranked factors influencing improvements in their confidence in science and its teaching. The two most highly ranked factors were the professional experience round (from those who were able to teach science on their placement) and the teacher educator. These factors link directly to mastery experience and affective state of Bandura's (1977) sources of efficacy information. The affective factors associated with the teacher educator included humour, passion for science, approachability and friendliness. These factors are also likely to be linked to the verbal persuasion component of Bandura's (1977) set of sources of efficacy information.

Howitt's (2007) study demonstrates the significance of the affective component in providing a safe, supportive environment in supporting positive efficacy changes. She states that "learning environments need to be positive and supportive to minimise anxiety and encourage freedom to experiment and verbalise opinions" (p. 43). Selecting a science education unit with a dedicated science professional experience component also appears to heighten the success rates of increasing science self-efficacy beliefs in preservice teachers. It is important to support high levels of self-efficacy in practising and preservice teachers due to the link high levels of efficacy have with selection of instructional strategies and teachers' abilities to overcome obstacles such as access to resources and time.

2.12 Summary

The literature reviewed in this chapter highlights the range of factors that contribute to thinking about effecting change in primary science education outcomes, making any attempt to achieve such change a complex task. These factors centre on issues surrounding effective primary science education; teacher professional learning; and preservice teacher education.

Strategies for effective primary science education seem to focus around providing ‘nature of science’ experiences that promote current views of scientific literacy (Fensham, 2005; Goodrum et al., 2001; Hackling and Prain, 2005; Rennie et al., 2001; Tytler, 2002a) where the processes of science such as those linked to investigation and inquiry are included which are linked to the daily lives and experiences of students to promote relevance of science learning. One model that had been extensively trialled by teachers in schools through a research process that appeared to achieve the ‘nature of science’ inquiry approach was the Australian Academy of Science’s 5Es model. This model also incorporated learning underpinned by the theory of constructivism (Bybee, 1997; Cuttance, 2001; Duit & Treagust, 2003; Jones & Carter, 2007; Koballa & Tippins, 2001; Levitt, 2001; Skamp, 2004) which was also a significant theme in the literature for achieving effective teaching and learning.

This leads then, to the consideration of why science is not being experienced and enjoyed by many school students in Australia and world-wide. Here the literature shows that a large number of primary school teachers lack confidence in their knowledge and ability to teach science hence avoid teaching it where possible. Both their general content knowledge (GCK) and science specific pedagogical content knowledge (PCK) need to be developed, where PCK is seen to be most critical (Akerson, 2005; Goodrum et al., 2001; Tytler & Griffith, 2003). Other factors such as a crowded curriculum, limited access to appropriate resources and lack of time to prepare what is seen to be time-intensive organisation of science lessons are also factors impacting on teachers’ decision and ability to include science more often in their teaching programs (Appleton, 2003; Appleton & Kindt, 1999; Goodrum et al., 2001; Keys, 2005; Levitt, 2001).

Efficacy was one of the key issues associated with the low and/or poor approaches to science teaching evident in the literature. This is one of the most important areas of improvement to target due to the extent of its influence over the types of activities individuals elect to involve themselves in (in this case, science teaching) and their persistence with that activity in the face of challenges (such as incomplete knowledge, access to resources and time to organise equipment for science lessons) (Bandura, 1977). Goddard (2003) also links high levels of teacher efficacy with student achievement, a finding Bandura (1993) also reports. Providing mastery experiences (Bandura, 1977) is the most significant and lasting way in which to improve efficacy and will consequently need to be carefully considered in the design of the present study along with other efficacy-building factors discussed.

Access to appropriate professional learning in science was also cited as an issue for primary teachers (Keys, 2005; Levitt, 2001; Rennie et al., 2001; Sanders, 2004) and this led to the need to examine factors that make professional learning relevant, meaningful and effective. This is essential given the substantial impact professional learning can have on the quality of teaching and learning (Darling-Hammond, 2000a; Hewson, 2007). Constructivist theory is once again noted as an important underpinning for effective professional learning (Koballa & Tippins, 2001; Loughran, 1999; Posnanski, 2002). The literature also points to professional learning that is ongoing, that incorporates both content and pedagogical knowledge, that allows for active learning and that provides opportunities for reflection and discussion (Abell, 2007; Garet et al., 2001; Hewson, 2007; Ingvarson et al., 2005; Posnanski, 2002).

This raised the question of how reflective practice is achieved, and a range of literature pointed to critical reflection as the most effective form of reflective practice (Brookfield, 1995; Korthagen, 2001; Osterman & Kottkamp, 2004). Critical reflection appears to require focus on content (what is taught), process (how is it taught), and premise (why is it taught in this way) (Kreber & Cranton, 2000). It also seems to require the framing of a problem for focussing the reflection (Loughran, 2002) and should draw on a range of sources where possible (e.g. feedback from students, feedback from colleagues, link to theory as well as personal perspectives) (Brookfield, 1995; Korthagen, 2001; Kreber & Cranton, 2000). The literature also encourages the trialling of ideas to deepen the effects of reflection which links to ideas shared previously about the need for on-going professional learning; for its span across a period of time. This would best allow for experience, reflection and trialling of ideas for further reflection to occur (Korthagen, 2001).

The literature highlights too, the importance of reflective practice in preservice teacher education to help prepare developing teachers for the reflective nature of the profession they are training to enter (Parsons & Stephenson, 2005). In particular, the practice of reflection is linked to the effectiveness of bridging the theory-practice gap if reflection is built into teacher education courses (Korthagen, 2001; Korthagen et al., 2006; Loughran, 2002). Here again, models for reflection encourage experience of teaching and reflection on that experience that draws on a range of perspectives including discussion with peers and teachers, and links to theory.

If preservice teacher education is also important in effecting improved science teaching, then factors associated with best practice in teacher education also need to be considered. Here the literature highlights the tendency for surface approaches to be adopted in tertiary settings due to large class sizes, and competing pressures in the academic's role such as teaching, administration, research and publications (Biggs, 2003; Paris & Gespass, 2001; Zeichner, 2002). Biggs (2003) and Ramsden (2003) highlight strategies for deep approaches to tertiary teaching that challenge educators to provide more engaging learning and meaningful assessment that is informed by constructivist theory.

Professional experience and shortcomings in the way it is traditionally approached were also revealed as important factors in preservice teacher education (Paris & Gespass; Zeichner, 2002). Again, the notion of constructivist-informed approaches to the nature and assessment of professional experience was highlighted regarding how to make this critical component of preservice teacher preparation more effective (Paris & Gespass, 2001). Stronger links between theory and practice were also encouraged to improve professional experience (Darling-Hammond, 2006; Korthagen, 2001; Loughran, 2006) and university-school partnerships were viewed as critical in achieving this (Darling-Hammond, 2006; Zeichner, 2002).

The notion of making partnerships between universities and schools more collaborative was recognised and called for increasingly through the literature for over a decade (see SCTP, 1995; Darling-Hammond, 2000b). A number of benefits and challenges were recognised through the trialling of such a move. Some of the issues included personality issues, the manner in which individuals might approach the partnership (i.e. not as equals); and dedicating enough time to make the collaboration effective (Levin & Rock, 2003). However, in spite of these challenges, collaborative partnerships are still encouraged due to the mutual learning opportunities they provide for both the practising and preservice teachers involved. In particular, time for reflection that encompasses the components required for critical reflection becomes a natural part of the collaborative process. The potential for supporting preservice teachers' learning is particularly significant and issues associated with professional experience could be better addressed (Zeichner, 2002).

Zeichner (2002) challenged teacher education institutions to adopt new ways in which schools and universities relate to each other in order to support teacher education and the professional experience of preservice teachers. This seems to support the notion Korthagen (2001) and Loughran (2002) advocate about the need to develop the nexus between theory and practice and how reflective practice can be used to support this. It also fits with Zeichner's (2002) observation that suggests universities and schools need to have a better understanding and knowledge of one another's programs and philosophies to support the practical experience of the preservice teacher.

2.13 The Present Study

The present study attempts to grasp each of these threads of effective teaching and teacher preparation and weave them to produce a quality experience of science education and professional learning for teachers, with the ultimate aim of enhancing teaching and learning experiences for both practising and preservice teachers in science education. This is done in recognition of the complexity inherent in the field of education, which has important and equally significant theoretical and practical components; and where each of these must inform the other to be successful.

The present study attempts to achieve this theory-practice nexus through the development of collaborative partnerships between preservice and practising teachers as they plan and implement science lessons over a seven week period. Korthagen's (2001) model of Action-Reflection is the primary model shaping the structure of this planning and delivery. Brookfield's (1995) and Loughran's (2002) ideas for critical reflective practice help shape the reflective component of the action-reflection model. Elements of effective professional learning for practising teachers are taken from Ingvarson et al.'s (2005) guidelines which acknowledge the need for ongoing, collaborative learning with an active learning approach that includes content and pedagogical processes.

Elements of best practice teaching and learning are adopted, with a particular focus on constructivist approaches applied over a period of time, predominantly within practising teachers' classrooms. In particular, the Australian Academy of Science's (2006, 2009) 5Es constructivist, inquiry approach is used as the framework through which both practising and preservice teacher participants explore their science teaching. This is designed to provide practising teachers with what has been shown in research to be a sound, constructivist pedagogical approach (Hackling & Prain, 2005) that they can use to plan, implement and reflect on a series of science lessons in an on-going manner. Preservice teachers are engaged in a deep learning approach that attempts to bring about constructive alignment of their learning activities at university with teaching practice integrated into this experience through the seven week concurrent time in schools. This addresses concerns reported about the professional experience of preservice teachers.

The underpinning factor of this design is the mastery experience that Bandura (1977) reports as so important in improving efficacy. Providing an expert supported and facilitated professional learning experience for practising and preservice teachers that focuses on their ability to gain teaching experience using appropriate models of teaching and learning helps to build mastery experience and thus efficacy for teaching science. If successful, the lasting nature of mastery experience should help sustain participants' intention and desire to teach science beyond the research project.

The collaborative partnership approach to professional learning for practising and preservice teachers in primary science being explored in the present study is also important within the context of science education in Australia. It was recognised in the literature that science education is in need of reform (DEST, 2002, 2003; Goodrum et al., 2001). This makes the model being trialled here important and significant in helping to further inform how effective outcomes for science education might be achieved. This will further develop the science literacy of the Australian nation and potentially others, which will position them better as knowledge-based economies with citizens who can think with inquiring minds about their health, the environment and the ethics of living in a technological world towards a common, global good.

The next chapter describes how the range and complexity of the issues of providing effective science teacher education and practising teacher professional development using constructivist approaches involving critical reflective practice and efficacy-building experiences have been developed into a research design to provide answers to the research question and sub-questions. The research design is explored through the theoretical and methodological framework that informs a range of data collection strategies and subsequent data analysis within a qualitative research paradigm.

CHAPTER 3: THEORETICAL AND METHODOLOGICAL FRAMEWORK

We don't see things as they are; we see things as we are.

Anais Nin.

3.1 Introduction

Chapter 2 discussed the range of literature that informs the design of this study. In this chapter, the theoretical and methodological framework is explored, along with the techniques adopted for data collection and analysis. It highlights the alignment of these techniques with the theoretical underpinnings of the study, which in support of the literature reviewed in chapter 2, is predominantly constructivist in nature.

3.2 Theoretical Framework

There are four key elements to research design: the methods (data collection techniques); the methodology (the strategy or plan of action for applying the data collection methods); the theoretical perspective (philosophy informing the methodology); and the epistemology (theory of knowledge embedded in the theoretical perspective and methodology) (Crotty, 1998). Within these elements are a myriad of options researchers have to select from. What must be ensured, however, is that selections are complementary to and inform one another, since particular theoretical perspectives are associated with particular epistemologies which are in turn linked to particular methodologies that have a set of associated data collection methods. Logical and rigorous research is couched in a framework where these elements are appropriately aligned.

The four elements of research tend to fall within a particular research paradigm, that of quantitative or qualitative research. One of the first decisions that researchers make is which paradigm their research will fall into, or whether it will contain elements of both. Crotty (1998) reports that beginning researchers often believe that all research is divided between these two paradigms, which are set against each other as polar opposites. However, he argues that "this divide is far from justified" (p. 15). Quantitative and qualitative research share all of the common elements of research design. Both approaches "state a purpose, pose a problem or raise a question, define a research population, develop a time frame, collect and analyze data and present outcomes" (Glense & Peshkin, 1992, p. 5).

Denzin and Lincoln (2000) offer this definition of qualitative research:

> Qualitative research is a situated activity that locates the observer in the world. It consists of a set of interpretive, material practices that make the world visible. These practices … turn the world into a series of representations, including field notes, interviews, conversations, photographs, recordings, and memos to the self. At this level, qualitative research involves an interpretive, naturalistic approach to the world. This means that qualitative researchers study things in their natural settings, attempting to make sense of, or to interpret, phenomena in terms of the meanings people bring to them. (p. 3)

Supporting this view, Richards and Morse (2007) indicate that qualitative research "seeks understanding of data that are complex and can be approached only in context" (p. 47). It is value-laden (Denzin & Lincoln, 2005; Lichtman 2006) and attempts to capture and discover meaning (Neuman, 2007), particularly meaning that is created in social processes and contexts (Wiersma, 2009; Denzin & Lincoln, 2005; Neuman, 2007). It is characterised by words rather than numbers (Lichtman, 2006; Neuman, 2007; Denzin & Lincoln, 2005). It is concerned with describing, understanding and interpreting phenomena rather than measuring it for cause and effect (Lichtman). The qualitative researcher is inherently involved in the situation under study rather than being an objective observer in a detached role (Wiersma, 2009; Lichtman, 2006; Neuman, 2007; Denzin & Lincoln, 2005). In fact Glense and Peshkin (1992) define the researcher as the research instrument in qualitative research, as they interact in an in-depth manner with participants.

One of the key factors that define qualitative researchers is tied to the assumptions underpinning their beliefs and attitudes about social life, and what counts as evidence (Neuman, 2007). Qualitative researchers acknowledge multiple realities, multiple voices and the subjectivity of data and interpretation (Lichtman, 2006; Denzin & Lincoln, 2005; Wiersma, 2009). Anfara and Mertz (2006) and Lichtman highlight the importance of the theoretical underpinnings that influence the qualitative researcher. In qualitative research, the role of researchers is critical as they act as the "conduit through which information is gathered and filtered" (Lichtman, p. 16). The theories underlying the beliefs, ideas and assumptions of the researcher in this situation will influence the way in which these data are gathered and interpreted, and the research findings essentially become a construct of the researcher based on these interpretations and ways of seeing the world. They usually employ data collection methods such as “case study, personal experience, introspection, … interview, … observational, historical, interactional, and visual texts – that describe routine and problematic moments and meanings in individual’s lives” (Denzin & Lincoln, 2005, p. 3). These factors are characteristic of the post-modern research period (Denzin & Lincoln).

In contrast, quantitative research is defined as the collection or expression of data as numbers (Neuman, 2007). It is concerned with “objective truth and meaning” (Crotty, 1998, p. 6) and places the observer in a detached role (Wiersma, 2009) whose goal is to remain as objective as possible by distancing themselves from the research instrument (Glense & Peshkin, 1992). This approach seeks to ensure that the researcher, as an objective observer, “neither participates in nor influences the data being studied” (Wilson, 2002).

Quantitative research stems from positivist thinking which “offers assurance of unambiguous and accurate knowledge of the world” (Crotty, 1998, p. 18) and is closely associated with the behaviour of scientists. It is concerned with determining relationships, causes and effects (Wiersma, 2009). Its strengths are seen to lie in precision and control (Burns, 2000) and context-free generalisations from findings (Wiersma). It is focussed on individual variables and factors rather than values, thoughts and feelings (Burns). It adopts experimental methodologies that test hypotheses (Mertens, 2005) and usually adopt numeric scales that lend themselves to statistical analyses (Wiersma).

This study is primarily concerned with people’s experiences of learning and development in partnership with one another as they work in schools. It considers the development of preservice teachers as teachers, and the learning of both practising and preservice teachers through reflective practice and collaborative partnership. It probes the factors within the partnership that participants view as influencing the depth of their learning and their knowledge, attitudes, confidence and self-efficacy. It uses the theory of phronèsis, “a form of practical wisdom that is derived through understanding specific situations and cases” (Korthagen et al., 2001 (as cited in Loughran, 2006, p. 8)). Science lends itself as a context in this investigation, and the researcher is inherently involved as a participant observer. These factors represent the key elements of qualitative study: practising teachers in the context of their own schools and classrooms; preservice teachers working with practising teachers through the requirements of their university science education coursework; the meaning-making from sharing of stories and experiences of which I, as the researcher, as lecturer and professional learning facilitator, am actively involved as a participant observer. These driving factors place the present study primarily within a qualitative, post-modern view of research.

Denzin and Lincoln (2000) indicate that all qualitative research falls into the realm of interpretivism and that at the most general level, there are four major interpretative paradigms. These are "positivism and post-positivist; constructivist-interpretive; critical (Marxist, emancipatory); and feminist-poststructural" (pp. 19-20).

Positivist and post-positivist paradigms are associated with quantitative approaches and fall outside the realm of the present study. "The constructivist paradigm assumes a relativist ontology (there are multiple realities), a subjectivist epistemology (knower and respondent co-create understandings), and naturalistic (in the natural world) set of methodological procedures" (Denzin and Lincoln, 2000, p. 21). Mertens (2005) also defines the epistemologies of constructivists as interactive, where knowledge and findings are co-created. She defines constructivist methodology as qualitative and hermeneutical, where the meaning of something is interpreted from "a certain standpoint or situation" (p. 12). Critical and feminist-poststructural paradigms adopt materialist-realist ontologies (Denzin and Lincoln) where the real world is seen to make a material difference in terms of gender, race, economics, and politics (Mertens). Epistemologies are subjectivist and methodologies are naturalistic, usually in the form of ethnography (Denzin & Lincoln).

The present study is situated within a constructivist paradigm because it is this paradigm that dominates my assumptions about how learning occurs. It adopts an ontology, epistemology and methodology associated with the constructivist paradigm. Each of these is defined and described below in the context of the present study.

Ontology

Ontology is concerned with the perspective of researchers (Denzin & Lincoln, 2000) and how they see reality (Lichtman, 2006). The ontology within a constructivist paradigm dominates the present study. The constructivist ontology assumes that reality is socially constructed (Mertens, 2005). Meaning is not discovered, but rather, "constructed by human beings as they engage with the world they are interpreting" (Crotty, 1998, p. 43). This means it acknowledges the multiple perspectives and perceptions of reality that may emerge and change throughout the research process. Constructivist researchers also reject the notion of an objective reality and embrace the multiple social constructions of meaning and knowledge (Mertens).

The constructivist paradigm has its basis in hermeneutical phenomenology (Mertens, 2005). A hermeneutical phenomenology “offers a descriptive, reflective, interpretative, and engaging mode of inquiry from which the essence of an experience may be elicited” (Richards & Morse, 2007, p. 49). Hermeneutics is the study of interpretative understanding or meaning and was originally associated with interpreting text (Lichtman, 2006) but constructivist researchers see it as “a way to interpret the meaning of something from a certain stand point or situation” (Mertens, p. 12). Constructivism also “connects action to praxis … while encouraging experimental and multi-voiced texts” (Denzin & Lincoln, 2005, p. 158). These themes come through strongly in the research design of the present study due to the emphasis placed on reflection and discussion of personal experiences of participants and the way these are interpreted by themselves and myself, as the researcher.

Three kinds of knowledge, often attributed to Aristotle, are those of *epistèmè* (scientific knowledge); *phronèsis* (practical wisdom); and *technè* (technical knowledge) (Rogers, 2007). Phronèsis is concerned with practical wisdom (Rogers) and is related to knowledge gained through experience (Loughran, 2006). It takes into account cognitive and affective dimensions of individuals within particular settings (Korthagen et al., 2006). It provides a capacity to act and requires the “ability to understand, discern, appraise and manage the complexities of specific situations” (Rogers, p. 92). Phronèsis stands in contrast to epistèmè, a more traditional view of knowledge construction that considers knowledge as objective, timeless and generalisable (Loughran). Epistèmè is “universal and unchanging” (Rogers, p. 91) and is formulated in the abstract, unaffected by the affective domain (Loughran).

Phronèsis is the view of knowledge important in this study. This research is built on the assumption that individuals gain knowledge through the cognitive and affective domains and that teaching is inherently linked to cognition about content matter, pedagogy, *and* feelings. It is also assumed that teaching is value-laden and that reactions to situations are determined by how those situations are viewed and interpreted. Constructivist principles also underlying the theoretical assumptions about learning in this research, indicate that these views will be individually experienced and socially constructed, again aligning with a phronetic view of knowledge. Phronèsis also aligns with a reflective practice view of learning, another significant component of this research.

Epistemology

Epistemology is the term used to describe the standards of evaluation of how we conceptualise reality and construct images of the world (Denzin & Lincoln, 2005). In early positivist thinking it was believed that the researcher and the research subject were independent of one another, that they had no influence on one another (Mertens, 2005). Modern views of research do, however, acknowledge that the beliefs held by the researcher (his/her ontology) could in fact influence what is conducted, observed and interpreted. This places the epistemological beliefs around “the nature of knowledge and the relationship between the knower and the would-be-known” (Mertens). The epistemology associated with a constructivist paradigm is one of subjective knowledge (Denzin & Lincoln) and interaction between the researcher and participants where values are made specific (Mertens) and where understandings are co-created (Crotty, 1998; Denzin & Lincoln, 2005; Mertens, 2005).

The epistemology of constructivist ontology is transactional, subjective and based on created findings (Denzin & Lincoln, 2005). Knowledge is socially constructed by people active in the research process and interpretations are made from an “attempt to understand the complex world of lived experience from the point of view of those who live it” (Mertens, 2005, p. 13). It is acknowledged also that different people may construct meaning in different ways (Crotty, 1998) and so consensus is an important feature in creating shared meaning and understanding (Denzin & Lincoln). The researcher and the subjects of the study are interactively engaged in observing and interpreting and meaning; “each influences the other” (Mertens, p. 14) in this process. This meaning-making is of critical importance to the constructivist research because it is the meaning-making that shapes action (Denzin & Lincoln).

In the present study, the meaning-making that shapes action is the basis of the research. The action-reflection that informs further action exemplifies the constructivist epistemology discussed by Mertens (2005) and Denzin and Lincoln (2000). The nature of knowledge is based on individual reconstructions of experiences reaching consensus and the researcher’s position is as a facilitator of the multiple participant voices as they construct knowledge from their experience. The concept of objectivity is replaced by confirmability where data can be tracked to their sources, and the logic used to assemble interpretations is made explicit in the narrative (Mertens). This aligns with Denzin and Lincoln's definition of the nature of knowledge and the voice of the researcher within the constructivist inquiry paradigm.

Methodology

Methodology is concerned with the way in which inquirers go about their inquiry. It encompasses the approaches taken to collect data and the tools used for their analysis. The interactive nature of the constructivist paradigm is linked to a hermeneutical and dialectical methodology. Mertens (2005 describes this:

> This interactive approach is sometimes described as hermeneutical and dialectical in that efforts are made to obtain multiple perspectives that yield better interpretations or meanings (hermeneutics) that are compared and contrasted through a dialectical interchange. (p. 15)

The hermeneutical methodology "emphasises a detailed reading of text, which could refer to a conversation, written words, or pictures" (Neuman, 2007, p. 76). The researcher then attempts to create meaning from the analysis of this text. Dialectic refers to "the idea of a paradoxical inner conflict or contradiction that brings about change" (Neuman, p. 82). Dialectic interchange occurs when this 'conflict' is expressed through the examination of ideas by debate or discussion, thus linking to the constructivist-interpretative paradigm calling for consensus of ideas.

The present study adopts its naturalistic, qualitative approach to method, primarily through the use of case study. Qualitative research helps make sense of "events and experiences of those who participate in those events as they occur in natural settings" (Richards and Morse, 2007, p. 4-5). The naturalistic settings in this case include both the teachers' classrooms and preservice teachers' university setting and the study seeks to collect the multiple stories and personal perspectives of the participants that influence them. This is also consistent with constructivist methodologies which are considered to occur in the natural setting of participants (Denzin & Lincoln, 2005).

Case Studies

Case study research is not a methodological choice *per se*, but rather a choice of what is to be studied (Stake, 2000). Stake indicates that the greater the uniqueness of the object of study, the greater the rationale for calling it a 'case study'. The unique nature of the collaborative partnership that calls for preservice and practising teachers to work as equals in the planning, implementing and reflecting on a series of science lessons lends itself to Stake's argument for using case study research.

Case studies are explorations of "bounded systems … over time through detailed, in-depth data collection involving multiple sources of information rich in context" (Creswell, 1998, p.61). Yin (1989) describes a case study as an empirical inquiry that:

- Investigates a contemporary phenomenon within its real-life context: when
- the boundaries between phenomenon and context are not clearly evident; and in which
- multiple sources of evidence are used. (p. 23)

The present study utilised a single case study design where the cohort of preservice teachers was considered as a single case for one aspect of the study, as was the cohort of practising teachers. Each of these single case studies adopted multiple approaches to data collection methods through the use of a questionnaire and transcripts of discussions conducted through participant workshops, and round table and online sessions.

Elements of multiple case study analysis also took place as the stories of each preservice and practising teacher partnership were explored through interviews and written reflection. Multiple case studies are those that contain more than one unit of study. Yin (1989) provides a typical example as "a study of school innovations … in which independent innovations occur at different sites" (p. 52). He indicates that in such an example, "each site might be the subject of an individual case study, and the study as a whole would have used multiple-case design" (p. 52). This example is very similar to the individual collaborative partnerships in the present study, who each worked with the same theoretical and action-reflection framework, within their individual classrooms or 'sites'.

Concerns associated with case study design, and in fact nearly all qualitative research, are mainly centred on the subjectivity of researchers as they select which aspects of data to report to support or refute particular explanations or phenomena (Burns, 2000). This is linked to the idea of interpretation, and how the researcher's sensitivity, integrity and tendency to exaggerate may lead to erroneous conclusions (Burns). These issues are tied to the trustworthiness and credibility of the research findings, terms in qualitative research that relate to internal validity (Denzin and Lincoln, 2000; Mertens, 2005) which are discussed next.

Credibility and Reliability

A research project has credibility when the explanation proffered by the researcher fits the viewpoint of the participants (Mertens, 2005). In other words, how trustworthy the explanation of the events, feelings and stories of the participants is, and how well it represents participants' interpretation of events, feelings and stories. In phenomenology, validity refers to the reporting of ideas in the research being well-grounded and supported by the material or data collected (Creswell, 1998). Credibility can thus be enhanced when the research design is rigorous and when multiple strategies are used to collect data on which to base explanations (Mertens). Another critical factor in determining credibility is member checks. This is where the data collected from participants are summarised and/or recorded by the researcher and given back to the participants to check for accuracy (Mertens, 2005; Denzin & Lincoln, 2005). This can reduce the risk of the concerns expressed by Burns (2000) of inaccurate interpretation and exaggeration.

Burns (2000) also reports on concern with the generalisability of case study research. Generalisability is linked to external validity in quantitative research (Wiersma, 2009; Denzin & Lincoln, 2005; Burns, 2000; Mertens, 2005). The qualitative researcher however, is concerned with multiple realities (Lichtman, 2006) and does not seek to generalise findings beyond the actual case under study. Burns also tells us that "case studies are focussed on circumstantial uniqueness and not on the obscurities of mass representation … [where] … complicating interaction effects are not thought of as hindering understanding" (p. 474). External validity in the qualitative paradigm is replaced with transferability, the "extent to which results can be transferred to other settings" (Lichtman, 2006). Strategies for enhancing transferability include provision of "rich, thick description" (Creswell, 1998; Mertens, 2005) which entails detailed descriptions of participants and events that might enable the reader to transfer findings on the basis of shared characteristics in another setting or context (Creswell).

Reliability requires that the results obtained in a study would be replicated if it were to be repeated (Richards & Morse, 2007). This is highly unlikely in case study research (Burns, 2000) because, as Richards and Morse tell us, "the data are richly within the particular context" (p. 190). Instead, dependability is the qualitative researcher's measure of reliability. Dependability is achieved when the researcher documents any changes that occur in the context of the study to account for the consistency within the particular context of study (Mertens, 2005). This can be applied as the research unfolds. Dependability is also enhanced when researchers explicitly examine any biases they might bring to interpreting data, and through the use of an audit trail that documents the steps taken in collecting and analysing data to enable authentication of the manner in which the data is collected and used (Burns).

The present study adopts a number of strategies to minimise the limitations in the research design and method used. Multiple sources of data collection, including reliability tested and established questionnaires, interviews, round table and online discussions and participant responses in workshop activities. As highlighted above, the use of multiple data collection techniques increases the credibility and trustworthiness of results and should minimise any subjectivity the researcher brings. Transferability will be addressed by ensuring the ‘rich, thick descriptions’ of cases are provided. An audit trail will be established to increase the dependability of findings. As the researcher, I will attempt to always query conclusions made from looking at the data and specifically look for any biases that may exist, further enhancing the dependability of explanations given.

Table 3.2.1 summarises the theoretical and methodological framework of the research. Following this the participant recruitment is described before the data collection methods and analysis techniques are discussed.

Table 3.2.1: Summary of Theoretical and Methodological Framework

	Research in General		This Research
Ontology	What is the perspective of researcher and how he/she sees reality?	Constructivist where the world is seen as universal and absolute realities are considered unknowable. Inquiry is an individual perspective based on construction of reality.	Constructivist, Phronètic, Hermeneutical, Phenomenological
Epistemology	What is the relationship between the knower and the inquirer?	Joint process of co-construction of knowledge. Knowledge is constructed through phronèsis which acknowledges the cognitive and affective domains of the individual.	Subjective, Social Constructivist
Methodology	How can the inquirer go about their inquiry?	Naturalistic, qualitative research methods.	Hermeneutical, dialectical Constructivist Case Study

3.3 Data Collection Methods

To collect the stories and perspectives of participants in this study, and build credibility and trustworthiness in the findings, a number of data collection methods was utilised. As noted earlier, it is important to have a number of data collection methods in qualitative studies to enhance the likelihood that a deep understanding of the situation(s) is gained, especially when there are a number of facets in the research question. This is explained by Richards and Morse (2007):

> An interesting research question will usually require several strategies for making data. Relying on one technique may produce homogenous data, which are unlikely to provide enough sources of understanding and ways of looking at a situation or a problem. (p. 78)

The range of data collection methods adopted in the present study is listed below, followed by a detailed description of each.

1. Pre and post questionnaires;
2. Round table discussions;
3. Online discussions;
4. Semi-structured interviews;
5. Responses to workshop activities;
6. Planning and reflection Booklets.

1. Pre and Post Questionnaires

Questionnaires were administered to all preservice and practising teacher participants to mark the beginning and the conclusion of the data collection period. The results of these were used to establish the initial attitudes, confidence and self-efficacy participants had towards science and its teaching in the primary school sector and any changes in these factors after the partnership teaching period.

A number of different instruments were investigated for use in the present study, including the Science Teaching Efficacy Belief Instrument (STEBI) developed by Riggs and Enochs (1990); the Science Attitude Inventory (SAI) developed by Moore and Sutman (1970), the revised SAI II developed by Moore and Foy (1997); and the ROSE questionnaire (Jenkins & Pell, 2006). The SAI and SAI II were rejected due to their focus on research of school children's attitudes towards science rather than those of teachers. Similarly, the ROSE questionnaire targets students nearing the end of secondary schooling, so was also discarded. The STEBI instrument was designed "to specifically assess science teacher self-efficacy" (Enochs & Riggs, 1990, p. 695) for primary school teachers involved in science professional development. This instrument was later adapted for use with preservice teachers (Enochs & Riggs). The revised version saw questions reworded into the future tense to meet the situational context of preservice teaching better. The two versions of the instrument are now known as the STEBI-A (original version) and the STEBI-B (revised version). The similar nature of these instruments and the fact that they are designed to target the particular participant cohorts in the present study made them ideal for use. For these reasons the STEBI instruments were selected for use in the present study.

The STEBI Questionnaires

The STEBI-A and STEBI-B instruments consisted of 25 and 23 statement items respectively, a number of which were negatively worded to control for response sets in the participants. The instruments utilise a five-point Likert scale to collect information on the level of agreement participants have with a range of statements concerning their perceived level of knowledge of science and ability to teach it. Response options provided are Strongly Agree, Agree, Uncertain, Disagree and Strongly Disagree. Each item on the questionnaires is scored out of a possible 5 points. These scores and how they were assigned to each level of agreement is given in Table 3.3.1. Items with negative scoring were re-coded as shown in Table 3.3.2.

Table 3.3.1: Values and Measures for STEBI Questionnaires

Value	Measure
SA: Strongly Agree	5
A: Agree	4
UN: Uncertain	3
D: Disagree	2
SD: Strongly Disagree	1
Missing Data	-9

Table 3.3.2: Coding for Negatively Scored Items in STEBI Questionnaires

Participant Response	Original Score	Re-coded for Negative Scoring
SA	5	1
A	4	2
UN	3	3
D	2	4
SD	1	5

This scoring resulted in the PSTE scale being measured out of a total of 65 points for both practising and preservice teachers, and the STOE scale out of a possible 60 points and 50 points for practising and preservice teachers respectively.

Items have been grouped by the creators of the instruments to form two scales. The first scale measures respondents' Personal Science Teaching Efficacy Belief (PSTE) and the second measures their Science Teaching Outcome Expectancy (STOE). The PSTE scale provides a measure of teachers' personal self-efficacy, or rather, their belief in their ability to teach science (Riggs & Enochs, 1990). The STOE scale is a more general measure of teachers' beliefs that certain behaviours in science teaching will produce desirable outcomes (outcome expectancy) (Riggs & Enochs), regardless of their personal ability to enact these behaviours. In the present study the PSTE scale is of particular importance as it is directly concerned with practising and preservice teachers' personal self-efficacy beliefs in science which is associated with two of the research questions in this study.

The STEBI-B contains the same questions as STEBI-A, less two items which had significant cross factor loadings. Riggs and Enochs (1990) have reported STEBI-A Cronbach alphas scores of .92 and .77 for the PSTE and STOE scales respectively. The two sub scales within the STEBI-B yielded alphas of .90 for the PSTE and .76 for the STOE. These reported alphas indicate that each of the STEBI instruments is statistically reliable.

Whilst providing a reliable measure of self-efficacy belief through the PSTE scale, the STOE sub scale has been known to have some issues. Morell and Carroll (2003) indicate that instruments purporting to measure general teaching efficacy, such as the STOE sub-scale, are generally problematic. Posnanski, 2002 (citing Borchers et al., 1992), discussed the possibility that "outcome beliefs are more stable and not as easily influenced as self-efficacy beliefs" (p. 213) and that "outcome expectancy beliefs may not be related to changes in teacher behaviour" (p. 214). Riggs and Enochs (1990) themselves acknowledged the difficulties involved in designing the STOE scale due to the number of variables that can influence teachers' judgements in items associated with this scale, in particular those factors over which they feel they have little control. Another phenomenon recorded in relation to the STEBI instrument is that of the ceiling effect (Morrell & Carroll, 2003). This is where initial high scores (over 50) tend to be resistant to change regardless of the experiences put in place to effect increases in efficacy beliefs. These issues are of minor consequence in the present study as the

PSTE scale is the one of interest and if participants are scoring initial results over 50, then their self-efficacy beliefs are not of any great concern.

The full STEBI-A and STEBI-B questions sets can be found in Appendix 3. The particular questions relating to the PSTE and the STOE scales for each instrument are given in Table 3.3.3. Negative scored questions are marked with asterisks.

Table 3.3.3: Questions relating to each scale in the STEBI A and STEBI B Instruments

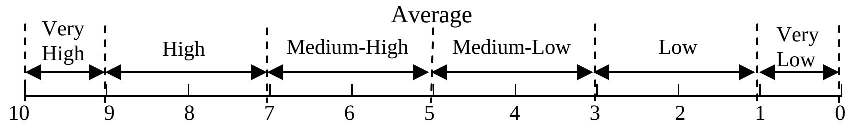
Scale	STEBI A (Practising Teachers)	STEBI B (Preservice Teachers)
Personal Teaching Efficacy (PSTE)	2, 3*, 5, 6*, 8*, 12, 17*, 18, 19*, 21*, 22, 23*, 24*	2, 3*, 5, 6*, 8*, 12, 17*, 18, 19*, 20*, 21*, 22, 23*
Outcome Expectancy (STOE)	1, 4, 7, 9, 10*, 11, 13*, 14, 15, 16, 20*, 25*	1, 4, 7, 9, 10*, 11, 13*, 14, 15, 16

In addition to the STEBI items, the initial questionnaires included a range of questions to collect background data. Practising teachers were asked for their age, years of teaching experience and whether there was a science co-ordinator and/or science budget in their school. They were also asked how much science on average they taught in their classrooms, whether they had used the 5Es framework before and whether they had studied science in formal coursework or in professional development prior to the project. These data help to indicate the level of previous experience practising teacher participants had prior to the project and the level of some of the support structures they have for science in their schools.

Preservice teachers were also asked their age, their study load (full/part time), whether or not they entered university straight after Year 12 and the level to which they studied science in secondary school. Information about other science studies they had undertaken, for example a minor in their Education course, was also requested, along with an indication of how many lessons of science they had taught on previous professional experience rounds. These data help to indicate preservice teachers' previous science experiences that may impact on the results of the study.

Both cohorts were also asked to rate their confidence in teaching different areas of science using a continuous scale. The areas of science targeted were Biological Science, Chemical Science, Earth and Space Science and Physical Science as these are the areas associated with the Victorian science curriculum documentation (VCAA, 2007). The scale provided for participants to record their responses had graduations ranging from Very Low to Average and then up to Very High as shown in Figure 3.3.1.

Figure 3.3.1: Values and Measurements for the Scale - Confidence Levels across Areas of Science



The final questionnaires administered to each participant cohort asked for some of the same background data as those in the initial questionnaire. These were used to help identify matching pre and post questionnaires so changes in STEBI and self-confidence results could be investigated.

Each of the initial and final questionnaires also contained an open-ended section. This asked participants what they would like to achieve/gain from their involvement in the project (initial questionnaire) and what they achieved/gained from their involvement (final questionnaire). The final questionnaire also asked what they feel they would need to achieve more from a project like this; whether their involvement influenced the frequency with which they intended to teach science, and if so, how; and what they saw as barriers to teaching science in the open-ended response section.

These questions helped to identify strengths and weaknesses of the collaborative partnership model used in the study and helped meet the aims of the study concerned with the level of priority science had in participants' teaching repertoire as well as what barriers they saw to increasing the profile of science in primary school classrooms (see section 1.4 Statement of Aims from Chapter 1 for these aims and how they relate to the research questions).

Each of the initial and final questionnaires for preservice and practising teachers can be found in Appendix 3.

2. Tutorial and Workshop Activities

Initial Participant Workshop

Practising and preservice teacher participants attended an introductory workshop, where they met their partners and began exploring the ideas behind the seven week school based experience. The initial workshop, with all participants, served as an introduction to exploring the beliefs and attitudes of participants towards science and its teaching. It was also used to communicate the impetus behind, and purpose of, the research project to participants and to build shared understandings of what the project entailed. Some of the guiding principles were also shared to encourage a common understanding of where the project came from and how it was intended to unfold. These principles included a summary of the literature both highlighting the importance of science education and guiding the research design; the 5Es framework; and the model of reflection to be used. A PowerPoint presentation and a range of activities including a De Bono's (1992) thinking hats activity were used as tools to create this shared understanding.

The initial workshop introduced participants to Bybee's (1997) 5Es approach, to constructivist learning, and the Primary Connections (Australian Academy of Science, 2006) resource materials as a model of linking science with literacy outcomes. The way the 5Es framework was to be used as the planning framework for partners to use in their planning was explained, as discussed in Chapter 2. The Primary Connections model of the 5Es framework was selected here as it is a research-based resource that has been trialled in primary schools, informed by practising teachers and science education researchers and is based on a constructivist model of inquiry learning (Hackling & Prain, 2005). These factors align with research about effective learning which has established links to constructivist principles and inquiry learning, which in turn aligns with the inquiry nature of science. As such, it provides participants with a sound, research-based pedagogical model for effective teaching and learning which better allows for focus of the research to be on the partnership model and individual participants' change in attitude, efficacy and knowledge using this model. It also helps to address the lack of expertise commonly found in practising teachers' science knowledge and pedagogy (Goodrum, et al., 2001; Keys, 2005) which may impact on their ability to provide effective role modelling of science teaching.

Participants' seating for the workshop was arranged so that they were sitting with the individuals who were going to be their partners for the project. This was achieved by using named folders containing the workshop materials as place markers. The intention behind this was to ensure that individuals got to know each other over the course of the workshop by completing the discussions and activities set with one another. However, their introduction as partners was delayed, with the intention that they would achieve better focus on workshop activities if they were not distracted by thinking 'we'll be working together, what should we do' before the scaffolding had been put in place for the partnerships to work. Indeed, this was one of the key objectives for this workshop: to provide a scaffold for successful partnerships by building relationships through sharing of ideas and beliefs about science education. One of the strategies for achieving this was to engage participants in a reflection on their own beliefs about science education using De Bono's (1992) Thinking Hats framework.

As discussed in Chapter 2, De Bono (1992) proposed the use of six 'thinking hats' to encourage diverse thinking about a topic or issue. Each of De Bono's hats relates to a different form of thinking and is characterised by its colour (see Table 3.4.4). The red feelings, yellow benefits and black caution hats were used, in that order, to access participants' individual feelings towards science and/or of teaching science (red hat), their beliefs about the benefits of having science as a part of the primary school curriculum (yellow hat) and their concerns about its teaching (black hat). This was important in the present study as it enabled participants to articulate their different thinking associated with science and helped to establish initial attitudes towards science.

Large hats were cut out in the appropriate colour and displayed on a wall in the room. Participants were asked to jot down a word or a short phrase to describe their feelings and thoughts for each hat, one at a time, on a post-it note, and to attach this to the hat under consideration. The white, green and blue hats were explored more generally by the way activities in the remainder of the workshop were structured around them. Once participants posted their responses for a particular hat, the responses were read aloud to the whole group. This was designed to help individuals obtain a sense of how others in the room were feeling and thinking, while protecting anonymity. When used in this way in the past, my experience is that groups who tend to have high anxiety levels about science are put at ease through the anonymous sharing of their feelings and attitudes as they realise the similarities between their own and others' feelings.

This activity helps establish an initial idea of participants' feelings and attitudes towards science which addresses research sub-questions one and two that ask: what attitudes and levels of self-efficacy beliefs do preservice and practising teachers have towards science before and after the partnership period? Results were used as part of the analysis of themes emerging from the data. The thinking hats framework and its application in the project is summarised in Table 3.3.4.

Table 3.3.4: De Bono's Thinking Hats

Hat	Hat Meaning	Application in this Project	Theoretical Underpinning
Red Hat	Feelings; Emotions; Intuition	Participant response to question 'How do you feel about science and/or about teaching science?'	Science attitudes and efficacy (Goodrum et al., 2001)
Yellow Hat	Positives; Good Points.	Participant response to question 'What are the benefits of teaching science in the primary curriculum?'	Science attitudes and efficacy (Goodrum et al., 2001)
Black Hat	Judgements; Caution; Bad Points.	Participant response to question 'What are your concerns about teaching science?'	Science attitudes and efficacy Barriers to teaching science (Goodrum et al., 2001)
White Hat	Information; Questions.	Information about 5Es inquiry teaching framework explored during the workshop through practical examples and theory.	Professional learning content and pedagogy focus (Hackling & Prain, 2005; Ingvarson et al., 2005); Vicarious Experience (Bandura, 1977)
Green Hat	Possibilities; Creativity; Suggestions.	Partnerships meeting to begin planning how they might implement 5Es in their collaborative teaching experience.	Building collaborative partnerships (Levin & Rock, 2003)
Blue Hat	Processes; Organisation of Thinking.	Organising the timeline for planning, teaching and reflecting on the collaborative teaching.	Building collaborative partnerships (Levin & Rock, 2003); Action-reflection model (Korthagen, 2001)

Once initial feelings and beliefs were articulated and shared with one another, the session moved into the White Hat phase: dealing with information. This information was provided through a session on the anticipated outcomes of the partnerships the practising and preservice teachers were about to enter. The partnerships' purpose of planning, implementing and reflecting on a series of science-based lessons in the classroom over a period of six to seven weeks was explained. Lessons that integrated science with other areas of the curriculum were encouraged, but not made mandatory. The planning of the lessons had to be consistent with the 5Es inquiry framework. In order to achieve this, the next hour of the workshop was devoted to exploring and exemplifying the 5Es framework.

Participants were introduced to the phases of the 5Es and their definitions as set out by the Australian Academy of Science (2005). An activity from the Primary Connections facilitators pack, the 5Es card sort, was conducted to help participants think about each of the phases and how they might be translated into teacher and student practice in the classroom. The card sort activity was conducted in groups of approximately four participants, which, due to the seating arrangement that had been organised, involved participants working with their partners and one other partnership, and thus resulting in a mix of practising and preservice teachers.

The card sort activity lists the five phases ‘Engage’, ‘Explore’, ‘Explain’, ‘Elaborate’ and ‘Evaluate’ represented on separate cards which participants set in a vertical line down the centre of their workspace. They then take the set of cards containing descriptions of teacher behaviours (denoted by a ‘T’ in the corner of the card) and student behaviours (denoted by an ‘S’ in the corner of the card), and set about to arrange the described behaviours on either side of each phase, as they believed them to match.

This activity promoted discussion amongst the participants about what each of the five phases of the 5Es means and how the formal definition provided could be translated into behavioural practice in a classroom. It also provided participants with an opportunity to internalise the meaning of the 5Es framework which was intended to help increase their retention of the ideas behind each phase and to enhance their intuitive ability to apply it or recognise it in classroom activities. After some discussion and sharing of the placement of cards between groups and further clarification of terms and intentions behind the 5Es framework, an agreed answer set was established and discussed in relation to the example answer set provided in the 5Es facilitator materials (Australian Academy of Science, 2005). This is consistent with the overall constructivist framework being applied in this study, as preservice and practising teachers had the opportunity to recognise their prior knowledge and construct new knowledge through the activities and discussion in which they were engaged.

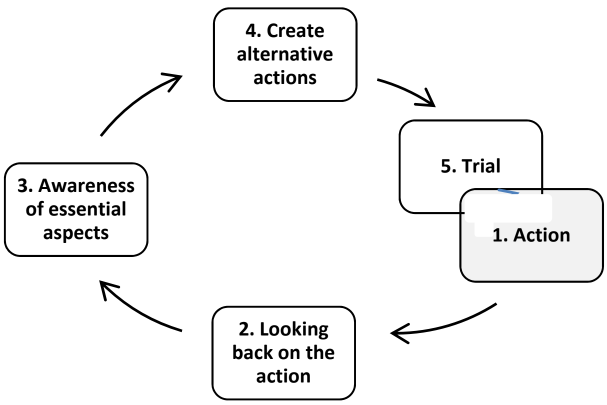
To further explore the framework, the Elaborate phase was then exemplified through an activity. The Elaborate phase was isolated in this manner as it involves the use of student designed investigations, something that is not generally conducted in primary classrooms (Goodrum et. al, 2001). It was essential to include a worked example of this phase to help participants understand how to conduct student-designed investigations, and to provide participants with a model for replicating it in their classrooms. This provided participants with at least one shared vicarious experience that Bandura (1977) indicates reinforces efficacy beliefs. Preservice teachers had a number of other vicarious experiences in the initial few weeks of the unit through tutorial sessions where science activities were conducted and analysed. Participants were led through an example of how to identify and select variables, how to design an investigation question and how to report back on their findings in order to establish discussion among the class. A variable grid template from the Primary Connections resources and a Student Designed Investigation template adapted from Primary Connections resources were provided.

The final 40 minutes of the workshop were dedicated to the Green and Blue Thinking Hats. Participants were formally introduced to their partners for the project, to discover they had been sitting, talking and working with them for the duration of the session so far. The Green Hat (Possibilities) was introduced by encouraging partners to begin exploring ideas for a unit of work that they may like to investigate that involved the linking of science outcomes with other curriculum areas in their classrooms. It was expected that this experience would create a shared vision for the seven week school-based experience that would provide a new approach for both the practising and preservice teacher to work on, rather than the preservice teacher adopting the already established practices of the classroom teacher that Maynard (2001) warns against. It also allowed for autonomy in selecting topics of interest for teaching, or topics relevant to other school activities such as inquiry themes that may already have been in operation. This supports the social constructivist assumptions underlying the project design by enabling both the preservice and practising teacher to construct knowledge as they plan, implement and reflect together. It also helps to address Levin and Rock's (2003) guideline four (Figure 2.1.1) that indicates that action research questions should emerge from the interests and concerns of the participants. Even though this is not strictly an action-research project, the same principle applies to participants generating topics that address their interests and/or needs as related to their own schools, classrooms and experience.

The Blue Hat (Processes) was introduced through the dissemination of a planning and reflection booklet that was created for each partnership, and an outline of the planning and reflection framework. The planning and reflection booklet contained a timeline for partners to complete with dates for planning meetings, classroom implementation sessions and reflection meetings. Partners were encouraged to complete this before leaving for the evening. A sample planning and reflection booklet is provided in Appendix 4.

Overall, the cycle of planning, implementing and reflecting used in the partnership model is based on Korthagen's (2001) model of action-reflection. Korthagen's ALACT model describes the cycle of Action, Looking back on the action, Awareness of essential aspects, Creating alternative actions, and Trialling those actions, which serves as the new Action that recommences the cycle. The ALACT model is shown in Figure 3.3.2. This links to notion of reflection occurring before, during and after a teaching experience.

This model is incorporated in the current study through the design the planning and reflection cycle used in the study (shown in Figure 3.3.3).



Korthagen, 2001, p. 44

<u>Figure 3.3.2: Korthagen's ALACT Model</u>

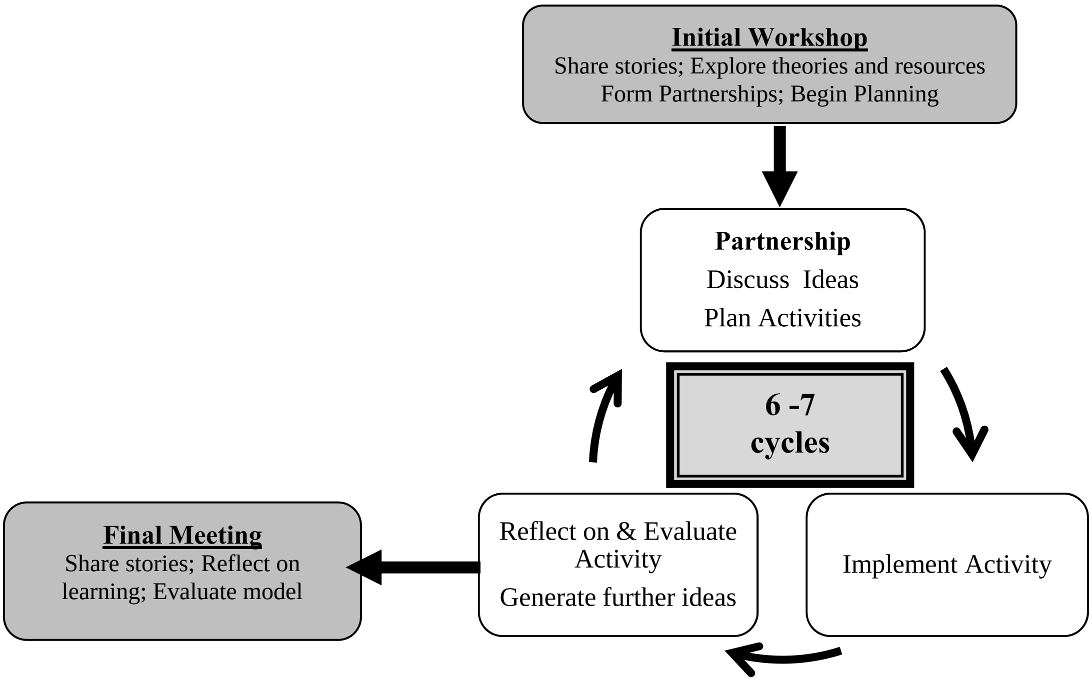


Figure 3.3.3: Participant Model of Action-Reflection

The initial participant workshop provided the content focus of the professional learning model which Ingvarson et al. (2005) purport as being important for effective professional development. The ongoing nature of the professional learning opportunity was then met by enabling partnerships to plan, implement and reflect on their own experiences of the content introduced in this workshop in a series of cycles. This represents the opportunity for follow up, active learning and feedback the Ingvarson model asserts. It is built into the cycle of planning, implementing and reflecting and using reflection to this inform further planning, implementing and reflecting as shown in Figure 3.3.3.

In summary, the primary purpose of the initial participant workshop was to develop shared understandings of the research design, its impetus and requirements, and to introduce partners so they could begin the planning process. It also provided an opportunity to collect initial data on participants' attitudes and self-efficacy beliefs towards science through the De Bono Thinking Hats Activity. The initial questionnaire was also distributed at this workshop.

Final Participant Workshop

To mark the conclusion of the partnership experience, participant partnerships also attended a final two hour workshop. Here, the opportunity for reflection on learning and evaluation of the partnership model took place.

This workshop began with a short presentation reminding participants of the definitions for each phase of the 5Es according to Australian Academy of Science (2009) (see Appendix 7), prior to being asked to recall, record and share what they believed to be their best example of each phase from their teaching partnership. The reminder of the 5Es prior to discussion was expected to support participants' recall and to encourage inclusion of particular components of each phase in their presentations. For example, the Engage phase includes two key components: capturing students' interest and curiosity in the topic; and eliciting students' prior knowledge through diagnostic assessment techniques. Each of these components needed to be evident for this phase to be judged as being applied effectively.

Partnerships then shared what they considered to be their best achievements at each stage of the 5Es framework, and some provided samples of children's work. This helped to address four key goals for the workshop. Firstly, participants' sharing helped expand individuals' ideas for activities and how to best implement them using the 5Es framework, thus extending some of their content ideas for ongoing science teaching. Secondly, the presentation to one another helped address Levin and Rock's (2003) second guideline (Figure 2.1.1) for creating collaboration, where they suggest that setting up informal or formal presentations increases ownership and instils accountability.

Including the sharing of children's work samples also links to Levin and Rock's (2003) guideline six (Figure 2.1.1) where they state that encouraging data collection in the form of student work samples (as one example) increases the reflection on addressing children's needs in the classroom. The recording, presenting and submitting of 5Es application across each phase helped achieve the third aim of providing data in regard to how the 5Es model was implemented to provide data in regard to participants' understanding of the pedagogical model used. Finally, it also allowed an opportunity for practising and preservice teachers to receive feedback on their achievements from their colleagues and the researcher/facilitator of the workshop, thus addressing one of Jones and Carter's (2007) required components for enhancing teachers' efficacy.

The second half of the final workshop was dedicated to evaluating the partnership model for professional learning. Participants contributed their ideas on the main benefits and challenges that the partnership had for their learning by recording on cardboard leaves. Participants attached their 'benefit' leaves to a branch of a cardboard tree displayed on the wall. Once all contributions had been attached, the benefits recorded were shared with the group. When recording the challenges/drawbacks of the partnership model for their learning on additional cardboard leaves, participants were also asked to indicate any ideas they had for addressing these issues. 'Challenge' leaves were then attached to a second branch on the display tree and shared with the group. Leaves were not identifiable to individual participants. These leaves, once attached to the display tree, created what was termed the 'Partnership Tree of Knowledge'. This is depicted in Figure 3.3.4.

Figure 3.3.4: Partnership Tree of Knowledge

The sharing of the aspects that did and did not work for preservice and practising teachers served as an introduction to the next key activity. Here, participants were split into practising and preservice teacher cohorts and asked to complete a recommendation statement on how to create partnerships that are successful for learning. This yielded a statement from practising teachers on how partnerships can be made effective models for professional development; and from preservice teachers, a statement on how partnerships can be made effective for teacher education. The initial leaves activity helped pool the individual experiences and helped individual participants obtain an overview of the issues from both cohorts. It also allowed a small amount of reflection on these issues before the recommendation statements were made.

To achieve the recommendation statements, the practising teacher cohort received a single sheet of recording paper headed with the stem: ‘To be successful for teacher professional development, a partnership model needs:’. The preservice teacher cohort similarly received a page with the stem: ‘To be successful for preservice teacher education, a partnership model needs:’. Each cohort was seated in a round table fashion in separate rooms to encourage group discussion that could be kept private from one another in case sensitive discussion topics arose that they may have preferred to share only with their immediate peer group.

Professional Development Certificates accredited and signed by the university and the local Catholic Education Office were awarded to practising teacher participants. The recognition of the professional learning for practising teachers helped to acknowledge the value of their time. This is important for strengthening relationships between schools and universities. The certified professional learning was used as a strategy to attract teacher participants to the project. It contributed to teacher registration renewal requirements where a certain number of professional development hours need to be accrued. This further helps to achieve Levin and Rock’s (2003) guidelines for engaging practising teachers in collaborative partnerships where guideline 3 (Figure 2.1.1) states “Establish ways for experienced teachers to receive credit for their efforts by earning professional development or renewal credits from their district” (Levin & Rock, p. 148).

The final participant workshop provided a range of important data. Partnerships’ ‘best example’ of each 5Es phase was recorded and used to help assess their knowledge of this pedagogical framework. Their presentations to each other were recorded and used to confirm and/or clarify their written statements about each phase. The ‘benefits and challenges’ leaves from the ‘Partnership Tree of Knowledge’ were used to examine strengths and weaknesses of the partnership model and the recommendation statements prepared by each participant cohort were used to help form recommendations about collaborative partnerships as a model for professional learning.

3. Round Table Discussions with Preservice Teachers

Round table discussions provide "the reflective space for the systematic unpacking of learning" (Brandenburg, 2004, p. 166). They encourage the development of effective reflective practice by helping preservice teachers "evaluate and articulate *their* learning from *their* experiences of teaching and to share *their* developing knowledge in meaningful ways" (emphasis in original, Loughran, 2006, p. 132). Brandenburg also tells us that a round table approach to learning creates a deeper understanding of self and opportunities of transformation through "experience, shared ownership, systematic reflection and the development of collegial relationships" (p. 166). An effective physical arrangement of the classroom is also necessary, where tables and chairs are arranged in a 'round table' fashion to promote co-operative learning (Gillies, 2003). Brandenburg highlights the beliefs underlying a round table approach to learning which are also adopted in this study:

- Roundtable reflection would provide opportunities for preservice teachers/teacher educator to make sense of experiences in a supportive environment;
- Preservice teachers would generate the discussion by raising issues related to (their teaching) experience;
- The role of the teacher educator would be to introduce the session, clarify the framework and consciously refrain from leading and/or dominating discussion;
- All preservice teachers would be provided with an opportunity to raise an issue, and thereby be granted 'voice';
- The learning outcomes could not be predetermined;
- Learning/s would be made explicit;
- Opinions would be respected; and
- References would be made to the ALACT model of reflective practice.

Brandenburg, 2004, p. 170-171

During the seven week school-based experience, the voice of the preservice teacher participants was followed through the use of round table discussions which were conducted twice during the seven-week school experience. The round table discussions were intended to enable preservice teachers to share their experiences, successes and challenges of their planning and implementing. Links to theories covered in lectures were also highlighted and discussed where relevant. This helps to achieve the effective teaching and learning that Lord (1997) and Biggs (2003) associate with the extent of opportunity students have to interact with their peers. My participation as the tutor was to use guiding questions to facilitate this discussion when necessary and encourage preservice teachers to respond to each others' stories and questions. This resembles characteristics often associated with unstructured, group interviews (Burns, 2000). The discussion and guidance essentially evolved as it unfolded, and I endeavoured to be responsive to the context and the experiences of the participants, a characteristic of qualitative study (Richards & Morse, 2007), thus supporting the overall theoretical framework of the study. Consequently, a good source of data collection as well as an effective learning experience was able to be created.

The round table discussions also acted as a source of social persuasion (Bandura, 1977) where preservice teachers acted as supportive elements for one another. I was also able to use verbal persuasion to assist with preservice teachers' efficacy when required. These occasions arose when the group was unable to respond constructively to a particular situation being discussed, although these occasions were rare in the overall time dedicated to round tables. Social/verbal persuasion helps to further reinforce efficacy changes (Bandura, 1977) in preservice teachers if efficacy is an issue for them.

Each of the round table sessions was recorded, providing transcripts for analysis. Insights into the development of attitudes towards and ideas about science teaching and learning were ascertained from these transcripts. Insights into the model of professional experience and delivery of the unit in this way also emerged. The guiding framework for round table discussions can be found in Appendix 6.

4. Online Discussion with Preservice Teachers

Preservice teachers were required to discuss their own and others' experiences in an online discussion. This helped to promote some of the effective reflective practice encouraged by Loughran (2002), Korthagen (2001) and Korthagen et al. (2006). Koballa and Tippins (2001) indicate that "opportunities to engage in discussion and debate with fellow learners is necessary for meaningful learning" (p. 222) and that online discussion is a useful tool for achieving this. They also promote the use of online discussions to facilitate social construction of knowledge.

In a meta-analysis of research into the use of online discussions to support learning in higher education, Hammond (2005) identified the strong link between this mode of teaching and learning and the principles of social constructivism. This sees the use of online discussion as another component working towards the achievement of the principles of social constructivism underpinning this project. Hammond also described the range of benefits of online discussion reported in the literature which, among other less relevant aspects, include:

- Interaction that could not otherwise take place easily due to distance;
- Student appreciation of opportunities for online discussion;
- Social support learners find in the online discussion forum and subsequent motivation to study;
- Higher order discussions and knowledge building within forums;
- Added value to the learners' experience.

Hammond, 2005, p.15

In addition to these potential benefits, a number of guidelines for establishing effective learning through online discussions was provided. These included the need to build in opportunities for reflection, provide structure and roles for contributors, and include instructor support and guidance (Hammond, 2005). Ryan and Scott (2008) also highlight the importance of intervention by experienced educators to ensure discourse is conducted critically, and warn that without such intervention, discussion forums tend to be limited to communication and sharing of information, which while albeit useful as a descriptive exercise, do not necessarily engender learning.

In response to these ideas, the online discussion forum used in this project made use of a discussion topic question that asked preservice teachers to share the critical moments of reflection they had conducted with their practising teacher partners, and to help each other identify the links between these experiences and the theoretical components of the course work, and the 5Es framework in particular. This provided opportunities for sharing, reflection and critical discourse and thus helped to strengthen the theory-practice nexus that many teacher education researchers (Korthagen, 2001; Darling-Hammond, 2006; Loughran (2006) identify as essential. I also contributed to the discussion on a regular basis (at the end of each week) and used prompting questions in response to preservice teachers' postings to help strengthen the analytical component of the discourse.

The data from online discussions were downloaded and analysed for themes and evidence of increasing theory-practice knowledge.

5. Interviews with Practising teachers

Practising teacher participants were interviewed separately from one another and from preservice teachers towards the end of the partnership experience. This provided additional insight into the practising teachers' experiences as well as giving voice to their views on the partnership model.

A semi-structured interview format was adopted. This form of interviewing was selected for its balance between structured and unstructured interview features. Structured interviews tend to be surveys that are delivered orally. A pre-determined set of questions is developed and delivered in the same order with the same wording to all interviewees (Burns, 2000; Denzin & Lincoln, 2005; Wiersma, 2009). Responses tend to be limited to a few types of responses and open ended questions are not a common feature (Denzin & Lincoln). Unstructured interviews tend to provide depth of data (Denzin & Lincoln). They also offer participants an opportunity to share their story with minimal interruption by the researcher (Richards & Morse, 2007). Burns encourages the use of unstructured interviews when an individual's subjective experiences are sought and when the required information can not be directly observed by the researcher.

The nature of the data sought in this research is qualitative and the personal experiences and subjective voices of participants are sought in order to help create an understanding of the experiences of participants. For this reason, open-ended questions dominated the interview making the unstructured interview the predominant format applied. However, there was some focus needed because the experiences of particular aspects of the partnership model were required to answer the research questions. This means a set of guidelines to shape the interview was helpful to address different aspects of the partnership experience. This then took on some characteristics of the structured interview, where an overall, albeit general, format for the interview content was used for each participant. The overall format therefore fits the definition of semi-structured interview as offered by Lichtman (2006):

> This type of interview involves your developing a general set of questions and format that you follow and use on all participants. While the general structure is the same for all individuals being interviewed, the interviewer can vary questions as the situation demands (p. 118).

The interview questions used with practising teachers are listed in Appendix 5.

6. Reflection Booklets for Practising and preservice teacher Partnerships

Partners were asked to keep a planning and reflection booklet in which the joint planning, implementing and reflection required by the partners were to be documented. This booklet focused participants on the outer cycle of the ALACT model (Korthagen, 2001) being applied in the research design. Partners planned the lesson they were going to implement, highlighted the areas of curriculum to be integrated in the lesson, and documented areas of the lesson they felt concerned about due to lack of knowledge, experience, resources or other sources they wished to identify. After implementing the lesson participants were asked to reflect on ways in which they felt the lesson was successful and what they based these judgements on, aspects of the teaching and/or learning that concerned them and ideas for overcoming these concerns in future lessons. Each subsequent lesson also asked participants to identify any aspects of previous lessons that informed them in the most recent lesson planning and delivery, and how they influenced their practice.

The reflection booklet helped to provide the structure that contributed to a critical reflection on practice. This was designed to avoid the more descriptive approaches to reflection that Parson and Stephenson (2005) warn of. Questions in the booklet focused reflection on the use of the 5Es model addressing the theoretical components of the lesson, identification of an area(s) for improvement and action links to the next lesson in the cycle. As discussed, these components linking theory, practice and action-on-reflection are crucial for achieving critical reflection for professional learning.

These documents also present another form of data that are designed to provide insights into the shared voice of the practising and preservice teacher partners. The format of the booklet essentially makes it an open-ended questionnaire that is completed by participants regularly throughout the research period. A sample of the reflection and planning booklet is provided in Appendix 4.

A summary of each of the data collection methods is presented in Table 3.3.5. This table maps the data collection methods against the research questions and the participant cohort targeted for each method. The underpinning theoretical dimensions taken from the literature are also matched to each method.

Data collection methods were instigated at the initial participant workshop where the partners explored the 5Es framework, were introduced to the cycles of action-reflection, met their partners and began their planning. The results of the thinking hats activity from this workshop and other data collection methods are presented in the next chapter where they contribute to the exploration of the impact of collaborative partnerships for professional learning in primary science.

Table 3.3.5: Relationships between the Research Questions, Data Collection Methods and Underpinning Theory

Research Questions	Data Collection Methods	Participants	Underpinning Theory
1. What attitudes and levels of self-efficacy belief do preservice teachers have towards science before and after the partnership experience?	Questionnaires Thinking Hats Activity Round Table Discussions Reflection Booklets	Preservice Teachers	Attitudes and self-efficacy link to teaching decisions (Jones & Carter, 2007); Impact of mastery experience (Bandura, 1977); Reflective practice (Loughran, 2006).
2. What attitudes and levels of self-efficacy belief do practising primary school teachers have towards science before and after the partnership experience?	Questionnaires Thinking Hats Activity Reflection Booklets	Practising Teachers	Attitudes and self-efficacy link to teaching decisions (Jones & Carter, 2007); Impact of mastery experience (Bandura, 1977).
3. What are the effects of action-reflection in collaborative partnerships between practising and preservice teachers on knowledge, attitudes and self-efficacy beliefs of preservice teachers towards science education?	Semi-structured Interviews Round Table Discussion Online Discussion Final Workshop Activities	Preservice Teachers Practising Teachers	Building content and pedagogical knowledge in primary science professional learning (Abell, 2007; Ingvarson et al., 2005; Posnanski, 2002). Theory-practice nexus (Korthagen, 2001; Loughran, 2002). Benefits and challenges of collaboration (Levin & Rock, 2003). Call for collaboration in professional experience (Zeichner, 2001; Darling-Hammond, 2006).
4. What barriers are perceived to exist to increasing the priority of science in primary school classrooms?	Semi-structured Interviews Round Table Discussions Final Questionnaires	Preservice Teachers Practising teachers	Barriers to teaching science (Aikenhead, 2006; Appleton, 2003; Goodrum et al., 2001).

3.4 Data Analysis

In line with the theoretical and methodological framework of the study, an interpretative and descriptive approach was taken to data analysis. Analytical induction (Burns, 2000) was applied to the data emerging from online and round table discussions with preservice teachers and interviews with teachers. Averages were taken of the numerical data from the STEBI and self-assessed confidence levels associated with pre and post questionnaires. These were then used in a descriptive manner since sample sizes were too small for formal statistical analysis (Burns).

Analytic induction is a qualitative method for building up causal explanations of phenomena from a close examination of a small number of cases (Bernard & Ryan, 2010). It is similar to Richard's (2009) 'analytical coding' which she describes as "considering the meanings (of data) in context, and creating categories that express new ideas about the data, coding to gather and reflect on all the data related to them" (pp. 102-103).

Bernard and Ryan (2010) indicate that analytical induction is a powerful, qualitative method of data analysis but also warn that it is only accounts for data already collected and does not allow prediction of individual cases that might present in future. In spite of this, they highlight its effectiveness for providing understanding of a small number of cases that enables strong predictions about "aggregates of cases" (p. 332) that might arise. This makes the findings from analytical induction useful for general indications about large populations even though an individual case (or partnership in the case of the present study) may not respond as expected. This makes it similar to statistical induction (Bernard & Ryan). Its general lack of application beyond the data collected aligns the analytical approach with the credibility and dependability of case study data discussed previously.

In the present study, data were systematically examined and coded in initial categories of phenomena. This is consistent with Richards' (2009) description of analytical coding. It is also representative of other common descriptions of approaching qualitative data analysis, such as that stated by Miles and Huberman (1994) who list the "sorting and sifting" (p. 9) of data to "identify similar phrases, relationships between variables, patterns, themes, distinct differences between subgroups, and common sequences" (p. 9) as one of a set of processes involved in qualitative data analysis.

Initial themes, were guided by the particular questions posed in each setting (e.g. 'Describe the nature of your partnership' in interview questions and round table discussions) which allowed a starting point for the coding of themes. These themes were formed by physically cutting and arranging typed transcripts of each data set. This approach is "central to qualitative inquiry" (Richards, 2009, p. 96) as it "leads to the emergence of themes and theory affirmation" (p. 96). Because of this, Richards warns, it should never be automated. Sub-themes within themes arose from participants' responses.

These were key in the in-depth exploration of the ways in which the collaborative partnership impacted on participants and their learning. Gee's (1999) notion of 'activity building' that describes the use of "using cues or clues to assemble situated meanings about what activity or activities are going on, composed of what specific actions" (p. 86) help to determine this. His description of 'connection building' between data collected at intervals throughout the data collection period also helped provide information in regard to learning. In addition, Gee's discussion around 'semiotic building' which considers the relevance of the system and 'socio-cultural-situated identity, relationship building' and 'political building', particularly between practising and preservice teachers and the power relationships between them, helped to build an analysis of the meaning in the discourses arising from data collection methods.

Refinement of themes and creation of relevant sub-themes were performed as subsequent data were scanned, compared and categorised. Multiple passes of the data performed through a number of instances of revisiting the coded data (Richards, 2009) helped to ensure that related themes were connected appropriately, either by combining or separating initial themes, and honing the sub-themes created. This involved the initial data themes being reviewed and compared a number of times to ensure there was no overlap between them. In instances where overlap was evident, data reduction (Bernard & Ryan, 2010; Richards, 2009) was performed to reduce the number of relevant themes and/or sub-themes.

The revisiting of coded data was a natural part of the analysis process as themes established from the initial data set (preservice teacher round table discussions) were reviewed and refined as each subsequent set of data (online discussions, teacher interviews) were analysed and matched to help establish or refine themes. Some of the themes began to emerge as the data were being collected due to my participant status in the round table and online discussions, and as the interviewer. Themes were further formed in mind as the transcripts were being typed. I opted to be responsible for each of these stages of data collection and presentation to increase familiarity with the data in order to aid the analysis process. Finally, in the reading, re-reading and physical arrangement of raw data into thematic categories, did formal data analysis begin. Burns (2000) indicates that researchers should "reread their notes many times before they can begin to grasp major themes" (p. 288) and it is expected that completing data collection and preparation of transcripts would aid in capturing these themes more readily and in turn, aid the analytical induction method described by Burns.

Themes and sub-themes were arranged in a table with the supporting raw data and coded to enable easy reference to the initial data and to aid any checking of the context from which they arose, to better ensure appropriate meaning-making. These strategies collectively help to provide reliable and valid interpretation (Burns, 2000). From here, generalisations about the data were initialised. This beginning to form generalisations is one of the final steps of qualitative data analysis as described by Miles and Huberman (1994). Thinking Hat responses were coded according to the colour of the hat and an assigned number ranging from 1 through to the total number of responses for the particular hat being examined. For example the sixth response selected from the Yellow Hat responses was coded Y6. This helped trace the response back to its originating source once data from different sources were collated supporting the audit trail process required to help authenticate the data and reduce bias as is discussed further in the next section on limitations.

3.5 Limitations and Delimitations

This study has been delimited to a small cohort of students within the third year of a Bachelor of Education course studying Science Education in one regional university setting. This cohort matched the number of students required to form one tutorial group within the wider preservice teacher population for the unit concerned. This delimitation was implemented to limit the data collection to a manageable amount, and to address the issue of finding the required number of teachers and schools in which to place students.

Selection of practising teachers was also delimited to schools local to the same regional centre in which the university was located. This delimitation was put in place due to the competing demands the university timetable placed on preservice teacher participants who needed to be able to travel between placement schools and university on the same day.

The limited number of preservice teachers that could be managed in the research meant that a process for recruiting these participants from the wider preservice teacher cohort had to be considered. Ethical considerations required that this recruitment was conducted through a call for volunteers.

Practising teachers were also recruited through a volunteer process. The use of volunteers from both the preservice teacher cohort and practising teachers may bias the results of the study.

Sampling bias occurs “when a sample fails to represent the population it was intended to represent” (Wiersma 2009, p. 331). It is generally associated with samples that are non-randomly selected (Wiersma). The level of sampling bias is determined by an estimate of sampling error (Wiersma) which is the statistical measure of the difference or variation between the sample and the population it represents (Mertens, 2005). To minimise sampling error and thus bias, random sampling methods are recommended (Burns, 2000; Mertens, 2005; Wiersma, 2009).

The use of volunteers falls into the method of non-random, opportunistic sampling (Burns, 2000), or convenience sampling (Mertens, 2005), thus the risk of bias is generally considered high (Neuman, 2007). However, Burns indicates that this method of sampling may or may not produce biased results, an outcome that can never be determined with any certainty due to the lack of ability to estimate the sampling error. This is because the calculation of sampling error relies on the sample being selected in a random manner (Burns).

The present study adopts a non-random approach to sampling for a number of reasons. Firstly, in qualitative studies non-random sampling methods are generally used (Neuman, 2007), and they are particularly common in case study research (Burns, 2000; Yin, 1989). In addition, being a qualitative case study, the findings of the present study are not sought to be generalised to a larger population. This reduces the need for a random sample, whose purpose is to provide representative sampling in order to provide generalisablity (Neuman, 2007; Wiersma, 2009). Yin also highlights that the discussion around sampling design is inappropriate when considering case study design since case studies rely on analytical generalisation rather than the statistical generalisation that sampling designs are informed by. Finally, Mertens (2005) points out that due to ethical considerations, all research samples are effectively volunteers as participants elect to return/respond to data collection methods. Considering these points, the use of volunteers in the present study is valid and reliable as long as a conscious effort is maintained not to try to generalise the findings beyond the case.

As noted earlier, subjective bias is a particular concern in case study research (Burns, 2000) and thus presents another limitation of the present study. This is where the risk of selecting or ignoring particular results to support or refute findings must be kept in mind through out the analysis process. Constant and vigilant awareness of any biases I bring to the study were both kept in mind during analysis and discussion of results and an audit trail to authenticate the data collected and used was adopted to minimise the risk of this subjectivity. The multiple sources of data used to help identify themes also build trustworthiness.

External validity in the present study, which is linked to generalisability (Denzin & Lincoln, 2005; Mertens, 2005), was achieved through the strategies applied to ensure transferability of the research. The rich descriptions of data collection methods, findings and situations given provide the necessary tools for other researchers to transfer the findings to different settings and contexts.

3.6 Ethical Considerations

Ethical considerations identified with this study mainly surround the fact that the research was connected to a preservice teacher education unit that I also taught. Preservice teachers could have felt either advantaged or disadvantaged in their academic achievement due to their involvement, or lack thereof, in the school based alternative delivery of the unit. To overcome this it was essential to make involvement in the research voluntary. It was also essential that a pathway existed for students who wanted to withdraw their participation once the data collection period had begun without jeopardising their chances of passing the unit. Consequently, I designed the unit to ensure that such a pathway existed.

There were a total of 76 students in the science education unit tagged to this study. Of these, only 13 volunteered to be involved. Both cohorts of students within the unit had to satisfy the same learning outcomes and had to be assessed using the same assessment criteria. This meant the design of the assessment in the unit had to meet the needs of both cohorts and their unique learning experiences. This was achieved by tagging the school-based experience of the research cohort of preservice teachers to an assessment task that required them to submit a detailed lesson plan and reflection on one of the lessons they taught in schools. Non-research preservice teachers worked in small groups to plan, implement and reflect on a micro-teaching experience that was conducted in tutorial time. Assessment for each cohort of students focussed on their planning, explanation of the 5Es utilised in their lesson and reflection on the experience. Neither cohort was assessed on their teaching performance *per se*. this meant that while the research cohort were in schools, the non-research cohort were involved in the micro-teaching experience. At any time, research participants could have opted out and still satisfied the assessment in the unit.

In addition to planning the assessment to ensure a pathway existed for preservice teachers to opt out, the weekly schedule for both cohorts was also designed so as not to disadvantage either group, and to allow easy transition from the research to the non-research cohort if a preservice teacher opted out of the project. This is reflected in Table 3.6.1 which shows the tutorial schedule for each cohort. Both cohorts attended the same lecture for the duration of the unit.

Table 3.6.1: Science Education Unit Tutorial schedule

STUDY WEEK	RESEARCH PARTICIPANTS	NON-RESEARCH PARTICIPANTS
1	Mad Hatter’s Tea Party – fair testing	Mad Hatter’s Tea Party – fair testing
2	Technology – design brief	Technology – design brief
3	Preparing for School Experience: Constructivism 5Es SiS Model of reflection - Meeting teachers.	Preparing for Micro-Teaching: Constructivism 5Es SiS
4	Discovery Learning in Sci – Magnetism & Electricity	Discovery Learning in Sci – Magnetism & Electricity
5	Excursion Time School Placement	Excursion Time
6	School Placement	Lesson Presentations –Micro teaching
7	School Placement	Lesson Presentations –Micro teaching
8	School Placement	Lesson Presentations –Micro teaching
9	Week 9: Round Table 1 School Placement	Lesson Presentations –Micro teaching
10	Global Ed School Placement	Global Ed
11	School Placement	Lesson Presentations –Micro teaching
12	Round Table 2 & Debriefing	Lesson Presentations –Micro teaching

Table 3.6.1 demonstrates that the program for each cohort is quite similar. This was planned to ensure that the experiences were similar enough to enable common assessment and achievement of the common learning outcomes in the unit, a requirement of the university. This also means that

students who want to opt out of the research model could do so without jeopardising their chances of successfully completing the unit, a requirement of the research ethics.

The only significant difference is in the teaching experience for each cohort. The research group will gain more teaching experience by working in schools with a collaborative practicing teacher partner for a number of weeks where as the non-research participants will work in a small group of their peers to plan and present one lesson in a micro-teaching experience for the rest of their tutorial group. The context of this teaching experience was just more authentic for those who completed it in the science classroom than for those who were involved in micro-teaching to their peers.

A further concern may have arisen if students felt advantaged or disadvantaged depending on whether or not they volunteered. I can only provide assurance that a decision to volunteer or not did not in any way affect preservice teachers' treatment or opportunity to excel in their chosen mode of study for the unit.

Only one tutorial group out of three for this unit participated in the school-based mode of delivery. This resulted in research participants being easily identifiable. Confidentiality was, and will continue to be, protected in reporting on results. The study was approved by the university research ethics committee (Human Research Ethics Committee [HREC] Registration Code: V200607 74).

3.7 Participants in the Study

This study explored collaborative partnerships between practicing and preservice primary teachers as a model of professional learning in primary science education. Participants were selected from practicing primary teachers in a regional town of Victoria, Australia and from a local university in the same regional setting. Practising and preservice teachers were placed in partnership groups for the project. Participants and partnerships are described below.

Preservice Teacher Participants

Volunteer preservice teachers from a third year Bachelor of Education core Science Education unit were called for prior to the beginning of the semester of study. The unit was explained as being offered in a research and a non-research mode of study. The research model and the structure of the assessment for each group were explained to the entire cohort of students before volunteers were called for. Those interested in studying the unit in the research mode were then asked to make contact via email or a sign-up list that was made available for a two-week period.

A total of 54 preservice teachers studied the Science Education unit in the period of data collection. A total of 13 (24%) preservice teachers from the student cohort elected to complete the unit in the research mode. Although there were 11 (20%) male students in the total cohort studying this unit, all of the volunteers for the research mode of completing the unit were female. Eleven (85%) of these volunteers entered the Bachelor of Education course straight after Year 12, the final year of secondary schooling. Two were mature age students, aged 34 and 31, and both had families of more than one child. One participant was 21 years old and the remaining ten students were all aged 20 years.

The research participants attended all lectures for the unit, but some of the tutorial time was given in lieu of time spent working in schools in their collaborative partnership with a practising teacher. Their overall program consisted of six weeks of science education tutorials and six weeks of partnership collaboration working in schools, plus twelve concurrent weeks of lectures. Preservice teachers were required to attend two tutorial sessions in addition to the partnership collaboration during the partnership period. This is when round table discussions were conducted.

The experiences of the research and non-research preservice teachers were planned to ensure enough similarity to enable common assessment and achievement of the common learning outcomes in the unit, a requirement of the university. This also meant that students who wanted to withdraw from of the research model could do so without jeopardising their chances of successfully completing the unit, a requirement of the research ethics. The main difference between the groups was that the research cohort gained its teaching experience by working with practising teachers in their classrooms. The non-research cohort was engaged in micro-teaching experiences in peer groups which were delivered in tutorials over the same six week period the research participants were involved in collaborative partnerships. While mastery experience was still possible for the non-research group, it was not as strong or frequent as the mastery experience of those in the research group, due to the limitations of time in the semester and the simulated nature of the micro-teaching experience (Stajkovic & Luthans, 1998).

Practising teacher Participants

Practising teachers were recruited through consultation with the Catholic Education and Department of Education Offices in the regional setting. With the permission of each of these organisations, schools were approached by telephoning school principals. A brief outline of the project was given and if further interest was expressed, a follow up email was sent with additional information. These emails were sent in a letter format and are presented in Appendix 2. An education consultant from the Catholic Education Office (CEO) also assisted in recruiting practising teachers, a strategy suggested by the CEO.

A total of eight teachers was recruited, three teachers from two different Catholic schools and five teachers from four different government schools. Of these, two (25%) were male and six (75%) were female. Overall it was difficult to find teachers who were willing to be involved. Awkward timing between the university and school semesters made for a late start in contacting and following up schools, which may have been a factor in the recruitment of only a small number of teachers. Science education is often not a priority area for professional learning in primary schools and this may also have been a factor contributing to the recruitment difficulty.

It is unknown what level of coercion versus volunteering was experienced by some of the practising teacher participants. It is known that two of the teachers came to the project after being identified and approached by their principals, and one teacher was recruited by one of the preservice teacher participants stemming from a classroom helping relationship already established between them. Two other teachers' names were given by the principal for direct contact and both of them agreed to be involved once the project had been outlined to them. One further teacher was approached directly at my own children's school, although there was no previous relationship with the particular teacher concerned. It is not known how individual principals informed and recruited the other two practising teachers who became involved.

The Collaborative Partnerships

A number of strategies for forming and supporting practising and preservice teacher partnerships that were collaborative rather than just cooperative were informed, in particular, by Levin and Rock (2003). Partnerships were required to participate in a collaborative manner to plan, implement and reflect on a series of science lessons, integrating other areas of the curriculum where possible. An action-reflection cycle was introduced to assist partners to reflect on successful moments and areas needing improvement which was anticipated would inform further planning in their teaching sequence. This helped to provide the structural framework that Russell (2005) and Parsons and Stephenson (2005) indicate is necessary, particularly for beginning teachers/reflective practitioners. This also ensured opportunities for mastery experiences (Bandura, 1977) for practising and preservice teachers were available. As mastery experiences were set in the classrooms of practising teacher participants, the impact on practising teachers would were expected to be significant according to Jones and Carter (2007), who indicate that teachers' belief in particular strategies is determined by their ability to witness success in their own classrooms.

Other strategies informed by the literature were strongly linked to Levin and Rock's (2003) guidelines for engaging practising and preservice teachers in collaborative action research (see Figure 2.1.1 in Chapter 2). Given that the present study is concerned with collaboration but not with action research *per se*, those guidelines pertaining to the formation of effective collaboration were selected from Levin and Rock's set for use in establishing partnerships in this study. Levin and Rock's guidelines are written specifically for collaborative partnerships in action research projects. Partnerships in the present study were involved in action-reflection cycles where reflection on action informed aspects of the next planning, implementing and reflecting cycle, but there was not an overarching action research question being investigated and responded to as true action research would require. This means that while there are parallels between action research and the present study, it is not action research *per se*. However, Levin and Rock's guidelines are still applicable to some extent as they highlight strategies that best contribute to the formation of collaboration between preservice and practising teachers which is the main feature underpinning the research in the present study.

For example, Guideline 2 states "Increase ownership and accountability of experienced teachers by setting up informal group presentations and/or formal school presentations of action research projects; in other words, provide a wider audience for sharing and disseminating the results of action research" (p. 148). This was achieved by requiring partnerships to develop a short presentation on their partnership experience in the final participant workshop.

Guideline 3: "Establish ways for experienced teachers to receive credit for their efforts by earning professional development or renewal credits from their district, or by earning university credit" (p. 148) was acknowledge by providing professional learning certificates signed by the university and a Catholic Education officer crediting practising teachers with six hours of professional learning time which could be used towards teacher registration renewal. Guideline 6: "Encourage data collection strategies that include information gathered from students' perspectives … because collecting data from students (e.g., individual interviews, class surveys, student work samples) provides valuable knowledge about students, which appears to help both preservice and experienced teachers focus (or refocus) on students' needs in the classroom" (p. 148), was addressed by asking partners to collect work samples to use in their final presentation to help demonstrate the application of 5Es in the teaching partnership and the response and achievement of children during this time.

The remainder of Levin and Rock's (2003) guidelines for achieving collaborative partnerships were also reflected in the design of the partnership tasks in the present study. Guideline 1: "Provide both preservice and experienced teachers adequate training, and, if possible, give preservice teachers prior experience with action research before they complete a collaborative action research project" (p. 148), was reflected in the initial participant workshop where the 5Es framework was introduced, explored and exemplified. Their fourth guideline: "Allow action research questions to emerge from the interests and concerns of the experienced veteran teachers and the preservice teachers and not solely from the university's agenda" (p. 148), was acknowledged by enabling individual partners to select their topics for teaching as suited to the school's needs and the partners' interests. Finally, Guideline 5 states: "Give adequate time and support to the question formulation period and to discussion and assessment of the value and practicality of the action research questions posed …" (p. 148). This was addressed by providing time at the initial participant workshop for partners to discuss their interests and to receive feedback from other partners and myself about their ideas, particularly in regard to resources that might be required and the feasibility of accessing these.

From the practising and preservice teachers recruited, partnerships were established consisting of either one preservice teacher and one practising teacher or two preservice teachers and one practising teacher. As there were only eight teachers and thirteen preservice teachers, the one-to-one partnerships intended for the project could not be fully realised and the contingency plan of partnering two preservice teachers with one practising teacher had to be implemented in five cases. Some partners were matched on the basis of information preservice teachers had provided. For example, the preservice teacher and the practising teacher she recruited using their established relationship, were partnered together. One preservice teacher indicated she would prefer to work on her own with a practising teacher rather than in a partnership of three, so this was taken into consideration. The remainder of the partnerships were formed on a random basis. This involved pulling names out of a hat and matching preservice and practising teachers in this manner.

In each of the situations where two preservice teachers were partnered with a practising teacher, the practising teachers was asked if he/she would be happy to work as a small team rather than as a pair, and all expressed their willingness to do so. This resulted in a total of eight collaborative partnerships, three of which consisted of one preservice teacher and one practising teacher and five consisting of two preservice teachers and one practising teacher. Partners' names and schools have been coded to protect confidentiality and are listed in Table 3.7.1. Coding of names reflects gender of the individuals involved. Practising teachers are also referred to by their title to help distinguish them from preservice teachers. Catholic schools are denoted by a 'St.' in front of their code name.

A description of each partnership and some of the background data provided by their partner members on their respective initial questionnaires are then detailed below.

Table 3.7.1: Collaborative Partnerships and Schools

PARTNER-SHIP	SCHOOL	PRACTISING TEACHER	PRESERVICE TEACHER 1	PRESERVICE TEACHER 2
1	Europium Primary	Ms Marie Curie	Anita Roberts	
2	St. Praseodymium Primary	Ms Rosalind Franklin	Barbara McClintock	
3	St. Neodymium Primary	Ms Dianne Fossey	Jocelyn Burnell	
4	St. Neodymium Primary	Ms Jane Goodall	Gertrude Elion	Helen Dunbar
5	Samarium Primary	Ms Annie Easley	Rachel Zimmerman	Gerty Cori
6	Cerium Primary	Ms Virginia Apgar	Maria Mayer	Grace Hooper
7	Promethium Primary	Mr John Dalton	Lise Meitner	Dorothy Hodgkin
8	Promethium Primary	Mr Robert Boyle	Linda Buck	Rachel Carson

Partnership 1

Partnership 1 took place at Europium Primary school and involved a female practising teacher, Ms Marie Curie, and preservice teacher Anita Roberts teaching a composite Grade 1/2 class. Ms

Curie self-identified as having low to average confidence in science in her interview. She was in her first year of teaching and had never taught science before. She dropped high school science after Year 10 and had not engaged in any under-graduate or post-graduate science other than that in her Bachelor of Education course. Ms Curie reported having been involved in one two-hour professional learning workshop for science since becoming employed. She reported that there was a Science Coordinator at Europium primary school and a science-specific budget. Science was however, not reported to parents as a part of the school reporting system. Ms Curie was unable to attend the initial partnership workshop and did not return the initial questionnaire provided to her. Consequently the questions regarding background information presented here were attached to her final questionnaire.

The preservice teacher Anita Roberts had an established working relationship with Ms Curie as a classroom helper, mainly in the area of numeracy, in which she had been involved since Term 2 of the school year. It was Anita who approached Ms Curie and asked if she would be willing to participate in this project. On the initial questionnaire Anita self-identified as having average confidence in science and had studied Biology and Chemistry up to a Year 12 level. She indicated that she had never taught science on any of her previous professional experience rounds. Anita reported that she hoped to obtain different approaches to science, new ideas and experiments, an ability to motivate students through science and to increase her confidence to teach science by being involved in this project (Anita Roberts, Initial Questionnaire).

Partnership 2

The second partnership involved Ms Rosalind Franklin, another first year teacher, and preservice teacher Barbara McClintock at Catholic primary school St Praseodymium, with a Grade 3 class. Ms Franklin rated her confidence to be at an average level. She reported never having seen science taught before, but had spent two hours per week on it with her class for just the one term of the school year. Ms Franklin studied science up to Year 10 of secondary school and had been involved in a previous two hour workshop for science since becoming employed as a teacher. Ms Franklin reported that there was no Science Coordinator at St. Praseodymium and whilst there was no science-specific budget, she did have access to some funds if required. Science was not a part of the school reports sent home to parents at St Praseodymium, and Ms Franklin had not applied the 5Es framework in science teaching prior to this project (Ms Rosalind Franklin, Initial Questionnaire).

Preservice teacher Barbara McClintock partnered Ms Franklin in this project. Barbara reported having an average level of confidence in teaching Biological Science and a slightly above average confidence in Chemical and Physical Science. Her confidence in teaching Earth and Space Science was Medium-High. Barbara studied Psychology to Year 12 in secondary school and had taught two lessons of science on previous professional experience rounds (Barbara McClintock, Initial Questionnaire).

Partnership 3

Practising teacher Ms Diane Fossey and preservice teacher Jocelyn Burnell made up the third partnership at St. Neodymium Primary School. They taught a composite class of Grade 5/6. Ms Fossey did not attend the initial participant workshop and did not return the initial questionnaire provided during the one-on-one meeting held with her to introduce the project. Ms Fossey did state in her interview however that she avoids teaching science as she was not ‘very sciencey’ (Interview with Ms Diane Fossey).

Jocelyn Burnell, the preservice teacher partnered with Ms Fossey, identified her confidence to teach science at an average level for Chemical and Physical Science and a medium-low level for Biological and Earth and Space Science. Jocelyn reported that she studied science to the end of Year 10 in secondary school and indicated that she had never taught science on previous professional experience placements (Jocelyn Burnell, Initial Questionnaire).

Partnership 4

Partnership 4 was also based at St. Neodymium and consisted of experienced teacher of 20+ years, Ms Jane Goodall, and preservice teachers Gertrude Elion and Helen Dunbar. This partnership worked in a composite Grade 3/4 classroom. Ms Goodall did not attend the initial workshop or return the initial questionnaire. As with Ms Curie, some of the background questions were attached to Ms Goodall’s final questionnaire in order to gather background data presented here. Ms Goodall reported having completed an elective unit on Environmental Education as a part of her Bachelor of Education and studied science to a Year 9 level at secondary school. There was a Science Coordinator at St. Neodymium and access to some funds if required, but no science-specific budget. She also reported that St. Neodymium included science as a part of their reporting home to parents. Whilst Ms Goodall did not nominate a time that she spent teaching science on her questionnaire, she did report that she 'likes science and makes sure we have it a couple of times a week' (Interview with Ms Jane Goodall). She did not provide a self-rating of her initial confidence levels because she did not return her initial questionnaire, but she did report that she had not applied the 5Es framework to science teaching prior to this project (Ms Jane Goodall, Final Questionnaire).

Ms Goodall worked with preservice teachers Gertrude Elion and Helen Dunbar. Gertrude identified her confidence in teaching science at a medium low level in Biological and Physical Science and a low level in Chemical and Earth and Space Science. She studied science in secondary school up to the end of Year 10 and had taught two lessons of science on previous professional experience rounds (Gertrude Elion, Initial Questionnaire).

Helen reported her confidence levels to be average in Biological and Chemical Science, just below average in Physical Science and just above average in Earth and Space Science. She studied Biology in her Year 12 of secondary schooling and completed a minor science elective in the first and second years of her Bachelor of Education. Helen reported having four lessons' previous experience teaching science on professional experience rounds (Helen Dunbar, Initial Questionnaire).

Partnership 5

At Samarium Primary school, experienced teacher of 34 years, Ms Annie Easley, worked with two preservice teachers Gerty Cori and Rachel Zimmerman in Partnership 5. They had a class of Grade 1/2 who came to science with Ms Easley while their classroom teacher had planning release time. Ms Easley saw herself as having quite high levels of confidence in teaching science with Biological Science rated Very High, Chemical and Physical Science as High, and Earth and Space Science as Medium-High. In addition, Ms Easley had spent some of her career offering professional learning workshops to other primary teachers in science education as what she describes as a provider, creator, facilitator and participant in a Digital Discussion Network State-wide Primary Science in the role of moderator. Ms Easley reported spending approximately one hour per week teaching science and she was the coordinator of science in the school. She had both a science-specific budget and access to further funds if required. Science was a part of the reporting system to parents and Ms Easley had implemented the 5Es framework in previous science teaching. She also had a Certificate level qualification in science in addition to her teaching qualifications (Ms Annie Easley, Initial Questionnaire). This range of experiences set her apart from most of the other practising teachers.

Preservice teacher Gerty Cori had no previous experience in taking a science lesson but reported an average to high confidence in her ability to teach it. Specifically, she felt a high confidence to teach Biological Science and a medium-high level of confidence in Chemical, Physical and Earth and Space Science. Gerty completed a minor in behavioural science as a part of her under-graduate studies and had studied Biology in Year 12 of her secondary schooling (Gerty Cori, Initial Questionnaire).

Rachel Zimmerman also indicated an average to high level of confidence to teach science with Very High rating for Biological Science, High for Earth and Space and just above Medium for Chemical and Physical Science. She completed Psychology in Year 12 of secondary school and studied a minor in Behavioural Science as a part of her Bachelor of Education. Rachel reported having one to two previous lessons of experience teaching science (Rachel Zimmerman, Initial Questionnaire).

Partnership 6

Partnership 6 involved another experienced practising teacher in Ms Virginia Apgar, who taught a Grade 5/6 class. Ms Apgar had been teaching for 23 years and in that time had only participated in a single two-hour workshop as a part of science professional learning. She studied science until Year 12 in secondary school and qualified for teaching through a Bachelor of Science (Education). Ms Apgar reported that there was no Science Co-ordinator at her school and no science-specific budget, although she could access funds for science if required. Science was due to be included in reporting home to parents for the first time in 2008 at Cerium Primary school. Ms Apgar indentified her confidence levels in teaching science as High for Physical Science and Very High for Biological, Chemical and Earth and Space Science. She reported spending approximately one hour teaching science each week but had never used the 5Es framework (Ms Virginia Apgar, Initial Questionnaire).

Preservice teacher Maria Mayar, reported a medium-high level of confidence across all areas of science and indicated that she had one to two previous lessons of experience teaching science. Maria was a mature-aged student who had been employed in childcare and family duties prior to her enrolment in the course. She had studied science to Year 12 at secondary school (Maria Mayar, Initial Questionnaire).

Preservice teacher Grace Hooper, was also a mature aged student but unfortunately did not return the initial questionnaire to provide data on her previous experience and initial confidence in teaching science.

Partnership 7

Partnership 7 was based at Promethium Primary school with a male practising teacher, Mr John Dalton, who was in his fourth year of teaching. Mr Dalton had a Grade 5/6 class and was about to take over the Science Coordination in the school. He rated his confidence as Very High for Biological and Earth and Space Science, Medium-High for Physical Science and Medium for Chemical Science. Mr Dalton had studied science through to the end of Year 12 in his own secondary schooling. He reported that he spent approximately one hour per week teaching science but had never applied the 5Es framework to science teaching prior to this project. He indicated that the school had a science-specific budget and that science was a part of the reporting home to parents. Mr Dalton had also attended a full day workshop dedicated to science professional learning in the past (Mr John Dalton, Initial Questionnaire).

Mr Dalton worked with two preservice teachers, Lise Meitner and Dorothy Hodgkin. Lise rated her confidence at the average level for Biological and Earth and Space Science and just below average for Chemical and Physical Science. She had studied Biology until the end of Year 12 and had never taught science in previous professional experience rounds (Lise Meitner, Initial Questionnaire).

Dorothy also reported having no prior experience in teaching a science lesson and her confidence levels were slightly below those of Lise. She reported a low level of confidence in Chemical Science and just below average for Biological, Physical and Earth and Space Science. She had studied science to the end of Year 10 in her secondary schooling (Dorothy Hodgkin, Initial Questionnaire).

Partnership 8

A second teacher from Promethium Primary, Mr Robert Boyle, also participated in the project with his Grade 2 class. Mr Boyle had been teaching for eight years and had been the Science Co-ordinator up until the previous year. He rated his confidence in teaching science as High in Chemical Science and Very High in Biological, Earth and Space and Physical Science. He indicated that he taught science for approximately three hours each week but had never applied the 5Es framework to his science teaching. Mr Boyle had studied science until the end of Year 11 at secondary school and reported having attended a two-hour professional learning workshop in science since becoming a teacher. Promethium Primary had a science-specific budget and included science in teachers' reporting home to parents. Mr Boyle also reported having been recently involved in tutoring in a science education unit of a preservice teacher education course on a casual basis (Mr Robert Boyle, Initial Questionnaire).

Mr Boyle worked with two preservice teachers, Linda Buck and Rachel Carson. Linda reported her confidence levels to be at the average level in Biological and Physical Science, Medium-Low in Chemical Science and Medium-High in Earth and Space Science. She had studied science to the end of Year 9 in her secondary schooling and had never taught science in previous professional experience rounds (Linda Buck, Initial Questionnaire).

Rachel's confidence levels were at a low to very low level across all areas of science in spite of having studied science to the end of Year 11 in her secondary schooling. She also indicated having had six lessons of previous experience teaching science on rounds (Rachel Carson, Initial Questionnaire).

Partnerships Summary

A summary of the partnerships is provided in Table 3.7.2. This shows the range in age and experience of the practising teacher participants, the range in year levels of children involved and a summary of the self-assessed confidence levels of individual participants within each partnership. Ages of practising teachers ranged from late twenties to early sixties, and their experience as qualified teachers ranged from 1st year to 34 years. Confidence of participants within partnerships was reasonably well matched. It was interesting to note the levels of similarity in the resulting partners' self-assessed confidence in teaching science despite the random assigning that had occurred. The most significant exception to this was in Partnership 8 where the practising teacher had a very high self-assessed confidence compared to the medium and low self-ratings of the preservice teacher partners.

There were two cases where the data were not available (denoted NA in Table 3.7.2) which occurred when the participants did not return the relevant questionnaire. Otherwise the confidence levels ranged between the partnerships, although few participants marked the extremes (Very High or Very Low) so confidence tended to vary from medium high to medium low in most cases. The use of a categorical, ordinal scale such as this one lends itself to the difficulty recognised by Foddy (1993) where he describes the manner in which respondents select their responses on a categorical, ordinal scale: “the tendency for respondents to choose central response options rather than extreme ones” (p. 167). This may be a contributing factor to the self-rating exercise performed in this questionnaire and thus providing a condensed range of confidence level results.

Table 3.7.2: Partnerships Initial Summary Information

Partnership No.	School	Year Level of Class	Practising teacher	Teacher Age	Years Experience	Preservice Teacher(s)	Preservice Teacher Age(s)	Summary of Confidence Level: Practising teacher	Summary of Confidence Level: Preservice Teacher
1	Europium Primary	1/2	Ms Marie Curie	27	1	Anita Roberts	20	Low - Average	Average
2	St Praseodymium Primary	3	Ms Rosalind Franklin	28	1	Barbara McClintock	20	Average	Average
3	St Neodymium Primary	5/6	Ms Diane Fossey	NA	NA	Jocelyn Burnell	20	NA	Low-Average
4	St Neodymium Primary	3/4	Ms Jane Goodall	49	20+	Gertrude Elion Helen Dunbar	20 20	NA	Medium-Low Average
5	Samarium Primary	1/2	Ms Annie Easley	60	34	Gerty Cori Rachel Zimmerman	20 21	High	Medium-High Medium-High
6	Cerium Primary	5/6	Ms Virginia Apgar	44	23	Maria Mayar Grace Hooper	34 31	Very High	Medium-High NA
7	Promethium Primary	5/6	Mr John Dalton	27	4	Lise Meitner Dorothy Hodgkin	20 20	Average to Very High	Average Medium-Low
8	Promethium Primary	2	Mr Robert Boyle	42	8	Linda Buck Rachel Carson	20 20	Very High	Average Low

CHAPTER 4: RESULTS AND ANALYSIS

The human being who is a teacher has a way of being that is uniquely hers as a teacher

(Feldman, 2002, p. 1039)

4.1 Introduction

The previous chapter described the various data collection methods and their theoretical underpinnings. In this chapter, the results from each of the data collection methods are reported and analysed. Results from practising teacher interviews and questionnaires, and preservice teacher round table and online discussions, and questionnaires, are analysed alongside responses to relevant participant workshop activities. The results from each of these methods are used to establish key themes in the partnership experience to help address the overarching research question:

What is the impact of collaborative partnerships between preservice and practising teachers, using a model of critical reflection for action, on the knowledge, attitudes and self-efficacy beliefs of teachers towards teaching and learning of science in primary schools?

Each of the results sections is aimed at particular components of the overarching research question. These components were considered by the four sub-questions which served as the key research questions to be investigated in order to answer the overarching research question.

1. What attitudes and levels of self-efficacy belief do preservice teachers have towards science before and after formal science education studies?

2. What attitudes and levels of self-efficacy belief do practicing primary school teachers have towards science?

3. What are the effects of action-reflection in collaborative partnerships between practising and preservice teachers on knowledge, attitudes and self-efficacy belief of preservice teachers towards science education?

4. What barriers are perceived to exist to increasing the priority of science in primary school classrooms?

In order to best address the research sub-questions, the sections of this chapter have been selected to align data with areas relating to the questions. In particular, Section 4.2 establishes themes associated with the participants' attitudes towards science and Section 4.3 explores the data relating to levels of self-efficacy beliefs of practising and preservice teachers before and after the partnership experience. Together, these two sections provide the data necessary to answer research sub-question 1 and 2. These data stem from a range of sources including initial and final questionnaires, responses to De Bono's thinking hats activity in the initial participant workshop, interviews and round table and online discussions. Single case study analysis is adopted as the efficacy levels of the practising and preservice teacher case study cohorts are examined.

In Section 4.4 the data describing the nature of the partnerships are reviewed to determine the level of collaboration participants experienced. In Section 4.5 the development of knowledge is considered in terms of general content knowledge and pedagogical content knowledge. Data from round table and online discussions, teacher interviews, and the final participant workshop help the exploration of knowledge development. The benefits of the partnership model and its challenges and weaknesses are considered in sections 4.6 and 4.7 respectively. These then lead to Section 4.8 where participants' recommendations for improving the partnership model to strengthen science teacher education and professional learning opportunities are considered. Each of these aspects of data collection will aid the exploration of the effects of the collaborative partnerships and consequently help to answer research sub-question 3.

Section 4.9 explores the barriers preservice and practising teachers perceive to teaching science thus providing data to address the final research sub-question. Questionnaire data and responses from the final participant workshop are used to explore participants' intention to teach science and the barriers they feel that impede them in teaching science in this section. Finally, the set of results are summarised in Section 4.10.

The rich, broad sources of data have afforded the opportunity to analyse and reflect on results in detail which has created a lengthy results chapter. This however, was necessary to build a rich and thorough picture of as many aspects of the partnership model as possible in order to create the necessary credibility and trustworthiness discussed in Chapter 3.

4.2: Participants' Attitudes towards Science

This section explores the data associated with practising and preservice teachers' attitudes towards science. This is an important component of the results due to the links between attitudes and efficacy beliefs, and the subsequent likelihood of teachers overcoming perceived barriers and improving their selection of teaching strategies. These ideas are important in the field of science education where there are significant concerns with teachers' background knowledge and confidence to teach science and the approaches they consequently select when they do have to teach it. Data from De Bono's thinking hats activity and responses in the initial and final questionnaire are reported here to evaluate participants' science attitudes and self-efficacy beliefs. The relevant data supporting each of these areas is interpreted below.

Participants' initial attitudes towards science emerged primarily through initial activities in the data collection period including the De Bono's thinking hats activity in the initial participant workshop and through open responses on the initial questionnaires. Whilst not necessarily designed to elucidate participant attitudes towards science, the responses provided in the thinking hats activities did in fact contribute to a sense of participants' attitudes towards science.

There was a number of benefits recognised for including science in the primary school curriculum from the responses obtained from Yellow Hat (Benefits) thinking. These included the hands on/practical benefits of science which emerged from responses like '*Can be very practical and therefore engaging'* (Thinking Hats Y3) and '*Hands on experience'* (Thinking Hats Y1), revealing a belief in the benefit of hands on learning and the ability to achieve this through science. A category emerged associated with how science allows for development of awareness of the world. It was defined by comments such as '*Understanding the world around them'* (Thinking Hats Y11), '*Teaching about the world*' (Thinking Hats Y13) and '*Understand how and why things work'* (Thinking Hats Y16). This was the strongest category to emerge with 30% of the19 participant responses and again indicated a positive attitude towards science and its ability to provide relevance in learning through the links to the world. Participants also acknowledged the potential for science to encourage thinking and provide student engagement. These categories were exemplified by the respective comments '*Makes children think why*' (Thinking Hats Y8) and '*Encouraging engagement'* (Thinking Hats Y6). A number of other general benefits of science included the responses: '*Inspire students'* (Thinking Hats Y17); '*Develops the whole child*' (Thinking Hats Y18); '*Gives kids a broad experience'* (Thinking Hats Y19) and '*Informative and beneficial'* (Thinking Hats Y20).

Together, these responses provided a sense that the general attitude of participants towards science was positive. There appeared to be a strong awareness of the potential for science to link to children's lives and interests and an overall belief that science is an important component of the curriculum. This comes through in particular from comments associated with the benefit of science to encourage thinking (20% of responses); develop awareness of their world (30% of responses) and the array of responses linking to the breadth of experience, development of the whole child and informative and beneficial nature of science curriculum falling in the general benefits category.

Some of the Black Hat (Concerns) thinking also suggested a positive attitude towards science and its place in the primary curriculum. To address Black Hat thinking, participants were asked to identify their concerns about science teaching. Among the responses, again positive attitudes towards science were gleaned. This occurred through the responses: '*That it is not done often enough or in an effective way*' (Thinking Hat B16), '*Not all teachers do it'* (Thinking Hat B17) and '*Little real science happening'* (Thinking Hat B18). These comments indicated a concern both about the frequency of science and the nature of science being taught in the primary school setting, which in turn suggested a positive attitude about the importance of science being taught often and taught well.

In the latter part of the initial participant workshop, practising and preservice teacher partners were introduced to one another and planning of topics for units began. There appeared to be a lot of positive energy in the group during this planning session. A number of ideas for unit themes and individual lessons were discussed and checked with each other and with myself. The apparent enthusiasm of participants in this session reflected positively on the attitude in the room towards the project.

In addition to this, responses on the initial questionnaire and in interviews helped to explore initial attitudes of all participants towards science, confirming that, in general, a positive attitude existed when it came to participants' attitudes about the importance of science in the primary school curriculum. This evidence emerged from some of the responses provided to the question on the initial questionnaire asking: '*What are you hoping to achieve through your involvement in this project?'* Practising teachers in particular revealed some of their attitudinal thinking in response to this question. A desire to increase children's understanding of and exposure to science came through from three of the eight practising teachers with comments such as '*Good for my kids to experience different approaches to science*' (Mr Robert Boyle, Initial Questionnaire) and '*a collegial opportunity to enrich the students' science program*' (Ms Jane Goodall, Interview).

Two of the practising teachers commented on their desire to assist preservice teachers in developing science knowledge and confidence with comments such as: '*Assist preservice teacher in gaining confidence and competence in teaching science lessons'* (Mr John Dalton, Initial Questionnaire). Ms Annie Easley reported her belief that the project provided '*a reason to indulge in a science area/topic'* (Initial Questionnaire). Each of these types of comments suggested that the respondents believed science was an important component of the curriculum and that it is important to build experiences of science learning for children and for science teaching for preservice teachers.

Preservice teachers also demonstrated positive attitudes towards science. This was suggested through their indicated desire to increase their knowledge in science and their confidence to teach it through comments such as:

> *Mainly I am hoping to increase my confidence in teaching science so that I will willingly and enthusiastically teach science in my classroom in the future.*
> (Gertrude Elion, Initial Questionnaire)

> *I hope I will become much more confident in teaching science to children … I think teaching science is an important aspect of primary education.*
> (Helen Dunbar, Initial Questionnaire)

Comments akin to these were included in all twelve of the returned preservice teachers' initial questionnaire. Although these comments depicted a state of generally low confidence levels, the strong desire for increasing confidence in order to teach science indicated that preservice teachers felt it was important to include science in the curriculum and to teach it effectively, which in turn suggests that their attitudes towards science and its place in the primary curriculum were positive, even if they were doubtful of their abilities to achieve it.

Throughout the project experience, participants contributed a number of comments that demonstrated an enhancement of these initial positive attitudes towards science. This was evident for preservice teachers primarily through their responses to the question, '*Has your involvement in this project influenced the frequency with which you intend to teach science once in schools? If so, how?'*, which was in the open response section of their final questionnaire. Each of the twelve preservice teachers who returned the final questionnaire indicated that their experience in the project had influenced their intention to teach science frequently once they were in schools. The range of reasons they provided for this intention collectively shaped their overall attitude to science, which was strengthened through their experience of teaching science and the results they obtained. Most significant in contributing to this enhanced attitude was the response children had to science, something that they were not expecting. This was communicated through comments such as '*children do actually enjoy science*' (Gertrude Elion, Final Questionnaire). Others highlighted the manner in which the students' response had directly influenced their intention to teach it and thus their strengthened positive attitudes:

> *Yes I'll teach science as much as possible because I've seen the benefit of it in the classroom.*
> (Jocelyn Burnell, Final Questionnaire)

> *Students' enthusiasm and learning encourages more science to be taught.*
> (Rachel Carson, Final Questionnaire)

> *I'm surprised by how enthusiastic they are about science, because I'm 'ohhh, I hate science', but then I guess in primary school they like it. And I was surprised by that. To see them and how excited they were about people coming to teach them science. I'll be more willing to teach it now I think, because I see that they do get enjoyment out of it, because before I was 'oh, I think they'd hate it'.*
> (Linda Buck, Round Table Discussion 1)

These comments were typical of the responses from preservice teachers throughout round table and online discussions and in the final questionnaire. They demonstrated how their exposure to science teaching and the enthusiastic attitudes from children had impacted their own desire and willingness to teach science. This indicated a strengthening attitude that went from believing science is important to actually increasing their desire to teach it.

Some practising teachers also communicated surprise at the level of student engagement in science lessons. For example, Ms Marie Curie, who indicated in her interview nervousness about teaching science and that she had not taught any science to her current class, commented:

> *We hadn't realised how much the kids were going to love it. That's one thing that really surprised me. I didn't think they'd be so engaged.*
> (Ms Marie Curie, Interview)

As a result, Ms Curie also responded with her intention to teach science more frequently in the final questionnaire. Mr John Dalton also indicated an intention to increase the frequency of his science teaching with: '*Definitely. Science now has a permanent place on the timetable'* (Final Questionnaire).

Most of the practising teachers reported having witnessed a high level of student engagement in the science lessons, but except for Ms Curie and Mr Dalton, no other practising teacher participants indicated that the experience would increase the frequency of their science teaching. This was explained in most cases to be due to the high level of science teaching they already conducted: '*Science is already a high priority in my classroom'* (Mr Robert Boyle, Final Questionnaire) and '*I can teach as much as 19 hours per week of integrated science'* (Ms Annie Easley, Final Questionnaire).

Overall, the various data from both practising and preservice teachers indicated that an already strong, positive attitude towards science existed. For those whose experience and/or attitudes were less well established, the exposure and experience to science teaching and the reaction of children helped to strengthen attitudes and enhance the desire and intention for increased science teaching, particularly for preservice teachers.

Closely linked to the strengthening attitudes were the increased levels of science teaching self-efficacy beliefs that became evident. This is explored in the next section of this chapter.

4.3 Participants' Self-efficacy Beliefs toward Science

Data sources that contributed to the exploration of participants' self-efficacy beliefs, or confidence in their science knowledge and teaching abilities, included De Bono's Thinking Hats activity from the initial participant workshop, closed and open questions in the initial and final questionnaires, and comments contributed in practising teacher interviews and preservice teacher round table and online discussions. Some of the responses provided in the evaluation of the partnership model in the final participant workshop also helped to develop a sense of participants' confidence as the project experience drew to an end.

To provide the initial picture of participants' levels of self-efficacy towards science, the closed items associated with the self-assessed confidence levels across different areas of science and the STEBI questionnaire results are reported for each participant cohort. Following this other data are reported for the single case study cohorts to provide verification of data collected through the closed questionnaire items.

Preservice Teacher Self-Efficacy Beliefs

Preservice teachers were asked to rate their confidence on a 10-point scale in both the initial and final questionnaires across the four main areas of science commonly associated with curriculum documentation: Biological Science, Chemical Science, Earth & Space Science and Physical Science.

This scale was discussed and visually represented in Chapter 3 (Figure 3.3.1). The results for preservice teachers' self-assessed confidence ratings for each area using this scale (1 low; 10 high) are reported in Table 4.3.1.

Table 4.3.1: Preservice Teacher Initial Self-assessed Confidence Levels for Science Before and After the Partnership Experience

Preservice Teacher	Biological Science		Chemical Science		Earth & Space Science		Physical Science		Average	
	Before	After	Before	After	Before	After	Before	After	**Before**	**After**
Anita Roberts	6	-	3	-	5	-	4	-	**4.5**	**-**
Barbara McClintock	5	5	6	5	7	5	6	8	**6**	**5.8**
Jocelyn Burnell	4	2	5	2	3	5	5	1	**4.3**	**2.5**
Gertrude Elion	3	1	1.5	3	1.5	5	3	5	**2.3**	**3.5**
Helen Dunbar	4.5	5	5	7	6	9	4	0	**4.9**	**5.3**
Gerty Cori	8	8	6	6	7	8	7	7	**7**	**7.3**
Rachel Zimmerman	8	10	2	6	2	8	6	6	**4.5**	**7.5**
Maria Mayar	7	9	7	9	7	9	7	9	**7**	**9**
Grace Hooper	-	7.5	-	7.5	-	8.5	-	9	**-**	**8.1**
Lise Meitner	5	7	4	7	5	7	4	7	**4.5**	**7**
Dorothy Hodgkin	4	7	2	4	4	4	4	4	**3.5**	**4.8**
Linda Buck	5	6	3	6	7	6	5	5	**5**	**5.8**
Rachel Carson	1.5	5	1.5	10	1.5	8	1.5	8	**1.5**	**7.8**
Average	**5**	**5.9**	**3.9**	**5.9**	**4.6**	**6.6**	**4.6**	**5.5**	**4.6**	**6.0**

Note: Averages in the 'Average' column include data only where both initial and final results are available.

These results indicated that of the 11 preservice teachers who completed both an initial and a final questionnaire, nine reported an increase in their average self-assessed confidence to teach across the different areas of science. Overall average scores also indicated that confidence to teach each areas of science increased. Confidence to teach Biological Science and Physical Science increased the least with small changes of +0.9 and +0.7 respectively. Greater increases in confidence were recorded for Chemical Science (+2.0) and Earth and Space Science (+2.1). The average scores increased by 1.4 points overall. All changes in scores are summarised in Table 4.3.2. Increases in scores are denoted by a + sign in front of the magnitude of the increase and decreases are denoted with a – in front of the magnitude of decrease. Scores for which there are no changes before and after the partnerships are denoted with a 0.

Table 4.3.2: Changes in Preservice Teacher Self-assessed Confidence Levels for Science Before and After the Partnership Experience

Preservice Teacher	Biological Science	Chemical Science	Earth & Space Science	Physical Science	Average
Anita Roberts	-	-	-	-	-
Barbara McClintock	0	-1	-2	+2	-0.2
Jocelyn Burnell	-2	-3	+2	-4	-1.8
Gertrude Elion	-2	+1.5	+3.5	+2	+1.2
Helen Dunbar	+0.5	+2	+3	-4	+0.4
Gerty Cori	0	0	+1	0	+0.3
Rachel Zimmerman	+2	+4	+6	0	+3.0
Maria Mayar	+2	+2	+2	+2	+2
Grace Hooper	-	-	-	-	-
Lise Meitner	+2	+3	+2	+3	+2.5
Dorothy Hodgkin	+3	+2	0	0	+1.3
Linda Buck	+1	+3	-1	0	+0.8
Rachel Carson	+3.5	+8.5	+6.5	+6.5	+6.3
Average	**+0.9**	**+2.0**	**+2.1**	**+0.7**	**+1.4**

Note: Averages in the 'Average' column include data only where both initial and final results are available.

Of the 11 preservice teachers who provided initial and final data on their confidence levels, four had a score below average prior to the partnerships that grew to above average after the experience (Helen Dunbar, Rachel Zimmerman, Lise Meitner and Rachel Carson). Three others (Gerty Cori, Maria Mayar and Linda Buck) were already at or above average in their confidence and reported a further increase in their confidence after the partnership experience. Two other preservice teachers (Gertrude Elion and Dorothy Hodgkin) began with below average confidence and although they also finished with below average confidence, there was some growth in their confidence. This gave seven of the preservice teacher participants experiencing an overall increase in their self-assessed confidence levels to teach different areas of science. One preservice teacher finished with above average confidence but did experience a decrease overall according to the data provided (Barbara McClintock). One other (Jocelyn Burnell) also showed a low confidence level at the beginning which slipped further into the below average ranking on the final questionnaire.

In addition to reporting these self-assessed levels of confidence, preservice teachers also completed the STEBI-B questionnaire before and after the partnership experience. Two scales are measured using the STEBI-B: the Personal Science Teaching Efficacy scale (PSTE) and the Science Teaching Outcome Expectancy scale (STOE) (see chapter 3 for further information). Preservice teachers' PSTE score is measured out of a total of 65 possible points, and the STOE scale out of a possible 50 points. This means the closer their score is to 65 and 50 respectively, the higher the preservice participants' Personal Science Teaching Efficacy Belief in themselves, and their Science Teaching Outcome Expectancy. Participants' scores for the PSTE and STOE scales from the STEBI-B are summarised in Table 4.3.3.

Table 4.3.3: Personal Belief Efficacy and Outcome Expectancy for Preservice Teachers (STEBI-B Results)

Preservice teacher	Personal Belief Efficacy Score (Out of Possible 65)			Outcome Expectancy Score (Out of Possible 50)		
	Initial	Final	Change	Initial	Final	Change
Anita Roberts	43	-	NA	27	-	NA
Barbara McClintock	46	48	+2	31	32	+1
Jocelyn Burnell	36	35	-1	36	31	-5
Gertrude Elion	42	46	+4	36	37	+1
Helen Dunbar	34	34	0	34	33	-1
Gerty Cori	38	48	+10	36	37	+1
Rachel Zimmerman	42	48	+6	36	33	-3
Maria Mayar	61	57	-4	37	36	-1
Grace Hooper	-	55	NA	-	41	NA
Lise Meitner	29	45	+16	33	37	+4
Dorothy Hodgkin	34	52	+18	39	36	-3
Linda Buck	42	55	+15	36	39	+3
Rachel Carson	32	50	+18	34	36	+2
Average	**39.6**	**47.1**	**+7.5**	**35.3**	**35.2**	**-0.1**

Note: Averages in the 'Average' column include data only where both initial and final results are available.

Of the 13 preservice teachers who participated in the project, 11 completed both the initial and final STEBI-B questionnaires. Of these 8 showed an increase in their personal science teaching efficacy beliefs, or confidence to teach science. These increases in score ranged from +2 (Barbara McClintock) to +18 (Dorothy Hodgkin and Rachel Carson) with an average increase of +10.9 amongst these eight preservice teachers. Two (18%) of the preservice teachers had a decrease in their PSTE scores of -1 (Jocelyn Burnell) and -4 (Maria Mayar) while one preservice teacher (Helen Dunbar) had no change.

The changes in STOE scores for preservice teachers were generally less noteworthy than those for the PSTE scale. Six (55%) of the 11 participants who completed both questionnaires showed small increases in their STOE scores. These increases ranged from +1 to +4 with an average of +2. The remaining 5 (45%) of the preservice teachers reported a decrease in their STOE scores ranging from a decrease of -1 (Maria Mayar and Helen Dunbar) to -5 (Jocelyn Burnell). The average decrease for these five participants was -2.6.

The data collected from preservice teachers' questionnaires indicate that confidence to teach science was positively impacted by experiences in the project. Generally, self-assessed confidence and STEBI self-efficacy belief scores showed small to large increases for most preservice teacher participants. Whether these increases are attributable to the partnership *per se*, or just the teaching experience generally is not clear from the data collected here and this will need to be considered further as more data are reported.

Other data supporting low efficacy beliefs among the preservice teachers as they entered the project came from the thinking hats activity in the initial participant workshop. Emotive responses to Red 'Feelings' such as '*scared*' (Thinking Hats R10), '*Apprehensive*' (Thinking Hats R14) and '*Terrified*' (Thinking Hats R11) conveyed a generally high level of uncertainty, and in some cases, heightened anxiety. Whilst some of these feelings may be attributed to the unknown element of a new experience, some of the Black Hat responses lent support to the notion that the reasons for the negative feelings expressed stemmed from other causes.

The Black hat, dealing with concerns participants had about science and/or its teaching, saw the emergence of an overwhelmingly strong category, that of 'lack of knowledge'. This category of responses was characterised by 11 of the 19 the comments made in response to Black Hat thinking. Characteristics of these comments were: '*Students may ask questions I don't know the answers to'* (Thinking Hats B8), '*My own knowledge is lacking'* (Thinking Hats B2), and '*I don't feel I know enough about science to teach it*' (Thinking Hats B9). Here, a significant lack of self-efficacy belief in their ability to teach science due to a lack of background knowledge in the area was clearly evident.

The STEBI and self-assessed confidence results indicated that concerns regarding lack of knowledge and feelings of negativity were made by preservice teachers. Initial self-assessed confidence of preservice teachers was 4.6 out of 10 and their STEBI results were an average 39.6 out of 65 for the PSTE scale that deals with personal efficacy belief in science. These results show relatively low confidence levels and are attributable to the more frequent responses of nervousness, uncertainty and fear communicated in the red hat thinking results. Further evidence supporting this judgement was provided through preservice teachers' responses to the question '*What are you hoping to achieve/obtain through your involvement in this project?*' on the open section of the initial questionnaire. Preservice teachers' responses to this question are characterised by the excerpts below.

> *I want to enhance my knowledge of science as I definitely wouldn't be confident in teaching science at this moment.*
> (Dorothy Hodgkin, Initial Questionnaire)

> *I'd also like to be able to answer students' questions without seeming like I know nothing of the subject.*
> (Rachel Carson, Initial Questionnaire)

> *I hope that I will gain a lot more science knowledge because I currently feel like I do not know much.*
> (Gertrude Elion, Initial Questionnaire)

Changes in Preservice Teachers' Self-efficacy Beliefs

As reported in Tables 4.3.1 and 4.3.3 respectively, self-assessed confidence levels and STEBI results indicated overall increases in preservice teachers' confidence level after their experience in the project. These results were supported by other forms of data collected from preservice teachers throughout the project. They appeared to be affected by the mastery experience of working in the authentic classroom setting, by reflective practice, and from children's engagement in science.

Confidence Gained from Mastery Experience

In the open section of the final questionnaire, preservice teachers were asked what they achieved/gained from their involvement. Confidence was the most highly reported response to this question with seven preservice teachers providing an indication that this was amongst their achievements. Their comments ranged from '*confidence in teaching science'* (Rachel Carson, Final Questionnaire) to '*My confidence has grown in teaching science and I am now more willing to implement science in my classroom'* (Gertrude Elion, Final Questionnaire).

Growing confidence was also a feature of round table and online discussions. Explicit mention of increasing confidence was reported by 10 of the 13 preservice teachers through online postings and round table discussions across the research period. Comments included:

> *I think being in the classroom for the last 2 lessons has made me more confident to teach science and I'm already excited about getting out there and doing it.*
> (Linda Buck, Round Table Discussion 1)

> *I believe that through these experiments and research before the lesson that I am increasing my own understanding in science knowledge. I believe that this important because with increased knowledge comes increased confidence.*
> (Barbara McClintock, Online Discussion September 5, 2007).

Anita Roberts offered another perspective on the building of successful feelings and its impact on growth in confidence in one of her post-lesson reflections. Using the planning and reflection booklet provided, she wrote:

> *Despite feeling that things were not working at times, my confidence has increased. I have seen that I can handle it when things do not occur as expected*
> (Ms Marie Curie & Anita Roberts, Planning and Reflection Booklet)

This comment addresses one of the key concerns felt by preservice teachers in relation to the impact their lack of knowledge may have in the classroom – they would not know what to do if something went wrong. Here, Anita faced that fear and found that when unexpected events did arise, she was able to cope with the situation and work through it. It is unknown how effective her solution was at the time in terms of content and pedagogy, but it is important that it was successful enough to help build her confidence. More of these experiences would likely contribute to further growth in confidence and gradually, greater accumulation of content and pedagogical knowledge so that the effectiveness of her approaches would be more certain.

Collectively, these comments highlight the role of mastery experience in building confidence. It provided preservice teachers with an opportunity to successfully deliver science lessons, and to realise that they were able to overcome difficulties and unexpected situations faced in the teaching experience.

Confidence Gained from Reflective Practice and Sharing with Peers

Both mastery experience and reflective practice appeared to contribute to growth in confidence for a number of preservice teachers. This was exemplified by Gerty Cori who offered the following comment:

> *I think having come to the end of this sequence of units that I am much more confident in my ability to teach science, …. I think I've learnt the most from the things that didn't work, by looking and why it was that they weren't very effective. It would be good to be able to try out the changes to see if we can create better learning experiences for the children.*
>
> (Gerty Cori, Online Discussion September 25, 2007)

There were a number of similar comments made throughout the research period. These examples highlighted how preservice teachers learnt from previous lessons and from their mistakes: '*We were able to reflect on the previous lesson and use this knowledge in the follow-up lesson'* (Anita Roberts). This demonstrated the importance of the role of reflection in the learning sequence. It provided the preservice teachers with a sense of control over the outcomes and it was pleasing to read of Gerty Cori's desire to implement the new ideas her reflection brought her to see if they would improve learning for children.

Further evidence of the impact of the project design on confidence came from the partnership experience of Helen Dunbar and Gertrude Elion who were partnered with Ms Jane Goodall in a Grade 3/4 class. Helen and Gertrude initially felt intimidated by Ms Goodall's science background knowledge, her expectations of them to teach together without her input, and the topic she had given them to teach. Gertrude expressed this:

> *We've got a 3/4 class and we're doing forensic science with them, which is pretty tough - we don't really know much on that and the teacher has already done a lot with them and knows a lot so we feel like we're a bit behind and that we don't know as much. …And I think it is a hard, it's a hard topic really, when you don't know much about science, it's a hard topic.*
>
> (Gertrude Elion, Round Table Discussion 1)

And from Helen:

> *We found with our teacher, she set the bar so high.*
>
> (Helen Dunbar, Round Table Discussion 1)

After debriefing with their peers and receiving a range of supportive comments and ideas for teaching in their unit, the following exchange occurred:

Helen Dunbar	*I'm getting excited about tomorrow though now because we've actually got some ideas . Like using different surfaces - having finger prints on different surfaces.*
Gertrude Elion	*I know I'm getting excited.*
Helen Dunbar	*And like have it on glass and wood and plastic and a few different surfaces and like some mightn't work and you could say 'why doesn't it work?' and use those questions like she wants us to.*

(Round Table Discussion 1)

The impact of this exchange on the confidence of Helen and Gertrude was quite visible at the time. They had come from a negative encounter with their teacher partner whose science knowledge and teaching expectations had made them feel intimidated. The sharing with peers and the suggestions their peers were able to provide gave them a sense of empowerment and control simply because they had a range of ideas to trial. Later in the research period, the following comment was posted in the online discussion.

> *Our confidence is growing with every lesson that we take and we are building a bank of science lessons that work well with children.*
> (Helen Dunbar, Online Discussion September 4, 2007)

The carry-over effect of that initial peer sharing became evident later in the semester through the online discussion posting where Helen highlights the way she was '*building a bank of science lessons'* and the inference that this contributed to her growth in confidence. This example in particular highlights the importance of both a 'bank of knowledge and/or activities' and the importance of reflective discussion and sharing with peers, for developing confidence.

Further evidence of the importance of the peer sharing and establishment of a bank of ideas was expressed by Maria Mayar. She highlighted how '*it's good to hear about what everyone else does and what's worked and what hasn't worked and just get ideas from people instead of trawl your way around the internet and find stuff but you don't know if they're really going to be successful or not'* (Maria Mayar, Round Table Discussion 1). This again highlighted how the peer support structure can contribute to building confidence through the sharing of materials and ideas that have been trialled by others, instilling confidence that they will actually be effective in the classroom.

Anita Roberts reported increases in her confidence in every posting she made. She also discussed increases in the confidence of the practising teacher she worked with in most of these postings. She attributed this growth in confidence to gaining experience in teaching science, something she had not had prior to this project. She also alluded to the learning from experience as she and her partner learnt from their successes and failures each week and that science was easier to implement than she had thought it would be. A selection of her postings is included to demonstrate the growth in her confidence over the project period. Collectively they indicate each of the elements discussed above: mastery experience and reflective practice; as well as suggesting how the response from children helps to build feelings of success.

> *This lesson improved my confidence, as it was the first science lesson I had been involved in.*
>
> (Anita Roberts, Online Discussion 29 August 2007)

> *Marie and I both agreed that our confidence had been increased after the previous week's experiment. We were able to reflect on the previous lesson and use this knowledge in the follow-up lesson.*
>
> (Anita Roberts, Online Discussion 4 September 2007)

> *Marie found that her confidence increased as a result of this lesson. She found that simple experiments are very easy for students at this level to be involved in. I have noticed a large increase in my confidence over the course of the project. Today I concluded the lesson, which I would not have been comfortable doing a few weeks ago. I am now more confident in my own abilities. Marie also feels more confident now, since science seems easy and students love our science lessons.*
>
> (Anita Roberts, Online Discussion 20 September 2007)

Confidence gained from Children's Response

The notion of feeling successful due to the response from children was also mentioned by Helen Dunbar: '*I guess it's just the enthusiasm of the kids that makes you feel like it's successful because they're enjoying themselves*' (Helen Dunbar, Round Table Discussion 1). This sentiment was expressed by nine of the preservice teachers who generally attributed student engagement to strengths in lesson delivery, i.e. success. It was particularly interesting to note that of the total 18 comments posted online in regard to student engagement, 11 (61%) of them were made after the first lesson they conducted. The remaining 7 comments were spread from the second to the final week. Certainly, students' easy engagement in science was an important insight preservice teachers gained from their experience in the project. Some of the comments made included:

> *The main strength with this lesson would have been the engagement. Kids were so excited by the hands on nature of the experiments.*
>
> (Grace Hooper, Online Discussion August 28, 2007)

> *The children really enjoyed this and I would say was the major strength of the activity that the students actually went beyond the questions we provided and wanted to know more and actually experimented them, which ensured they gained a better understanding of the topic.*
>
> (Dorothy Hodgkin, Online Discussion August 30, 2007)

It is clear that the responsiveness of the children to the science lesson was a significant factor contributing to the sense of success and thus growth in confidence preservice teachers reported.

Instances of Decreased Confidence

Although the majority of preservice teachers reported increases in their confidence to teach science, there were three preservice teachers who recorded decreases in confidence in closed questionnaire data: Barbara McClintock, Maria Mayar and Jocelyn Burnell. Barbara McClintock had a slight average decrease in her self-assessed confidence level (decrease by 0.2 out of 10 points). However, this decrease was not evident in other forms of data collected from Barbara. Her PSTE score showed a small increase of 2 points on average, and she did comment that as she felt her knowledge grow through her experience, her confidence also grew in an online discussion posting. The slight decrease in self assessed confidence is likely to have occurred due to what is possibly a wavering belief in her science knowledge and ability to teach it. This could also be inferred from what were only small indications of increases in confidence through other data.

Maria Mayar recorded a small drop of 4 points (out of 65) in the PSTE scale of the STEBI questionnaire. However her self-assessed confidence grew by 2 points (out of 10) and she commented having achieved '*confidence going into schools to teach students in the area of science*' in her final questionnaire section in response to what was achieved or obtained from her involvement in the project. She also wrote '*I feel quite confident in teaching science but more time to explore ideas would be good*' (Maria Mayar, Final Questionnaire). The drop in PSTE score may have resulted from the fact that her initial PSTE score was so high (61 out of 65 points) and the subsequent time spent in schools was simply too short to effect any increase in efficacy belief. With a score only 4 points away from the highest possible, there is very little room for growth anyway. Regardless, all other sources of data suggest that her confidence was improved in spite of the small drop in PSTE.

The one preservice teacher whose self-assessed confidence levels were clearly negatively impacted with an overall average decrease of almost 2 points out of 10 was Jocelyn Burnell. These results, supported also by the decrease in her STEBI score of -1 (out of 65) in the PSTE scale, also came through in her discussion of confidence in the online and round table settings. She discussed that '*my confidence completely diminished*' (Jocelyn Burnell, Online Discussion September 14, 2007) and that she felt '*like a novice in a field of experts, and an unwanted novice at that'* (Jocelyn Burnell, Online Discussion September 14, 2007). She attributed these decreases in confidence to the nature of the partnership she experienced with her practising teacher partner, Ms Diane Fossey. As a consequence of this poor experience, Jocelyn's confidence in her ability to teach science did decrease. This was reflected in all sources of data and also came across as the one barrier she listed to her teaching science. In spite of this she did report an intention to try to teach science once in schools due to the benefits she witnessed in the classroom which was reported earlier in this section.

The impact of the partnership that Jocelyn attributed to her decreased confidence was one of the first clear indicators that the nature of the partnership could be a critical aspect in the outcomes for preservice teachers, particularly in regard to confidence. This is explored further in the next section which deals more specifically with the impact of the partnerships.

Summary

Overall, the different sources of data indicated that preservice teachers' confidence to teach science was increased as a result of the project experience. The combination of mastery experience and the accompanying feeling of success brought about by children's positive response to science was a major contributor to this. When these experiences were not as forthcoming, as in the case of Helen Dunbar, Gertrude Elion and Jocelyn Burnell, the support structure of peer reflection and the accompanying social persuasion this provided helped to some extent. The sharing of ideas and activities formed a wider support structure for all preservice teachers involved that provided them with confidence in the materials and ideas they were taking into the classroom.

Practising teacher Self-Efficacy Beliefs

Practising teacher participants were asked to rate their confidence on the same 10-point scale used by preservice teachers across the four main areas of science: Biological Science, Chemical Science, Earth & Space Science and Physical Science. The same scale used with preservice teachers was used for practising teachers (see Chapter 3 Figure 3.3.1). The results for practising teachers' self-assessed confidence ratings for each area using this scale for both initial and final questionnaires are reported in Table 4.3.4.

These results show a range in practising teachers' confidence to teach science. Ms Curie's initial confidence appeared to be in a medium-low range and Ms Franklin's was average. Ms Easley, Ms Apgar and Mr Dalton all indicated high levels of confidence and Mr Boyle reported his confidence to teach science as very high. This range was not unexpected given that although school principals were approached with the project concept as a professional learning opportunity, it was never explicitly stated that teachers who were poor in confidence and/or science content knowledge were to be targeted. Rather, 'interested teachers' were called for. This left the door quite open for teachers both with and without experience and/or confidence in science to become involved, which appears to be the case from the data presented here.

Table 4.3.4: Practising teacher Initial Self-assessed Confidence Levels for Science Before and After the Partnership Experience

Practising teacher	Biological Science		Chemical Science		Earth & Space Science		Physical Science		Average	
	Before	After	Before	After	Before	After	Before	After	**Before**	**After**
Ms Marie Curie	-	2	-	3.5	-	5	-	4	**-**	**3.6**
Ms Rosalind Franklin	5	7	5	7	5	7	5	7	**5**	**7**
Ms Diane Fossey	-	-	-	-	-	-	-	-	**-**	**-**
Ms Jane Goodall	-	5	-	5	-	5	-	5	**-**	**5**
Ms Annie Easley	8.5	8.5	8	7.5	7	7.5	8	7.5	**7.9**	**7.8**
Ms Virginia Apgar	9	8	9	8	9	8	8	8	**8.8**	**8**
Mr John Dalton	10	10	5	5	10	10	7	8	**8**	**8.3**
Mr Robert Boyle	9	9	8	7	10	9	9	8	**9**	**8**
Average	**8.3**	**8.5**	**7**	**6.9**	**8.2**	**8.3**	**7.4**	**7.7**	**7.7**	**7.8**

Note: Averages in the 'Average' column include data only where both initial and final results are available.

Five of the eight practising teachers completed both an initial and final questionnaire. For these teachers, changes in self-assessed confidence levels can be examined. Except in the case of Ms Rosalind Franklin who had an average increase of +2 in her self assessed confidence across the areas of science, all other teachers who completed both questionnaires showed negligible changes as shown in Table 4.3.5. Note that increases are denoted by a + and decreases by a – in front of the magnitude of the increase/decrease.

Table 4.3.5: Changes in Practising teacher's Self-assessed Confidence Levels for Science Before and After the Partnership Experience

Preservice Teacher	Biological Science	Chemical Science	Earth & Space Science	Physical Science	Average
Ms Marie Curie	-	-	-	-	-
Ms Rosalind Franklin	+2	+2	+2	+2	+2
Ms Diane Fossey	-	-	-	-	-
Ms Jane Goodall	-	-	-	-	-
Ms Annie Easley	0	-0.5	+0.5	-0.5	-0.1
Ms Virginia Apgar	-1	-1	-1	0	-0.8
Mr John Dalton	0	0	0	+1	+0.3
Mr Robert Boyle	0	-1	-1	-1	-1
Average	**+0.2**	**+0.1**	**+0.1**	**+0.3**	**+0.08**

Note: Averages in the 'Average' column include data only where both initial and final results are available.

In addition to these self assessed confidence levels, the initial STEBI-A questionnaire was administered. Scores for the PSTE and STOE scales from the STEBI-A are summarised in Table 4.3.6 for practising teacher participants.

Table 4.3.6: Personal Belief Efficacy and Outcome Expectancy for Practising teachers (STEBI-A Results)

Practising teacher	Personal Belief Efficacy Score (Out of Possible 65)			Outcome Expectancy Score (Out of Possible 60)		
	Initial	Final	Change	Initial	Final	Change
Ms Marie Curie	-	40	NA	-	44	NA
Ms Rosalind Franklin	53	57	+4	48	50	+2
Ms Diane Fossey	-	-	NA	-	-	NA
Ms Jane Goodall	-	47	NA	-	45	NA
Ms Annie Easley	52	49	-3	48	50	+2
Ms Virginia Apgar	53	48	-5	57	50	-7
Mr John Dalton	53	63	+10	51	54	+3
Mr Robert Boyle	56	59	+3	50	50	0
Average	**53.4**	**55.2**	**+1.8**	**50.8**	**50.8**	**0**

Initial STEBI results indicated that practising teachers' self-efficacy beliefs about their ability to teach science were quite high and not greatly varied between individuals. All PSTE scores were in the low to mid 50s out of a possible 65 points. This indicated that the practising teacher cohort who completed the initial questionnaire were all fairly confident in their science teaching abilities. STOE scores showed a slightly larger range from high 40s to high 50s, all still relatively high scores indicating that the cohort of respondents held high beliefs about the ability of good teachers to affect student outcomes.

After participating in the collaborative partnerships, teachers were again asked to complete the STEBI-A. The results for the Personal Belief Efficacy and Outcome Expectancy scales after the collaborative partnership are also shown in Table 4.3.6. This table showed mixed results in the pre and post STEBI scores for practising teachers for both the PSTE and the STOE scales. Increases in PSTE scores occurred for Ms Franklin, Mr Dalton and Mr Boyle but decreased for Ms Easley and Ms Apgar. Ms Franklin, Ms Easley and Mr Dalton's STOE scores also showed small increases but Mr Boyle's STOE remained unchanged and Ms Apgar's actually decreased after the partnership model experience.

It is disappointing that three of the eight practising teacher participants did not complete both the initial and final questionnaires (and neither of them in the case of Ms Diane Fossey) and so their results can not be compared before and after the partnership experience. This has made it difficult to establish a general pattern in the initial and final STEBI-A results for practising teachers.

Unreturned questionnaires were not followed up in these cases for two reasons. Firstly, they involved the teachers who did not attend the initial participant workshop, so a reasonable amount of time had to be allowed after their 'catch up' meetings were held. Judging a 'reasonable' amount of time proved difficult in the truncated period of time partnerships had to work together. By the time this period was underway, it felt too late to pursue initial questionnaire responses which may already have been affected by partnership participation. Secondly, it was felt that attempting to follow up the questionnaires may have been perceived negatively by busy practising teacher participants and I had already been advised by the university professional experience office not to pressure practising teachers too much. This was due to the need to protect the relationship between schools and the university in order to ensure professional experience placements were not threatened.

The Red 'Feelings' hat used in the initial participant workshop supported questionnaire finding that practising teachers' initial self-efficacy beliefs were already high. Comments such as '*Excited!*' (Thinking Hats R5), '*Curious*' (Thinking Hats R1) and '*Fascinated*' (Thinking Hats R3) were examples of positive feelings communicated. These responses were more likely to be aligned with participants who were feeling reasonably confident in the science teaching experience ahead of them as they did not express any of the concern or fear of teaching science that a lack of confidence would likely bring. Based on self-assessed confidence levels and STEBI questionnaire results reported above, this makes these responses more likely to come from practising teachers who, generally speaking, had relatively high levels of confidence at the project commencement.

Unlike the preservice teachers, only two of the five practising teachers who returned the initial questionnaire indicated a desire for increasing their knowledge from their involvement. These included Mr John Dalton who hoped to '*increase my knowledge of up-to-date theories in teaching science'* (Initial Questionnaire) and Ms Rosalind Franklin who expressed a desire for '*P.D. on the 5Es/Science'* (Initial Questionnaire). None of the teachers expressed an issue with confidence. These results showed that practising teachers entered the project with generally high self-efficacy beliefs towards science and their ability to teach it.

Changes in Practising teachers' Self-efficacy Beliefs

STEBI data and self-assessed confidence levels from questionnaires generally indicated little change in practising teachers' self-efficacy beliefs towards teaching science. However, it was difficult to establish any pattern in the data as three of the eight practising teachers did not return one or other of the initial or final questionnaires.

Of those results obtained from questionnaires, the small increase of 2 points (out of 10) for Ms Rosalind Franklin was supported by a small increase of 4 points (out of 65) in her PSTE results. Her comments about achieving consolidation on the 5Es and having time for reflection on her own teaching may have helped to contribute to these small increases. Other than this, other changes in practising teachers' confidence were negligible. There were slight changes, but these were generally less than 1 point in value for self-assessed confidence and 2-3 points for the PSTE scale. In response to an interview question asking whether they felt they had learned anything from their involvement in the project, practising teachers provided the following sorts of comments which help to explain why their involvement had such negligible impact on their efficacy in science:

> *It wasn't really a new approach I suppose, but then see I'm not your average - I've got a strong science background.*
>
> (Mr Robert Boyle, Interview)

> *Coming fresh from uni last year, and I really enjoyed the science component of the course, so I think I already had that knowledge there fresh, so I haven't had to revisit.*
>
> (Ms Rosalind Franklin, Interview)

> *They're* [preservice teachers] *not skilled enough. No sorry.*
>
> (Ms Diane Fossey, Interview)

Two of the practising teachers did discuss the increase in confidence they experienced as a result of their involvement in the project. In the open section of the final questionnaire, Ms Curie, in response to the question asking what she achieved/gained from her involvement wrote: '*increase in confidence, not afraid to teach science now*' (Ms Marie Curie, Final Questionnaire). This is in line with the comment she offered in regard to feeling more confident in her interview:

> *Science is easy. Well not always easy, I shouldn't say that, it's easier than I thought it would be. I'm more confident with it. And I'm more willing to take on a challenge with science now.*
>
> (Ms Marie Curie, Interview)

This was a significant shift for Ms Curie who, as a first year graduate teacher, reported never having taught science before, and avoiding it due to her lack of confidence.

Mr John Dalton was already reasonably confident with his science knowledge according to questionnaire data, but he too reported an increase in his confidence. His confidence was related to getting his students to understand science. This is illustrated in the excerpt from his interview, where he notes that he feels an increase in confidence with other people in the room while he is teaching which appears to be related to his increased confidence in his ability to help his students understand the content.

> *John: When Robert asked me whether I was interested in doing it I thought yep, I've never had it before* [student teachers in his class]. *Maybe two parents I've had in the classroom in my 4 years of teaching and that's it. So it was a good step for me. So I said yeah, it'll sort of give me a bit more confidence as well.*
>
> *Mellita: So that's where you'd say that that's your main learning has been, just in that having somebody else, making you focus more on the way you're doing it.*
>
> *John: Yeah, delivering information, I find a lot, like I'm doing it now, I find a lot that I'm recording it and a little bit of time thinking how I can get it across so the kids can understand it.*
>
> *Mellita: So you're fairly confident with your science background?*
>
> *John: Yeah, yep.*
>
> *Researcher: So it more about the teaching of it than about the actual science?*
>
> *John: Yeah, getting the kids to understand it.*

(Mr John Dalton, Interview)

Mr Dalton's final questionnaire response re-iterated this notion. In response to what he achieved/gained from his involvement, he wrote '*became more motivated to teach science and allow others into the classroom (first time)*' (Mr John Dalton, Final Questionnaire).

These excerpts highlight that depending on where a person is in his/her professional growth, the collaborative partnership can offer some form of confidence building in the professional learning journey. For Ms Curie it was the exposure and initial experience of planning and implementing science in the classroom for the first time, offering a mastery experience that began to develop her science teaching self-efficacy. For Mr Dalton, the developing belief that he could help children understand science concepts helped him feel more confident to have other adults in his classroom as witnesses to his teaching. For the remaining practising teachers, the project did not address their professional learning needs particularly given they were already so confident and/or experienced in science teaching using the types of activities and approaches with which the project was concerned.

Ms Diane Fossey reported having a low ability to teach science and a tendency to avoid it where possible: *‘I'm not very sciencey, I like my Maths and I don't mind literacy, but science is something I tend to stay away from a little bit’* (Ms Diane Fossey, Interview). She had potential to benefit from the project in a similar way to Ms Curie but as is discussed in more detail in the next section, her non-participatory approach to the project meant she was unable to benefit from the types of experiences Ms Curie had and consequently she experienced no perceptible change in efficacy or learning.

The results here suggest, not unexpectedly, that changes in practising teachers’ confidence are only going to be perceptible if they enter a project such as this with low efficacy levels to begin with. This was the case for Ms Curie and she reported growth in confidence resulting in a reported intention to teach science more often as a result. Nearly all of the remaining practising teachers entered the project with high efficacy beliefs and consequently little to no change was able to be affected given the level at which the project was pitched.

Summary of Findings for Attitudes and Efficacy Beliefs

The data collected for the practising and preservice teacher single case study cohorts demonstrated that for each cohort, attitudes towards science and its importance in the primary school curriculum were positive. This was reflected through the thinking hats activity where participants linked science education to developing an understanding of the world, development of thinking skills and potential for student engagement in learning through hands on/practical teaching approaches. Other sources of data also suggested a positive attitude towards science. In particular, positive attitudes could be inferred from some of the goals participants hoped to achieve through their involvement. Practising teachers wanted to enrich their students’ experience of science learning, and they also wanted to assist preservice teachers’ science teaching opportunities and development. Preservice teachers wanted to increase their knowledge and confidence to teach science. Each of these desires indicated a belief that it is worth spending time delivering or investing in science education, reflecting an overall positive attitude about the importance of this area of the curriculum.

Throughout the project, examples of strengthening attitudes towards science were evident. For both preservice and practising teachers, the children’s engagement in science lessons acted as a powerful reinforcer of the potential for learning when engagement in learning is at a high level, thus strengthening attitudes towards science in the classroom. Preservice teachers reflected this strengthening attitude through the unanimous consensus that they would be including science as a high priority in their teaching once in their own classrooms. Most practising teachers already held strong positive attitudes towards science and this was evident through the amount of time they reported already dedicated to science teaching. For the two who lacked confidence in some areas of their science teaching, strengthened positive attitudes were evident in the increased intention to teach science more often they expressed.

Preservice teachers as a cohort also experienced strong growth in their science teaching self-efficacy beliefs. This was reflected in an average overall growth in self-assessed confidence of 1.4 (out of 10) points and which was as high as an average increase of over 6 points in one case. The STEBI questionnaire PSTE scale, dealing specifically with personal efficacy beliefs, also reflected an overall increase of 7.5 points (out of 65), and in five cases the growth was 10 points or more. These results showed that for preservice teachers with particularly low levels of confidence, involvement in the project had a positive impact on their belief in their ability to teach science. For preservice teachers with higher levels of content, and as the next section shows, where partnerships were less supportive, the growth was more conservative or in the one extreme case, actually decreased.

Practising teachers generally entered the project with high levels of self-efficacy in the area of science. Their average initial PSTE score was over 53 points (out of 65) and the average self-assessed confidence score was over 8 out of 10. This left little room for increasing efficacy beliefs in these participants. Not unexpectedly then, average scores for the final PSTE and self-assessed rating showed negligible improvement (an increase of 1.8 points on average for PSTE and 0.1 for self-assessed ratings). Two practising teachers did report some increase in confidence. One gained confidence in his ability to help students understand science concepts enough to feel confident in having other adults in the room while he taught. The other actually entered the project having never taught science before due to her lack of confidence, and whilst there is no quantitative data to support her claim as she did not return the initial questionnaire to allow a comparison, she did report through a variety of means (final questionnaire, interview, post-lesson reflections) that her confidence had increased.

These results suggest that for those with low efficacy in regard to science and its teaching, involvement in a project like this one can provide the types of efficacy-building experiences that can lead to an increased intention to teach science more often. A number of factors are likely to impact on this though, and the nature of the partnership experience has already pointed to this as a key factor.

The next section explores the collaborative partnerships in depth to determine how they impact attitudes and efficacy, and what learning they might provide practising and preservice teachers in primary science.

4.4: The Nature of the Collaborative Partnerships

The use of collaborative partnerships was the underpinning and unique aspect of the present study. The literature review presented a range of strategies that could each contribute to building efficacy or improve science teaching and learning, for school students, for teachers seeking professional learning, and for preservice teachers. It is through the collaborative partnership model that this project seeks to draw together all of the threads of best practice by targeting science teacher education and teacher professional learning together, through a collaboration of planning, implementing and reflecting, to affect teacher efficacy and teacher practice in primary science. The examination of this model then becomes central to the importance of the present study and the findings it uncovers.

This section explores the nature of the collaborative partnerships using multiple case study analysis. This analysis allows an insight into how the individual partnerships operated by exploring their characteristics, successes and failures. The nature of each of the partnerships is an essential component of this study since it is the lens being used to explore the impact on attitude, self-efficacy and knowledge of practising and preservice teacher participants. The nature of the partnerships was assessed using open-ended data provided by preservice teachers through their round table and online discussions and by practising teachers in their interviews. Closed questioning was also included on practising and preservice teachers' final questionnaire, when they were each asked to use a provided scale to judge the level of collaboration they felt they had experienced in the planning, implementation and reflection stages of working together. These results, summarised in Table 4.4.1 showed some inconsistency in the way in which partners judged the level of collaboration within their partnerships. These inconsistencies along with other characteristics of individual partnerships are described below.

Table 4.4.1: Level of Collaboration for Lesson Planning, Implementation and Reflection Reported by Preservice Teachers

	HIGHLY COLLABORATIVE	MOSTLY COLLABORATIVE	MINIMALLY COLLABORATIVE	NOT COLLABORATIVE
PLANNING	HIGH COLLABORATION	MEDIUM COLLABORATION	MINIMAL COLLABORATION	NO COLLABORATION
Preservice Teachers	5	4	2	1
Practising teachers	2	3	2	
IMPLEMENTATION	TEAM TEACHING	SOME TEAM TEACHING		NO TEAM TEACHING
Preservice Teachers	8	2		1
Practising teachers	3	4		
REFLECTION	ON BOTH PARTNERS	MOSTLY ON PRE-SERVICE TEACHER		TEACHER FEEDBACK
Preservice Teachers	5	3		4
Practising teachers	4	2		1

Partnership 1: Ms Marie Curie and Anita Roberts

The strongest collaboration appeared to exist for the partnership between Ms Marie Curie and partner Anita Roberts. Each of these partners recorded high levels of collaboration in their planning, implementing and reflecting phases in the final questionnaire.

Each partner was positive in talking about the other and each reported receiving significant value and experience through working together. It was clear that Ms Curie and Anita planned extensively together and set clear roles for getting lessons organised. There was evidence that this partnership also used team teaching approaches to lesson delivery. These aspects of their partnership are reflected in their comments:

> *And we kind of said 'alright we need these things' and Anita said 'well I'll get this' and I'd say 'and I'll get that' so we kind of worked together in that sense too, to even it out. Apart from that I say we did it as a team.*
>
> (Ms Marie Curie, Interview)

> *Planning was Thursday nights and teaching was Fridays…and we planned together and then at the end of our sessions we'd go through the book and find out what we wanted to do for the next one and just go that way. It was pretty easy, we worked really well together…It was good, very happy with it.*
>
> (Anita Roberts, Round Table Discussion 2)

Reflection was also conducted in a highly collaborative and formal manner. Ms Curie captures this in her account of how she and Anita went about the post-lesson reflection:

> *Anita and I used to go…she either go and sit over there and I'd sit here and we'd write them separate and then we'd sit down together and reflect together. So we'd go 'well alright, we both said this, but I said this' and Anita will go 'well actually I said this' and we'd compare it that way. And that seemed to work alright. I like that separate time to think about it ourselves first. That really helped actually. You had your own clear ideas first. And you get a bit of broader response as well. And they were generally the same or similar. Then occasionally 'oh, I hadn't thought about that'. So there were a few times we said that - 'oh I forgot to put that down' or 'that's a good point' and we were both in that same situation.*
>
> (Ms Marie Curie, Interview)

As can be gleaned from this description, reflection involved each partner sitting separately to write a lesson reflection, then bringing those reflections together to compare and contrast their thinking. They recorded these reflections in the planning and reflection booklet provided, adding further evidence to the collaborative and formal nature of reflection time. Ms Curie and Anita were the only partners to reflect in such a formal manner and they were the only partners to complete reflection and planning in the booklet provided. This provided excellent evidence of how one lesson's reflection was incorporated into planning and/or preparation for the next. For example, Anita indicated how from the experience of a failed experiment, she learnt to trial experiments prior to conducting them with the class: *'after last week we have planned to try this experiment prior to this lesson'* (Anita Roberts and Ms Marie Curie Planning and Reflection Book), and *'going for a more simple experiment that is hands-on for the students'* (Anita Roberts and Ms Marie Curie Planning and Reflection Book) after a more complex experiment saw them floundering with time and meaningful learning.

In assessing the level of collaboration she felt she had experienced in the partnership in the final questionnaire, Ms Curie selected the highest possible response for each of the categories included. This incorporated 'high collaboration' for the Planning category; 'team teaching' for the Implementing category; and 'collaborative reflection focused on both of our teaching and planning' in the Reflecting category. Anita did not return a final questionnaire so her assessment can not be compared on this questionnaire item, but the data she provided through other sources indicate she would likely have selected the same response items for each category.

Collaboration between these partners was also evident in the way they discussed accommodating each other when it was required. For example, Ms Curie discussed how their teaching schedule was moved on two different occasions to accommodate each others' needs:

> *Anita usually comes on a Friday, but this week we finish early and we've always been able to adapt it. Like last Friday we couldn't do so we moved it around. It's always worked out. We're both willing to shuffle things around to make it work.*
>
> (Ms Marie Curie, Interview)

The readiness to alter times to accommodate the teaching time further demonstrates the high level of collaboration that existed between these partners.

Partnership 2: Ms Rosalind Franklin and Barbara McClintock

Ms Rosalind Franklin appeared to have a medium level of collaboration with preservice partner Barbara McClintock, although these partners did not agree on the level of collaboration on any of the planning, implementing and reflection scales in their final questionnaire. Ms Franklin reported minimal collaboration for planning where as Barbara reported it at a medium level. Ms Franklin's minimal rating was explained by her comment about how she had already planned and begun to implement an inquiry unit with the class, which limited the amount of collaborative planning she could then undertake with Barbara:

> *Because the inquiry was already part planned, partly planned because you can't plan an inquiry, we got together and discussed - I said, well this is what you can do and we're leading up to this assessment.*
>
> (Ms Rosalind Franklin, Interview)

Barbara McClintock supported the description provided by Ms Franklin with her description of how they worked together in planning:

> *It was already pre-planned but the first two lessons we worked on together. She suggested ideas and I suggested ideas then we put those together.*
>
> (Barbara McClintock, Round Table Discussion 2)

However, here some level of collaboration is suggested here by the use of the term 'we': '*we worked on together'*, '*we put those together*'. The use of this inclusive language suggests that at least some collaboration was occurring where it was possible given the restrictions the partly implemented unit placed on the partnership.

There were further data that suggested that a limited level of collaboration was achieved in the planning phase. This is highlighted in the following interview excerpt:

Rosalind: Because there was only about the two lessons where it was left to Barbara to plan, I sort of went in and said well this is what I've been doing and left it quite open for her.

Mellita: So there were two lessons that Barbara planned pretty much on her own did she?

Rosalind: Pretty much, yep.

Mellita: And did she come to you before presenting them, for feedback?

Rosalind: Yep, Yes we chatted, yep.

Mellita: And how many lessons has she been here for, do you know off the top of your head?

Rosalind: Four or five.

Mellita: So the other two or three lessons - it doesn't matter how many exactly, but with those other ones, how were they planned?

Rosalind: That's when the students went on their on tangents, so it was more …we both had the same sort of role as in just helping them research their question.

Mellita: So there wasn't a lot of pre-planning for those?

Rosalind: No, it was just walk in and respond to the kids.

(Ms Rosalind Franklin, Interview)

This excerpt indicates that Barbara did the planning alone and then sought feedback from Ms Franklin for the two lessons that were still open enough for her to contribute to. A partnership with stronger collaboration would likely have seen Barbara and Ms Franklin planning and refining these lessons together.

From the feedback provided by Barbara and Ms Franklin when describing some of their lessons, it was also obvious that there was some team teaching occurring:

Then the students went on their on tangents, so it was more a…we both had the same sort of role as in just helping them research their question

(Ms Rosalind Franklin, Interview)

We're doing POE [Predict, Observe, Explain]. So they're predicting, observing, explaining and then we do - they do POET [Predict, Observe, Explain, Teacher Explanation] - so at the end it's Teacher Explanation.

(Barbara McClintock, Round Table Discussion 1)

It is the use of inclusive language (e.g. ‘we both had…’ and ‘we’re doing…’) that suggests the team teaching in these excerpts. This team teaching was recognised by Barbara’s High response to the item on collaboration in the implementation phase, but Ms Franklin only marked it as Medium. There was a situation where a timetable change at the school: ‘*I was unable to complete my science visit this week as Rosalind had to reschedule the lesson to a time where I could not possibly make it* ‘ (Barbara McClintock, Online Discussion September 19, 2007). This meant that Barbara could not make one of the classes and this may have impacted on Ms Franklin's judgement of the level of collaboration in the implementation phase.

Reflection was recorded as highly collaborative by Ms Franklin who indicated that it was focussed on the performance of both practising and preservice teacher. It is interesting then, that Barbara recorded her response at the low end of the scale, where she indicates she received teacher feedback but completed her reflection on her own. From the interview with Ms Franklin, a reasonable attempt at reflection was made, where they did sit together regularly, straight after each lesson:

> *We used to sit down, because we did have the recess directly after, and have a bit of a chat about how we thought it went and what we might do next time.*
> (Ms Rosalind Franklin, Interview)

The focus of reflection, according to Ms Franklin, was on '*how we thought it went and what we might do next time*' (Ms Rosalind Franklin, Interview) and she indicated having discussed classroom management, giving children instructions, and class preparation. However the lack of written reflection using the planning and reflection booklets made it informal in nature.

The contrasting levels of collaboration reported by these partners for the reflection scale is difficult to explain from other data collected. Ms Franklin, for example, reported that '*time for reflection of own teaching'* (Ms Rosalind Franklin, Final Questionnaire) was one of the key outcomes from her project involvement when asked what she had achieved in the final questionnaire. Perhaps Barbara had a different perception of what the joint reflection should have constituted, or perhaps they each completed more individual than collaborative reflection. From the data though, reflection appeared to be collaborative, though informal.

Taking all of these factors into account, this partnership appears to have been moderately collaborative.

Partnership 3: Ms Diane Fossey and Jocelyn Burnell

The partnership between Ms Diane Fossey and Jocelyn Burnell was possibly best described in the final workshop session when Jocelyn Burnell responded with '*What Partnership?'* when asked what the highlights and challenges of her partnership had been. There is no evidence that there was collaboration at any stage of the project between these participants. Ms Fossey was not able to attend the first participant workshop, and in her interview, when reminded about the date for the final workshop she responded with *'At this stage that should be ok, but who knows what might come up between now and then'* (Ms Diane Fossey, Interview). As anticipated from this response, Ms Fossey failed to attend the final workshop or notify anyone that she would not be able to attend.

When asked to describe the nature of the partnership in her interview, Ms Fossey responded with:

> *Well to be perfectly honest I don't like giving too strict guidelines to my students because I like to allow them to have a bit of initiative themselves. And to show some of their own kind of flair. So basically what I did with my student was I explained to her what our topic was and that we already had a few ideas for three or four or five science experiments and I showed them to her and I said that these were the sorts of things that we'd like to cover because it fits in with our unit, and I actually just gave her the guidelines for the lessons, and I just left it at that and we just arranged for a time. So, that's where I started.*
>
> *Actually the only other thing I probably would have put in guidelines was I just said to them that the children very much enjoy hands on things and so if she could give them something where they could get really involved and that we were also looking at the genre of procedural or experiment writing. So I said that at the end of each lesson I would like them to be able to complete one of those'*
>
> (Ms Diane Fossey, Interview)

The language used in this interview excerpt suggests that there was very little collaboration between the practising and preservice teacher. There is a clear distinction made between individuals: '*I let them know'* and '*I explained'*, '*I would like*'. This is quite different from the inclusive language used in the first two partnerships where inclusive language pointed towards collaborative partnerships.

Jocelyn's description of the first meeting she had with her teacher partner reinforces the assessment of this partnership as non-collaborative:

> *So she gave me these pages out of a folder that were photocopied out of a book … and she said 'off you go'. I came in with a lot of ideas about what I'd like to do and I told her about one prac … and she said 'that's silly, what would they get from that?' So I was just 'ugghhh, I can't do this' after that. So the first time I went I did the slinky prac … it just involved the kids modelling Earthquake waves with slinkies and she told me that I need to learn more about the topic but at the same time she just sat back and did nothing.*
>
> (Jocelyn Burnell, Round Table Discussion 2)

Ms Fossey confirmed that Jocelyn performed the planning on her own, without any guidance or input:

Mellita *With the planning then of the lessons, did Jocelyn do that on her own or did you do that together, in collaboration?*

Diane *No, she basically did that on her own. I didn't give any instructions on how the lessons should be planned because I thought that a 3rd year student* *should be able to do that.*

Mellita *Did she come and talk to you about the lessons, prior to delivering them? Like was there any sort of collaboration on the…*

Diane *Not really on the first two, but she just sent me a bit of a guideline for the third lesson, and that's explaining that she'd like the children put into groups and things like that, and what she's going to do. So I thought that was good, it looks like it's going to be more thorough this time.*

(Ms Diane Fossey, Interview)

In fact the preservice teacher, Jocelyn Burnell, had approached me quite upset about the way her partnership was unfolding. After indicating there had been little to no collaboration to date, I encouraged Jocelyn to take the plan for her next lesson to Ms Fossey and ask for some comments and feedback. The interview with Ms Fossey confirms that Jocelyn did do this where she indicates '*she just sent me a bit of a guideline for the third lesson … explaining that she'd like the children put into groups and things like that, and what she's going to do*', but it is difficult to judge the tone of the request and whether it would have encouraged any further collaboration between the partners.

Jocelyn constantly discussed feelings of frustration and embarrassment in working with Ms Fossey. It became apparent once the project had started that she already had a student teacher from a higher year level of the same course and same university, working with her in a formal professional experience round. Jocelyn reported an occasion where Ms Fossey left the room to conduct a recovery reading session with a student from another class while she was teaching:

And yesterday (she) actually left her fourth year student in charge while she sat out in the corridor and did reading tests with a child who wasn't even from her class
(Jocelyn Burnell, Online Discussion September 14, 2007)

Jocelyn recorded levels of collaboration at the lowest level for planning and reflection, but acknowledged Ms Fossey's contribution to one of the class discussion's held by recording 'Some Team Teaching' in response to collaboration on implementation.

In describing a typical post-lesson reflection, Ms Fossey explained:

Well I guess I haven't done any written reflections… Usually I would sit down and do a written reflection when the lesson was happening
(Ms Diane Fossey, Interview)

The wording of this suggests that Ms Fossey's idea of post-lesson reflection was to provide a written comment on Jocelyn's performance, similar to that in a teaching round situation, although if that was the case, there is no indication of why she did not even do that. Either way, it further reinforces the apparent lack of any understanding of working, or intention to work, collaboratively with Jocelyn. It is frustrating that this was how the partnership unfolded given the one-to-one time I spent with Ms Fossey to explain the project, the collaboration and the action-reflection cycle after she was unable to attend the initial participant meeting. All of the material was provided in both written format and the written material was used as a basis for the verbal explanation that accompanied it. This meeting was held at Ms Fossey's school at a time she nominated, so in terms of negotiating the most suitable time and place, Ms Fossey should have been able to absorb the information we went through together.

The extent of the non-collaboration and the impact it had was highlighted by one of the responses Ms Fossey gave in describing a post-lesson reflection:

> *I did just speak to her the other day and that was after the centripetal force one, and I said that they enjoyed it and all that sort of thing and the discussion that was in there was good… but she needed to be able to explain exactly why that happened. And I ... I'm embarrassed to say that she was embarrassed that I said that, but I felt it really had to be said. I said 'don't worry about it, but you did need to know that because you're the one imparting this knowledge so you have to be able to explain it'.*
>
> (Ms Diane Fossey, Interview)

Jocelyn described this situation as a humiliating experience of criticism given in front of the children and the 4th year student teacher and discussed its impact on her in her online discussion post:

> *Yesterday we did an experiment on centripetal force using buckets and water and when I attempted to have a discussion I was looking to her for clarification and later on (in front of the class) she told me that I needed to do more research because she didn't know anything about it. … Needless to say my confidence completely diminished when she said that and I'm sure the students lost any respect they had for me.*
>
> (Jocelyn Burnell, Online Discussion September 14, 2007)

Ms Fossey acknowledged in the interview that the feedback given had embarrassed Jocelyn and that she was embarrassed it had made her feel this way. What she did not realise was the lasting affect it had on Jocelyn, both in her confidence to teach science, and her confidence to approach Ms Fossey for any sort of direction. Jocelyn expressed this in one of the round table discussions when asked if she had approached Ms Fossey about getting back the equipment she had purchased and supplied, for the previous week's practical lesson, stating 'No. *I'm not comfortable being around her at all. I'm terrified of getting rounds at that school'* (Jocelyn Burnell, Round Table Discussion 2).

Jocelyn's already low confidence was adversely affected by her experience and possibly contributed to the extent of the lack of collaboration. Lacking confidence and being a fairly demure personality, working with the stronger personality in Ms Fossey meant that she avoided opportunities to approach Ms Fossey on planning or reflecting, and essentially waited and let Ms Fossey set the tone. Only after approaching me and being urged to take the next lesson's plan to her to ask to talk about it did she approach Ms Fossey at all. Even then Jocelyn 'dropped the lesson plan off' rather than trying to make a time for them to talk together.

In spite of having met with Ms Fossey to outline the project and provide some documentation after she did not attend the initial participant workshop, Ms Fossey still reported thinking she was going to get 'a science expert' to come and take some science lessons for her in her interview. In addition to information provided through her interview and descriptions from Jocelyn, it is clear that Ms Fossey had little to no understanding of the model that was supposed to be in place. Together these factors highlight how important the initial workshop is in creating a shared understanding and the beginning of fostering a supportive relationship between partners. It also demonstrates the destructive potential a poor partnership can have in a professional learning model such as the one encouraged in this project and certainly helps to explain why Jocelyn's self-assessed confidence and PSTE scores decreased after her involvement.

Partnership 4: Ms Jane Goodall, Helen Dunbar and Gertrude Elion

Ms Jane Goodall's partnership with Helen Dunbar and Gertrude Elion was also minimally collaborative. Ms Goodall, from the same school as Ms Fossey, had also been unable to attend the initial workshop, which may have impacted on her level of understanding of the model being used in this project, although again, she was provided with a range of documentation and a face-to-face meeting to go through it at a time and place she nominated.

In spite of this, Ms Goodall also indicated in her interview that she was expecting a 'science expert' who would be able to provide her with new ideas and enhance her children's learning in science: '*I was under the understanding that this was their specialist area and I thought we'd get some people with some real strength in science and understanding the process of the science inquiry'* (Ms Jane Goodall, Interview). However, this does not necessarily explain why such little collaboration resulted from the partnership. The lack of collaboration, as in the case of Ms Fossey, was recognised through the exclusive language Ms Goodall adopted in describing her partnership:

> *I let Gertrude and Helen know what we'd done so far as a focus …so having given the girls the background, I asked them did they have good resources because I pointed them in the direction of our resources, but they said they were pretty well resourced at Uni, so that was ok. Then I let them know the lessons we'd done in the first few weeks of this term and made a few suggestions about ways to go, but probably, I wanted to see what scope they had. There was no use in me just driving an engine that I could have done myself. It was let's see what new things are out there rather than what I'm thinking of. So the girls have devised that themselves.*
>
> (Ms Jane Goodall, Interview)

Again phrases like '*I let them ..*', '*I asked them ..*' '*I wanted …*' imply the lack of collaboration in this partnership. Ms Goodall also specifically stated 'I wanted to see what scope they had. '*There was no use in me just driving an engine that I could have done myself*' (Ms Jane Goodall, Interview) which emphasises her deliberate distancing from the preservice teachers' planning and teaching as she waited to '*see what new things were out there'*.

Reinforcing this interpretation of the partnership nature, Gertrude Elion reported:

> *We've only been once, so far and it probably wasn't that supportive ... The teacher hasn't supported us, like we've been left on our own to plan and that so we're a little unsure of what we're doing and what we could be doing.*
>
> (Gertrude Elion, Round Table Discussion 1)

This lack of collaboration did not change as time went on as this excerpt from the final round table discussion demonstrates:

Gertrude Elion	*Well, we worked together, but maybe without the teacher.*
Mellita	*So it was collaborative between the two of you?*
Helen Dunbar	*Yeah, at least we worked together well.*
Gertrude Elion	*If we'd been by ourselves I don't know how we would have gone.*
Gertrude Elion	*There was that one idea she gave us.*
Mellita	*Was that to give you an idea that you had to go and develop or was it to give you an idea and work with you to develop?*
Gertrude Elion	*The one idea she gave us? That was she wanted it done.*
Mellita	*And then made you go and develop it or worked with you to develop it?*
Gertrude Elion	*No. She said to us like 5 minutes after the lesson - we were going through what we had already planned - and she said I'd like you to do fossils. That was it. We had to work out what to do. We had to buy all the equipment. We had to set it up, everything. She didn't help one little bit.*
Mellita	*So you don't feel that it was very successful?*

Helen Dunbar *Not really. Especially because one week she got confused and when we rocked up they were off swimming - so we left her a note and left. That was a bit upsetting.*

(Round Table Discussion 2)

In discussing planning, Ms Goodall indicated that '*it would be good if they could either run things through you or me*' (Ms Jane Goodall, Interview) suggesting that the preservice teachers planned and implemented sessions without her knowing anything about the lesson content or strategies, further highlighting the lack of collaboration in lesson preparation. In spite of this Ms Goodall indicated that collaboration in planning lessons was at the medium level when responding to this item on her final questionnaire. Helen Dunbar and Gertrude Elion indicated a minimal level of collaboration on planning on their final questionnaires, and together these responses from Ms Goodall and the two preservice teachers suggests that the minimal rating Helen and Gertrude gave their collaboration was closer to the truth in terms of what was meant as collaborative planning in this project.

Implementation of lessons was also reported at a medium level of collaboration by Ms Goodall and Helen on their respective final questionnaires. Gertrude indicated there had been no team teaching in her response. The preservice teachers did allude to one occasion where Ms Goodall had contributed to a class discussion, which may be what was in the mind of the partners in indicating some team teaching on their questionnaire.

In terms of reflection, all three partners agreed that lesson feedback had been provided by Ms Goodall, but then the preservice teacher partners were left to reflect on this feedback on their own. This was also supported by comments Ms Goodall made in her interview about reflection:

> *I didn't ask for anything written, but I did specify along the way that they should be reflecting on what their process was and what their discoveries were and how to explain their observations. So I probably guided them in some ways as to the focus.*
>
> (Ms Jane Goodall, Interview)

Again the language '*I didn't ask for …*' '*I did specify …*' 'that they should …' indicates the manner in which Ms Goodall made reflection the sole responsibility of the preservice teachers rather than something to be shared that focused on each of them jointly.

The evidence from these partners points to the partnership as being non-collaborative in nature. This may have contributed to the small increases in confidence shown in Gertrude's and Helen's PSTE and self-assessed confidence scores which showed increases of 1.2 (self-assessed confidence) and 4 (PSTE) for Gertrude and 0.4 (self assessed confidence) and 0 (PSTE) for Helen. The one feature that appeared to save these preservice teachers from the same detrimental experience suffered by Jocelyn Burnell was that they had each other for support. Both Gertrude and Helen expressed this when they commented '*If we'd been by ourselves I don't know how we would have gone'* (Gertrude Elion, Round Table Discussion 2) and '*I don't think I would have coped if I had been by myself though*' (Helen Dunbar, Round Table Discussion 2).

This suggests that placing preservice teachers in pairs to form collaborative partnerships with practising teachers could provide a safety net in case the partnership with the practising teacher becomes unsupportive.

Partnership 5: Ms Annie Easley, Gerty Cori and Rachel Zimmerman

Ms Annie Easley appeared to have a moderately high collaborative partnership with preservice teachers Gerty Cori and Rachel Zimmerman. Each of the preservice teacher partners expressed this in her description of the partnership:

> *We did the planning together with the teacher; sort of sat there and went through what we might do for the first week. Like she had her ideas but she was very willing to take on board what we had to say as well which was good.*
> (Gerty Cori, Round Table Discussion 1)

> *We met together and so we planned together, so it was fairly collaborative …. She asked us what we wanted to do rather than just 'oh, we'll do this'.*
> (Rachel Zimmerman, Round Table Discussion 2)

Ms Easley was the student teacher coordinator and science specialist teacher in the school and made a number of comments concerning her ability to step back from these roles as she strove to achieve the collaboration in the partnership, particularly in the planning stage:

> *It's a challenge for a teacher to do that* (not dominate planning), *especially when you know what works for you and what doesn't, but that doesn't mean to say it's the same for them, it could be quite different. What doesn't work for you might be right - just in their personality and fit.*
> (Ms Annie Easley, Interview)

However, the feedback from the preservice teachers indicated she did successfully meet the challenge, and Ms Easley also acknowledged their team approach, discussing the shared responsibility they achieved:

> *But the planning: 'what do you want to do?'… sometimes they ummed and ahhed a little bit, and you could understand why. I know what I would do but I didn't push it necessarily. And I ummed and ahhed when I did suggest, giving the impression*

> *that I didn't necessarily ... and that I was willing to fit in, but the problem was all three of us were jockeying around. Between us we settled on something. 'You do something, I'll do that aspect, you do that aspect, but they all dove-tailed anyway. It was shared responsibility.*
>
> (Ms Annie Easley, Interview)

On the final questionnaire, Ms Easley indicated that the planning phase of the partnership had been achieved with a medium level of collaboration. Rachel Zimmerman also responded that planning had been achieved at a medium collaborative level. Rachel was the weaker of the two preservice teachers in this partnership, both in content knowledge, general academic ability and in strength of conviction. This may have contributed to some of the '*umming*' and '*aahing*' Ms Easley referred to in describing planning sessions. Gerty Cori, a preservice teacher with a strong personality, recorded the level of collaboration in planning to be at a high level. This suggests that Ms Easley must have convincingly established a role of equality in the partnership in spite of her extensive background in leading science professional development and as a student teacher coordinator.

In describing implementation of lessons, all partners indicated collaboration had been high with a team teaching approach. Comments from online and round table discussions and the interview with Ms Easley confirm this as each discussed running group rotation activities with each of them leading one activity each week. For example:

> *We'd each have a station and we wouldn't discuss really what we were doing in our own station, well not very deeply anyway. It was up to the individual person what they did. And that happened in quite a few of the lessons where they'd be split into sections and one person would take each section.*
>
> (Gerty Cori, Round Table Discussion 2)

> *We took little groups away so kids could have a, well, so they could have a small group as their first approach to the kids. So we operated three groups and we rotated them. So that just gave them a chance to have a small group to start with and good practice anyway.*
>
> (Ms Annie Easley, Interview)

However, reflection was not strongly evident in this partnership. Ms Easley reported that it was highly collaborative in the final questionnaire, but Gerty and Rachel both felt it was more focussed on their performance as preservice teachers than the performance of each partner. Perhaps this was where Ms Easley failed to meet the challenge of acting as partner rather than mentor. Whatever the focus of reflection, it was certainly very informal. This was captured by Ms Easley's description of reflection as being '*Very casual. No structure to it, because we didn't put structure to it'*

(Ms Annie Easley, Interview). This also indicated that this partnership failed to utilise the structure for reflection provided by the planning and reflection booklet.

Ms Easley did indicate that reflection was a 'chat' '*about what we'd do next, and we got together then on the Thursday after school and formalised that into a running sheet, that's literally what it was'* (Ms Annie Easley, Interview). She went on to explain why future direction was a natural form of reflection for their partnership:

> *I think you'd have to be aware of the need to [reflect], under certain circumstances. If the kids weren't managing the students I think you'd then need to go back to that step because it becomes an issue, but each of the three of us were comfortable just prodding the child, so that wasn't a real issue, the behavioural part. Just which things we were going to do we reflected on - we immediately turned our reflection on to the forward because there was not anything to dwell on.*
>
> (Ms Annie Easley, Interview)

Ms Easley's response here indicated that she viewed reflection as a tool for improving on things that were not working. Because she did not have a sense of anything 'going wrong' as such, it became natural for her to refocus reflection time into planning time '*we immediately turned our reflection on to the forward because there was not anything to dwell on'*. This was disappointing in that the benefits of looking at strengths as well as weaknesses were not articulated to ensure they were overt in further planning which could have helped all partners, and Rachel in particular.

Overall though, the evidence suggests that this partnership achieved a moderately high level of collaboration.

Partnership 6: Ms Virginia Apgar, Maria Mayar and Grace Hooper

In many regards, the partnership consisting of Ms Virginia Apgar, Maria Mayar and Grace Hooper was one of the most collaborative based on the variety of data collected from these partners. This was apparent from the comments each partner contributed through qualitative data collection. For example:

> *We brainstormed topics of interest and how we could present them. Then we went back to the 5Es and used it as a quick checklist on where each E was occurring in what we planned…We had the same workload. They were dedicated, hardworking and professional, and then the shared philosophy became evident.*
>
> (Ms Virginia Apgar, Interview)

> *Virginia's been really good because she - we kind of planned it all together, she kind of said here are some ideas we could have and we had ideas and we threw them all in on the table and planned the lesson. So she's been really good, really supportive.*
>
> (Maria Mayar, Round Table Discussion 1)

> *We organised the activities to be doing rather than recording to capitalise on this preferred method of learning.*
>
> (Grace Hooper, Online Discussion August 28, 2007)

Here there is both explicit evidence '*We had the same workload'* (Ms Virginia Apgar), *'we kind of planned it all together'* (Maria Mayar) as well as implicit indications that the partnership was collaborative through the inclusive style of language '*We organised …*', '*We brainstormed …*' that has been discussed in previous examples of collaboration.

Early in the partnerships however, there was one occasion of frustration expressed when Maria reported that Ms Apgar changed the planned lesson at the last minute and she felt that she had no real recourse:

> *Ultimately it's the teacher that says yay or nay and so it's a bit hard you know, negotiating. We came up all together with the idea of chromatography, … and we emailed her our ideas, but when we got there on Monday she'd changed it around so it wasn't kind of in the same context as we had it so it kind of made it hard … And then she changed around the engagement one where we were going to have with the secret note, that's the one that she said 'we'll do that at the end' but that was the one that was going to engage all the students and see if they could work out and see if they had prior knowledge as to what we could do.*
>
> (Maria Mayar, Round Table Discussion 1)

Apart from this occasion, all contributions from these partners indicated that a highly collaborative partnership existed. In fact each partner recorded planning, implementation and reflection to have been at the highest level of collaboration in responses on their final questionnaire, indicating that there was independent consensus between the partners that their planning was highly collaborative, implementation was achieved through tam teaching and reflection focussed on the performance and potential for improvement of all partners.

Although collaborative in nature, reflection was informal between these partners. Ms Apgar communicated this in her interview, stating:

> *We could have done a better job of reflection. We reflected on the run, it was incidental.*
>
> (Ms Virginia Apgar, Interview)

The planning and reflection book was again not employed as a tool to guide either planning or reflection in this partnership. This left the focus of reflection on the recollection of '*previous good things we wanted to incorporate again*' (Ms Virginia Apgar, Interview). She stated that '*Formal* *reflection would have been wonderful, but the girls had a lecture immediately after the teaching session*' (Ms Virginia Apgar, Interview).

Overall though, this partnership achieved one of the highest levels of collaboration, something that was acknowledged by all partners.

Partnership 7: Mr John Dalton, Dorothy Hodgkin and Lise Meitner

The partnership between Mr John Dalton, Dorothy Hodgkin and Lise Meitner provided another strong example of collaboration. Mr Dalton came to the project after being approached by the then science co-ordinator, Mr Robert Boyle, because Mr Dalton was to take over the coordination the following year. In spite of this, Mr Dalton confided that he was not especially qualified in science, but at the same time he did not shy away from it as many teachers do, so thought he could assist the school when they were looking for a new science coordinator. According to his responses on the initial questionnaire, Mr Dalton was relatively inexperienced, only in his fourth year of teaching, but appeared to be quite open-minded and enthusiastic. In his interview, he reported being nervous about having other adults in the room while he was teaching and avoided parent helpers for this reason. The opportunity to work with the preservice teachers was likely to act as a safe stepping stone to building confidence given they were not yet qualified, and did not have the vested interest a critical parent might have.

The questionnaire results on levels of collaboration were interesting in this partnership as there was little agreement between practising and preservice teachers. Mr Dalton felt that there had been minimal collaboration between them in the stages of lesson planning, but Lise ranked this at a Medium level and Dorothy thought it was High. Feedback through interview data and online and round table discussion suggest that it was reasonably high. For example:

> *We just sat down originally and discussed what each of us might want to do. The girls gave me a few ideas of what they wanted to do and I put down a few ideas and what weeks we wanted to do them. We have changed it a little bit. So yeah, we plan together.*
>
> (Mr John Dalton, Interview)

Lise and Dorothy also reported on their partnership as one of collaboration:

Lise	*We were at Promethium Primary with Mr John Dalton.*
Dorothy	*So we'd usually just go in there half an hour before to set up.*
Lise	*We'd plan them the week before at the end of the last lesson and then*

	we'd get them set up in that half an hour.
Dorothy	*And he was really, really helpful. He was really good.*
Researcher	*So it was collaborative you think?*
Dorothy	*Yeah*
Lise	*Yeah, he was really good at working with us.*
Dorothy	*Yeah, and even with the first one that we organised, he set up everything and helped us.*
Lise	*Yeah, he was really good.*

(Round Table Discussion 2)

Lise and Dorothy were both very positive in reporting on details of how planning, organisation and setting up of lessons occurred, stating explicitly in round table discussions that it was a collaborative process. It is more difficult to judge how collaborative lesson delivery was from data in the round tables, online discussions and teacher interviews. However, Lise and Dorothy both reported it at the highest level in their questionnaire responses. Mr Dalton indicated that there had been some team teaching by responding at the medium level response option. Similarly on the item concerned with collaborative reflection, Mr Dalton reported medium collaboration and Lise and Dorothy reported that it was at a high level. Again there was no explicit evidence in the qualitative data to confirm the level. It was however, very casual and occurred '*just when we're packing up, we'll have a talk about it, you know*' (Mr John Dalton, Interview). The focus of reflection in this partnership was '*around 'did the kids enjoy it?', um, then the other one we talked through is' did they understand it?' - did they understand the science behind it'* (Mr John Dalton, Interview).

While there is some discordance in the questionnaire responses from these individuals, other data support the assessment of this collaboration to be at a reasonably high level. There is evidence of collaborative planning and reflection from descriptions given by Mr Dalton and both preservice teachers. Comparing the feedback from this partnership with other partnerships, it would appear to have been moderately high in collaborative effort.

Partnership 8: Mr Robert Boyle, Linda Buck and Rachel Carson

Mr Robert Boyle and preservice teachers Linda Buck and Rachel Carson also reported their partnership to be one of moderately high level of collaboration. In fact, Linda responded at the highest level when she reported on collaborative levels across all phases of planning, implementation and reflection. Rachel also felt that lesson delivery was highly collaborative, but reported collaboration in planning and reflection to be at a medium level. Mr Boyle judged each area, planning, implementation and reflection, at the medium collaboration level.

From data collected in interview and through round table and online discussion, team teaching between each partnership member was evident. This has come from the descriptions given of particular lessons where it was clear what role each team member played. For example:

> *More of a team teaching thing you know I guess it would have been. And other times we did umm it has enabled us to run group rotations and there was a person at each table.*
>
> (Mr Robert Boyle, Interview)

> *He was really helpful and he joined in the discussions and like it was definitely a three way teaching of the lesson.*
>
> (Linda Buck, Round Table Discussion 2)

This is also true for planning, where ideas for individual lessons and refining of these ideas appeared to be a collaborative team effort using joint research and resources.

> *We'd go in the office and think about what we want to cover next. What ideas and then I'd pull out my resources and we'd try to decide on one or a few ways to cover the idea and experiments to support it and then we'd kind of roughly agree on who would get what, who would prepare what and then confirm via email early the next week. So it was ok but it was more adhoc than say lesson plans, but that's probably also reflective of teaching, you know of reality I guess too.*
>
> (Mr Robert Boyle, Interview)

> *We've had two lessons and I think it has worked out really well. Like our teacher was supportive he just feeds us all this stuff and he's given us resources, like ideas for resources.*
>
> (Linda Buck, Round Table Discussion 1)

Linda	*I think it went really well. We worked together really well.*
Mellita	*The three of you?*
Linda	*The three of us. Robert gave us ideas and sat down and said 'oh, we could do this and this'*
Rachel	*He gave us a lot of ideas but then it was up to us to choose what we really wanted to do.*

(Round Table Discussion 2)

Mr Boyle was an experienced teacher who indicated that science was a priority in his teaching. He was the science coordinator in the school and had recent experience as a sessional tutor in science education at a university level. He had fairly traditional views about professional experience and there was an indication that he was struggling to separate his view of professional experience with this partnership-based experience that was associated with an academic unit, rather than a professional experience round. This emerged through a number of interview responses, including the one shown above where he indicated planning was '*ok*' but '*a bit adhoc compared to lesson plans'*.

From the questionnaire responses, round table and online discussion data and interview data, this partnership did present as being of moderately high collaboration although one where Mr Boyle acted as more of a mentor than an equal partner. This is evident in the way he provided resources, but then '*let'* the preservice teachers '*choose'* as they described it. It was also evident through comments like:

> *Well I suppose, I guess it ummm, it is a partnership and I can jump in or they can jump in but I still kind of wanted them to have a go by themselves as well. So it' s a little bit like a round in that sense. That I …, I sort of think that they should make the most of it and have a go and do stuff. But then again for like we did we did share the jobs. Like today I introduced something and they did this and then you know ... there's three of us there.*
>
> (Mr Robert Boyle, Interview)

Here, Mr Boyle's stopping and starting, umming and repeating himself shows almost a reluctance to participate equally in the partnership. He appeared to feel a need to maintain the role of 'supervisor' of 'students on a round', where the focus was on 'them having a go' and on their learning.. Towards the end of the interview this was also communicated in how he defined his role in a general sense:

> *I always take opportunities for science teaching. I consider it as part of my role to spread the word as much as I can or encourage as many people as possible to have a go at teaching science.*
>
> (Mr Robert Boyle, Interview)

This did not inhibit the partnership experience though, as both preservice teachers reported strong growth in confidence and knowledge and were the two preservice teachers who showed the greatest growth in understanding of science pedagogy. This is discussed later in this section when growth in knowledge is considered in more detail.

Reflection was again quite casual in this partnership as highlighted by Mr Boyle:

> *More of an oral reflection, there was no written reflection, and it was fairly rushed because I had yard duty and they often come out and we'd have a bit of a chat while I was supervising the kids. Um, that was probably the most of it.*
>
> (Mr Robert Boyle, Interview)

The focus of their reflection was on whether experiments had worked well and whether underlying concepts had come through as well as where they would go next. The fact that this partnership taught a mini-unit rather than one off disconnected lessons did mean that reflection of this nature allowed greater opportunity to correct things they felt had not gone well and reinforce student understanding where they identified such a need. Overall, this partnership was one of a moderately high level of collaboration. This was recognised by the medium to high ratings of collaboration each partner gave the planning, implementing and reflecting processes, although there is a strong sense that Mr Boyle found it difficult to see himself outside the mentor role.

Summary of Partnerships

Results indicated that six of the eight partnerships were mostly collaborative. The level of collaboration in these partnerships varied between medium and high according to practising and preservice teacher partners involved. One partnership demonstrated an exceptionally high level of collaboration. This was the partnership between Ms Marie Curie and Anita Roberts. Four partnerships demonstrated moderately high levels of collaboration. These were those between Ms Virginia Apgar, Maria Mayar and Grace Hooper; Ms Annie Easley, Rachel Zimmerman and Gerty Cori; Mr John Dalton, Dorothy Hodgkin and Lise Meitner; and Mr Robert Boyle, Linda Buck and Rachel Carson. The partnership between Ms Rosalind Franklin and Barbara McClintock demonstrated a moderate level of collaboration. The extent of collaboration in this partnership was minimised by the fact that an inquiry unit was already underway when the partnership period began, rather than from a lack of willingness from either partner to collaborate.

There were two partnerships that showed little to no collaboration. This was reported emphatically by the preservice teachers involved and alluded to by the relevant practising teachers. The two partnerships concerned were those between Ms Jane Goodall, Gertrude Elion and Helen Dunbar; and Ms Diane Fossey and Jocelyn Burnell. There was some collaboration between the two preservice teachers Helen Dunbar and Gertrude Elion, who were fortunate enough to be paired together with their practising teacher, Ms Jane Goodall, who did not participate as an active partner at all. Jocelyn Burnell did not have a preservice teacher partner, and her practising teacher partner, Ms Diane Fossey, took no interest in her or the project, and did not participate at any stage of the partnership period. This left Jocelyn affected quite detrimentally when it came to confidence and a positive experience of science teaching.

In general, the nature of reflection between partners was very casual but was mostly collaborative. Reflection centred on a range of aspects including ideas for improving student understanding, changes to lesson structure, timing of lessons and their components, changes in the implementation of experimental work and research going into the preparation and planning of lessons. The 5Es model formed the basis for a specific component of reflection in the planning and reflection booklet (see Appendix 4). Had this booklet been used more widely by partners, reflection on the 5Es model may also have been more extensively represented in how practising teachers reported the focus of the partnerships' reflection. Further, had this booklet been utilised, aspects of lessons may have been highlighted as less effective. Usually when there is an expectation held by all parties to think about what is and is not working, ideas will begin to emerge. By omitting the opportunity for this it automatically ensured that this thinking and subsequent learning from it, would not take place.

The impact of the non-collaborative approach was evident in limiting growth in efficacy and in fact retarded efficacy levels in Jocelyn Burnell's case. What remains to be investigated is whether or not they provided an opportunity for the growth in knowledge to enable effective science teaching. This, along with participants' evaluation of the partnership model, is explored in the following sections of this chapter.

4.5 Development of Knowledge

The development of knowledge is an area of important focus for the research and relates to the third research sub-question: *What are the effects of action-reflection in collaborative partnerships between practising and preservice teachers on knowledge, attitudes and self-efficacy beliefs of preservice teachers towards science education?* Here, knowledge can be examined in two ways: general content knowledge and pedagogical content knowledge. Pedagogical content knowledge (PCK), relating to approaches to teaching science, was the primary area of knowledge development targeted in the research. This was informed by the literature review which indicated wide-spread concern with the poor approaches to science teaching often adopted in primary schools. Although general content knowledge (GCK) was also highlighted as a concern in the literature, it was hoped that by targeting self-efficacy beliefs and teaching approaches, more science teaching would result and development of GCK would follow later, as more teaching experience was gained after the project.

The focus on PCK was evident through the design of the research where the 5Es model was intended to be used as a framework for partnerships to base their science lesson planning and implementation.

A range of data sources was used to explore the development of GCK and PCK including practising teacher interviews, round table and online discussions with preservice teachers, and data from the final participant workshop. To explore the level of knowledge development, practising teachers were asked in interviews whether their experience in the partnership had had any impact on their learning about science in regard to their science knowledge and/or its teaching. They were also asked to discuss their use of the 5Es framework. This enabled data on specific teaching approaches as well as any other learning that may have occurred, to be shared. In round table discussions, preservice teachers were asked to highlight 'critical moments' and to discuss how they felt their knowledge and understanding of science and/or science teaching were being affected by their experience. They were also asked to discuss the application of the 5Es in both round table and online discussions. In the final participant workshop partners presented their best examples of applying the 5Es which provided an additional source of data to consolidate findings from interview, round table and online discussions.

These data were reviewed, coded and categorised into sub-themes under the two key categories of GCK and PCK which are discussed below.

Development in General Content Knowledge (GCK)

The development in GCK was reported by a number of the research participants, and was more evident in preservice teachers' comments than those of practising teachers.

Three practising teachers reported some growth in GCK as a result of their partnerships. These were Ms Annie Easley, Ms Virginia Apgar and Ms Marie Curie. Ms Easley shared that '*it pointed out that I don't know as much about the terminology for sound as I thought I did'* (Ms Annie Easley, Interview) while Ms Apgar stated '*I've learnt how to use the Interactive Whiteboard both generally and in a science context*' (Ms Virginia Apgar, Interview). Ms Curie shared a number of learning experiences such as '*I wouldn't have had a clue that vinegar and bicarb soda made a volcano erupt, little things like that*' and '*you can use any material and turn it into science, you just have to know how to do it*' (Ms Marie Curie, Interview).

A total of 10 of the 13 preservice teachers provided at least one comment that indicated a growth in their GCK at some point in the data collection period. For example, Gerty Cori stated: *'I think that my knowledge for teaching science is improving a lot as we go on, especially through learning from mistakes'* (Gerty Cori, Online Discussion September 6, 2007). Helen Dunbar also highlighted the contextualised nature that was reflected in content learning: *'As a result of this lesson we have learnt more about fossils and creating them'* (Helen Dunbar, Online Discussion, September 4, 2007).

Other comments did not explicitly acknowledge growth in knowledge but it was evident through the sharing provided. For example, Grace Hooper discussed a chromatography lesson. The manner in which she writes and her use of punctuation indicates the content was new to her:

> *Maria and I assisted Virginia yesterday afternoon with a Grade 5 class looking at Forensic science & Chromatography. It was really very easy to experiment with - little cost, little equipment, results almost immediately! Chromatography is the science of separating the coloured inks in dyes (we used coloured textas). Basically, you can expect green textas to separate into blues and yellows, oranges into reds and yellows and purples into blues and reds/pinks. What is most exciting for kids is the browns and blacks. Brown separates into all 3 primary colours and black inks separates with blues and pinks and purples, as well as some black - black ink is not necessarily black ink!*
>
> (Grace Hooper, Online Discussion August 28, 2007)

Preservice teachers also communicated a range of new ideas about science content. For example Linda Buck explained how to make green eggs and ham:

> *You use red cabbage, the juice in it. It reacts because of the pH level as either an acid or a base and the reason the eggs turn green is because they're a base. We got a sheet from science by email and we got a photocopy of the activity.*
>
> (Linda Buck, Round Table Discussion 2)

And Barbara McClintock queried Maria Mayar on how chromatography worked:

Barbara McClintock	*How did you do it?*
Maria Mayar	*You get a coffee filter paper and you get a texta and you write something on it and then dip the bottom of the paper in water and as the water travels up the inks dissolve and it separates it into the different dyes. We got them to write their names using different coloured textas, and some of them were permanent markers and some of them were normal textas and then when they put them in the water they all moved up the paper and then they had to work out why some moved and some didn't. That was a bit of their engagement.*
Barbara McClintock	*I've never seen this happen. I'm going to have to practice it; I've never seen it done.*

Maria Mayar	*Oh it's ace fun. Just get them to use their texta connector pens, they work really well.*
Helen Dunbar	*That's like when ink gets wet, it smudges, like computer print outs when you're running through the rain.*
Maria Mayar	*You can use all that cool chromatography stuff and blow her away next week.*

(Round Table Discussion 1)

These excerpts highlight how the round table discussions were useful for the sharing of experiences and to enable preservice teachers to query one another to learn exactly how to implement an activity or idea. It provided them access to knowledge of activities that had worked in the classroom and the details on how it was achieved were able to be clarified. There were a total of eleven discussion contributions where preservice teachers bounced ideas back and forth in a manner similar to the excerpt from Maria Mayar and Barbara McClintock shown above.

As already mentioned in the section dealing with changes in preservice teachers' self-efficacy beliefs, this sharing was also particularly beneficial for those preservice teachers who were lacking in confidence and background knowledge. This was best demonstrated by Helen Dunbar and Gertrude Elion who had been experiencing a lack of general support from their practising teacher partner, Ms Jane Goodall, when it came to sharing ideas and planning sessions. To recall their words after a round table discussion of sharing ideas with their colleagues:

Helen Dunbar	*I'm getting excited about tomorrow though now because we've actually got some ideas . Like using different surfaces - having finger prints on different surfaces.*
Gertrude Elion	*I know I'm getting excited.*

(Round Table Discussion 1)

Each of these excerpts indicates small changes in GCK specific to the contexts in which each practising and preservice teacher were working. They suggest that development of content knowledge was not broad, across a range of science concepts, nor particularly conceptual in nature for these participants. Rather, it addressed aspects such as terminology, basic reactions, and general topic-specific knowledge such as on fossils or on chromatography that were being addressed in classes. This situated knowledge development provided important background content required for teachers and relates to GCK development.

Generally the partnership experience based in the authentic school setting appeared to provide good opportunities for both practising and preservice teachers to develop new and different ideas for teaching science, expanding their GCK in certain areas. Whilst minimal in impact for practising teachers, it was more significant for preservice teachers. This was further supported and enhanced for preservice teachers through online and round table discussions where it was evident that a number of ideas were shared and then taken up by other partners.

Development of Pedagogical Content Knowledge (PCK)

Changes in pedagogical knowledge were identified through a range of general comments that reflected growth of insight into effective teaching approaches. It was a significant area of knowledge development and was evident through a range of comments that stemmed in particular, from preservice teachers. The extensive data associated with PCK development emerged and is reported through eight themes. Each of the practising and preservice teacher cohorts made a number of general comments linked to their developing PCK. Consequently two sub-themes were formed dealing with the general comments from each of these participant cohorts. In addition to these, five sub-themes associated with the selection of appropriate resources; timing of lessons; effective preparation and running of experiments; curriculum integration; and application of theories and their associated strategies for effective teaching and learning also emerged. This latter sub-theme covered the application of theories and strategies they had learnt about at university such as inquiry approaches and discovery learning, and concentrated on the 5Es framework in particular, which partners had been directed to both use and reflect upon. The final sub-theme dealt with the data from participants who indicated they had experienced no PCK development.

General Comments from Practising teachers

General comments regarding developing PCK were typical from practising teachers. For example ‘*My changes are more related to teaching and learning approaches*’ (Ms Virginia Apgar, Interview) and ‘*I did enjoy learning about the 5Es … it just made me think that you can incorporate it to even just a lesson rather than a whole unit’* (Ms Rosalind Franklin, Interview). Each of these comments show how practising teachers referred to enhanced PCK and four practising teachers in total made general comments similar to these.

More specific examples came from comments that showed how the partnership experience appeared to enable opportunities for sharing ideas for teaching different lessons and topics. This was highlighted well by Ms Virginia Apgar and Mr Robert Boyle in their respective interviews:

> *I've got lots of different ideas. I tend to stay with tried and true. The girls brought new ideas in to try and I'd think 'oh, why didn't I think of this? I've done chromatography the same way for 50 years! I married Art and science and made star templates. This gave me a whole different way of looking at things and a broader range of ideas on how to teach it.*
>
> (Ms Virginia Apgar, Interview)

> *Yeah I did* [gain knowledge from the experience]*… It's always fun, it's always interesting to try to find new ways of bringing concepts through.*
>
> (Mr Robert Boyle, Interview)

These practising teachers indicated that the sharing with preservice teachers in the partnership experience introduced new approaches to their teaching. Mr Boyle generally alludes to finding '*new ways to bringing concepts through'* and Ms Virginia Apgar relates one example of her experience of teaching chromatography as different to the '*tried and true'* way she had always approached it. She also referred to the '*marriage'* of science and art they incorporated, indicating new thinking about integrating science with another area of the curriculum.

Ms Apgar's use of the phrase '*why didn't I think of that'* was key in representing the professional learning as an expansion of ideas for teaching. It was something that once exposed to, Ms Apgar expected herself to have been able to see, showing she believed she had the knowledge necessary to construct the idea herself, but for whatever reason, she had just never done so. She also stated how '*Maria and Grace both had fabulous ideas that they shared, especially for using the Interactive Whiteboard'* (Ms Virginia Apgar, Interview). This highlighted how sharing in the partnership expanded the repertoire of ideas and access to resources to improve approaches to science teaching.

General Comments from Preservice Teachers

A number of general strategies associated with developing PCK were evident from preservice teachers in their online and round table discussions. For example, they recognised that the size and make-up of groups can impact individual children's ability to explore:

> *Marie pointed out that the students had not had a good chance to explore, as the 5/6 students assisted so much in the making of the volcanoes. If the 1/2 students had worked alone they would have had more of a chance to explore.*
>
> (Anita Roberts, Online Discussion September 20, 2007)

Being flexible and responsive to children's needs also emerged as an important insight into effective pedagogy. This was captured in particular by Gerty Cori's reflection:

> *There were a few times where you sort of went with the kids a little bit more and bounced off what they were giving you instead of what you were sort of planning and there were a couple of times when that was happening and that's where the best sort of learning happened as opposed to the set up bits you were trying to...that's what I felt.*
>
> (Gerty Cori, Round Table Discussion 2)

The amount of content to be covered and the complexity of some content matter were also revealed as presenting challenges in helping children achieve understanding:

> *I've also realised how much material there is that can be covered, especially after our 3rd week on sound, and this is only at a grade 1-2 level. It would be interesting to see how much students are retaining from what they learn.*
>
> (Gerty Cori, Online Discussion 14 September, 2007)

> *The final activity for the lesson was a quick insight into gas, which we found to be a hard topic to address as it can not be seen by the students.*
>
> (Rachel Carson, Online Discussion 4 October, 2007)

The effectiveness of the activities and approaches they had selected for the teaching of concepts were not always successful:

> *We started off by once again engaging students by getting them to move to music and respond to what they hear and felt. A few students seemed to pick up on it with some prompting, but as a whole, students didn't seem to be able to find the words. I think this is perhaps due to the fact that we didn't go through it with them first as we had talked about doing.*
>
> (Gerty Cori, Online Discussion 6 September, 2007)

This collection of sample contributions highlights some of the challenges preservice teachers became aware of through their experiences in trying to teach scientific concepts in a meaningful way. They added depth to the insights they gained about how to effectively achieve student understanding. They became aware of key issues such as the amount of content associated with topics and the issue of determining how much and which parts to teach. They highlighted the impact of group size and the challenge of getting children to work together so that it is effective for learning. They noticed how abstract concepts that lack concrete examples, such as 'gas', are more difficult to teach. They also reflected on the issue of how much or little prompting students should be provided when they are engaged in activities for which pre-determined outcomes are set.

Whilst they were not always able to answer the questions these issues generated for them, the preservice teachers did have the opportunity to explore possible strategies and to reflect on the level of success they had and thus how they might alter their approaches next time. This deepened their insight into the difficulties of achieving student understanding.

Selection of Resources

There were a number of insights into how the selection of resources can affect the achievement of student understanding which demonstrated developing PCK. These insights developed through experiences in the classroom, both successful and unsuccessful. For example:

> *Searching on the internet was harder then I initially thought as a lot of the information was too complex for student's understandings and for some students they became confused especially the group looking at gas as some sites used complex scientific language. This issue was solved by finding books based in the library that offered information using appropriate language and being more specific when searching on the internet.*
>
> (Barbara McClintock, Online Discussion 13 September 2007)

Here Barbara developed an insight into accessing resources appropriate for the level of students she was dealing with. She learnt that she needed to prepare resources carefully utilising materials from the school library which generally has more appropriate resources for primary children, and selecting sites that make children's internet time more productive.

Jocelyn Burnell also developed some insight into the use of appropriate resources as she worked with a teacher who, by her own admission, tended to avoid science teaching where possible. This avoidance is likely to have impacted on the use of prepared worksheets that Jocelyn discusses:

> *I feel that the pracs are almost too easy for a grade 5/6 class and the teacher seems to be quite lazy about teaching science. For example the sheets she has given me to plan lesson from really do not give much room for applying learning theories or enhancing children's' learning.*
>
> (Jocelyn Burnell, Online Discussion 14 September 2007)

Jocelyn clearly noticed the lack of theory she has been exposed to at university in the worksheets she was given to work with. These theories revolved around constructivist principles, discovery and inquiry learning and, for science, scientific processes. The important insight Jocelyn hopefully took from this experience is that worksheets, on their own at least, do not encourage effective learning and particularly in science, and do not enable scientific skills of questioning, investigating, analysing and learning from this process.

Anita Roberts' insights into achieving student understanding were tied to a range of ideas including effective grouping, role assignation and use of materials and discussion to promote learning, and thus helped her establish the link between classroom management and learning management. This is reflected in her comment:

> *Based on our previous experiments we have learnt to: group students with partners that they can work responsibly with, allow plenty of time for discussion, have plenty of materials available to students and allocate students roles during clean up time. Our next lesson will include all of these elements.*
> (Anita Roberts, Online Discussion 4 September 2009)

Linda Buck had a similar experience of noticing the difference between managing the classroom and managing the learning, as she reflected on the provision of hands-on experience and learning.

> *I have become aware that even though students are engaged in the activity, and are observing what is happening doesn't mean that we can forget that explanation or opportunity to look through the text books and find an explanation. Hands on experience I believe is not enough, there needs to be something else that connects to the experience to make it understood, rather then just being fun. I hope that we can in the next lesson, explore why this process happened, what caused it and perhaps think about what other things may change colour when adding red cabbage.*
> (Linda Buck, Online Discussion 5 September 2007)

Preservice teachers made six contributions overall that highlighted their increased awareness of availability and access to appropriate resources to achieve student learning. These included Gerty Cori's concern that specialist equipment is not always readily available:

> *I am learning that in science you have to be extremely resourceful with what you have and use it to its potential, but it's also important to look outside the classroom for equipment if possible….Unfortunately not many schools would have this sort of equipment to use* [sound level meters], *as it was something I borrowed and brought in. However, it was extremely effective in engaging the students*
> (Gerty Cori, Online Discussion September 14, 2007)

Maria Mayar realised that so many everyday materials can be readily sourced and utilised:

> *It is also amazing what you can bring from home to do science with - I had a big basket of 'surfaces' which were common, everyday items ranging from carpet, corduroy material, plastic and bubble wrap, to packaging materials and aluminium.*
> (Maria Mayar, Online Discussion September 13, 2007)

Access to appropriate space was also mentioned as a developing insight:

> *I was glad that we could attempt to do this experiment in the classroom, because it reinforces, yet again, that science (chemistry) can be done with limited resources and in a space not designed for it. And in the process have heaps of fun!*
> (Maria Mayar, Online Discussion September 19, 2007)

We had organised to swap classrooms with another class who were up on a second story so we could have a suitable distance for the egg drop.
(Lise Meitner, Online Discussion September 4, 2007)

While the number of insights gained into human and physical resources was relatively small, it does help indicate that again, it is through the authentic experience of planning and teaching science lessons that these ideas that contribute to the development of PCK, are able to develop at all.

Timing of Lessons

Time was one of the most frequently discussed issues among practising and preservice teachers with a total of 61 responses forming this sub-theme in interviews, round table and online discussions. Preservice teachers, with 43 of the contributions concerning time, developed awareness of the timing of lessons through the authentic teaching experience. The development of this important insight was evident over the period of the data collection and was closely connected to unsuccessful experiences of timing, such as those depicted in the following contributions.

I feel that the lesson was very successful, although it did go well over the time frame.
(Rachel Carson, August 30, 2007)

Even though we ran out of time in this session for the wrap up and evaluation, the class teacher was going to do this after lunch with some discussion and completion of a chart as a part of the evaluation. I can't wait to go in next week and see what the student's displays looks like!
(Maria Mayar, August 29, 2007)

Once again we didn't leave enough time at the end for our group rotations, so we decided to only do one of the groups and as a whole group. It ended up being the group I was going to take on pitch. It wasn't ideally suited to the whole group situation as students couldn't explore for themselves, also some of the concepts were perhaps too complex, though some students seemed really switched on.
(Gerty Cori, Online Discussion September 6, 2007)

Another weakness was the time allocation; a lot of children had really brilliant ideas in planning time, but with just one hour for the whole lesson they didn't have the time to complete what they had planned. John agreed this was a weakness in the activity, the next lesson follows the same sort of practice in free creating with materials (to make cars,) to solve this problem happening again John is going to get them to start it half an hour before we come in so they are started.
(Dorothy Hodgkin, Online Discussion September 6, 2007)

These comments highlighted the challenge timing presented at the beginning of the partnership period, highlighting preservice teachers' relative inexperience in delivering science lessons. Both Maria Mayar and Dorothy Hodgkin indicated their reliance on the classroom teacher to instigate/continue the lesson before/after the preservice teacher arrives, demonstrating a weakness in the model where preservice teachers come and go from the classroom and do not receive the full teaching experience or the implications this has when time does impact on other planned activities in the day.

Gerty Cori's comments, also concerned with timing, show her consideration of the implications last minute adjusting can have on learning. Her small group activity became a whole group activity and she commented on the complexity of the ideas that were compounded by the whole group situation, which meant individuals could not explore and 'discover' pitch concepts for themselves.

After even a short period of science teaching experience, a number of preservice teachers demonstrated improved awareness of planning for lesson time and timing of lesson components.

> *After running out of time last week, we spent only a short time on engaging the students and finding out their prior knowledge before getting stuck into the stations.*
> (Maria Mayar, Online Discussion September 3, 2007)

> *Judging from the first lesson I believe that students will need to complete some of the work at home due to time constraints in the class.*
> (Barbara McClintock, Online Discussion September 19, 2007)

Six preservice teachers offered comments at different points during the data collection period where this sort of improved planning for time was evident. This demonstrated how the experience of 'running out of time' served to focus teachers' thinking about timing in future planning sessions. Key to succeeding in improving time management was the time spent on reflection to provide insight into where timing could be improved. A number of these contributions focussed on a desire to improve the amount of discussion time they had in their lessons: '*I felt that that was one thing that sort of really let the lesson down. The fact that we didn't get to do that final sum up, it was sort of rushed a bit* (Rachel Zimmerman, Round Table Discussion 1) and: '*the problem is that the thing that gets sacrificed is the stuff near the end which is the evaluate and the discussion*' (Gerty Cori, Round Table Discussion 2).

Further evidence of this reflection included:

> *Main areas for improvement would be time management. There was no end discussion to round off the learning which we left for Virginia to complete another time.*
> (Grace Hooper, Online Discussion August 28, 2007)

> *Marie noted a critical time in our lesson to be our time management. We either needed to break the lesson into parts; limiting the time students spent on planning, decorating, sinking, etc; or do an activity like this over two lessons.*
>
> (Anita Roberts, Online Discussion September 4, 2007)

And as these excerpts show, they could appreciate that the time constraints and rushing were impacting on students' learning:

> *Mellita* — *You don't feel that they were taking it in?*
>
> *Gerty Cori* — *No, not really, nup…not with the time constraints we had. I think if we had more time.*
>
> (Round Table Discussion 1)
>
> *It's better not to rush it you know, if you want them to get the value out of it.*
>
> (Rachel Carson, Round Table Discussion 1)

These contributions show how partners used reflection to hone the timing for particular components of lessons, particularly the class discussion time where the drawing together of the learning experiences from the lesson would be conducted. They provide an authentic experience for reflection that helps the development of good pedagogy that the university setting would not be able to do.

Time was also discussed in regard to the amount of planning and reflection time partners had together. '*The only thing I would pick on with ours is that there wasn't much time for reflection with the teacher*' (Rachel Carson, Round Table Discussion 2). This was also picked up by a number of the practising teachers when they discussed the areas of improvement they felt were needed:

> *The planning stage wasn't quite as … good as it could have been because, well last week I wasn't here so the girls just ran it by themselves and in fact they got that grade involved as well. I guess the timing of it just because you know, the 1 hour stretched into two most days and then you don't really have time to sit down and do the thorough plans it's kind of a both planning and reflection on the run.*
>
> (Mr Robert Boyle, Interview)
>
> *Collaboration time, that's mine I think. Feedback time. Planning, collaboration, feedback.*
>
> (Ms Jane Goodall, Interview)

There was a tendency not to set formal times for planning and reflection and consequently it did tend to occur 'on the run' as Mr Robert Boyle communicated above. Acknowledging the need for more formal planning times, when Ms Virginia Apgar was asked what improvements she thought were needed, she stated '*Having a set time to plan. That's a bit idealistic, but it would be wonderful'* (Ms Virginia Apgar, Interview). These types of comments indicated both the 'busyness' of the classroom teacher and the impact this had on what should be an important component of the teaching role; making time for formal planning and preparation of teaching.

These experiences were important for shaping teachers' understanding of the importance of planning their lesson time effectively to ensure learning opportunities were maximised and other obligations in the teaching day were able to be met. It was clear that the authentic teaching experience provided the insights gained in regard to timing and it was encouraging to see evidence that participants realised more effective planning would contribute to more effective lesson delivery. There was, however, little evidence to suggest that they acted on this awareness by setting formal planning sessions. In fact, formal planning time was viewed in some cases as an unattainable ideal. Ideas that were acted on, however, included those associated with timing components of a lesson and better recognition of the amount of content that might fit a given time allocation, thus demonstrating enhanced PCK amongst these contributors.

Preparing and Running Experiments

The preparation and running of experiments helped develop an understanding of how appropriate experimental work is selected:

> *One of the difficulties I've found with a lot of the experiments, I mean you see a great experiment but there's not sort of the background to it, why it works. … some of the stuff on the internet, you think 'that would be really cool to do but I don't know why it happens'.*
>
> (Rachel Carson, Round Table Discussion 1)

Insights gained from conducting experiments formed another significant topic of discussion among preservice teachers. The greatest development appeared to centre on a realisation that experiments could be quite simple yet remain effective for learning. Two of the comments highlighting this realisation are provided below.

> *From this lesson I really learnt how simple experiments can be; the students were excited by something as simple as melting water which shows you do not have to go to a lot of trouble or use fancy and expensive materials.*
>
> (Rachel Carson, Online Discussion October 4, 2007)

> *Marie made an interesting point, stating that you can use any simple materials (e.g. play dough, vinegar, bicarb soda) and turn them into a science lesson. My ideas for science are that for younger classes especially, it is quite easy to do a science lesson since there is only very basic science involved. Keep science lessons simple, relevant, hands-on and fun.*
>
> (Anita Roberts, Online Discussion September 20, 2007)

These comments reflect preservice teachers' surprise at the simplicity of materials and even content (e.g. melting ice to form liquid water). This awareness of the simplicity of ideas that can be explored in primary science that still builds effective scientific processes and skills of inquiry and investigation is important. It helps preservice teachers build confidence and a sense of efficacy in their ability to teach science, even if their knowledge base is low. It also suggests that they may only think of science as complex and difficult, with content levels beyond their own reach, which in their minds, makes it even more unattainable for primary children. Experience in teaching science, using simple materials and covering basic concepts, has helped them develop both confidence to teach science and gain ideas for its teaching.

This experience also led preservice teachers to become aware of strategies they could use to improve practical work. Most of these improvements were to do with managing the selection of the most appropriate equipment for conducting experiments. Some examples are provided below.

> *The most critical time for me was when we sunk the first submarine. We had not actually realized, but by sinking the submarines we were ruining the students' carefully made artwork. …If I did this lesson again I would ensure that all objects are firmly stuck on, cardboard tubing is firmly pushed into the milk carton and objects such as blocks or water are used to sink the submarine rather than sand.*
> (Anita Roberts, Online Discussion September 4, 2007)

> *In this lesson however the straw Kazoo failed to work, despite testing all the experiments at home prior to the lesson. Some of the students were really disheartened over this and we had to explain that often science is based on trial and error. If I was to do this experiment again I would make sure that the scissors were sharper as I believe that this was partially the problem. I would also have a back up station for example making drums rather then Kazoos when it was clear that it was not working.*
> (Barbara McClintock, Online Discussion September 5, 2007)

> *How could I improve the science activity? Perhaps only have two experiments going at once, having enough materials for each of the children to explore with. Written a list of things that we explored. I would have liked to make a project wall about what we have found out about water at the end of the lesson so far and compare with it in the next lesson.*
> (Linda Buck, Online Discussion August 25, 2007)

These improvements cover a range of ideas. While they primarily dealt with issues of equipment selection, they all stem from a deeper concern about the teaching and learning relationship. The construction of the submarines that were damaged in testing, whilst instigating ideas about material selection, stemmed from a belief in the need for students' work to be respected and maintained; the need for sharper scissors to make the straw kazoo work stemmed from the disheartening witnessed in the students. Linda Buck's idea for a project wall of students' work reflects an understanding of connecting learning from one lesson to the next and also helps children celebrate the work they have completed. Overall these improvements highlight the link between organisational matters and effective learning.

Further insight into experiments in science came from the awareness of how physically 'messy' science could be depending on the design and management of practical work. Anita Roberts noted on three occasions that experimenting can be messy with comments such as '*A critical moment during this lesson was when we realized how much mess the lesson was making*' (Anita Roberts, Online Discussion September 20, 2007). This experience was shared by Linda Buck in a different activity involving water. She noted '*The activity was messy, water went everywhere*' (Linda Buck, Online Discussion August 25, 2007). Anita also indicated some insight into managing the 'messiness' of science practicals: '*Marie noted that cleaning up needs attention. This could be done by giving students certain jobs to do'* (Anita Roberts, Online Discussion August 29, 2007). These experiences helped teachers develop insight into how to manage potentially messy experiments, particularly those involving water, by using role assigning for collecting equipment and for cleaning up.

Maria Mayar shared her experience of managing a safety hazard in science experiments when to be successful, her lesson required the use of boiling water. This raised a further insight into conducting experiments which was the importance of planning for safe management of potentially risky equipment:

> *… we had to be careful in the explore and elaborate phases because the students were using chemicals and hot water. Hence, the students had to follow a set procedure and could not 'explore' at their own whim like they have been able to do in previous sessions. … The teacher was concerned about having boiling water in the classroom, so we did the first lot of experiments with warm water instead. … Because we could not dissolve much salt for the first round, I used boiling water for the next lot of students under strict supervision and we had more success that time.*
> (Maria Mayar, Online Discussion September 19, 2007)

This experience helped Maria think about when to allow students open exploration and when procedures need to be followed more strictly. It has also highlighted the issue of when to use a safer substitute (warm water instead of hot) and how to manage the situation if a safer alternative is not viable (such as teacher demonstration or small groups under strict supervision).

Ideas were generated about running experiments after lessons with limited success were experienced:

> *Probably for me, two of the experiments, one of them was first of all dropping a paper clip into water and that would sink straight away and then placing a paperclip on water and it was really difficult for a lot of the kids and in the end they all either did it or saw it being done and saw that it could be placed on the water and then once you added detergent to it breaks the surface tension and the paper clip zooms and then sinks straight away. But it was really difficult, and even I tried it at home before that and found it difficult.*
>
> (Rachel Carson, Round Table Discussion 1)

> *Well today we made straw kazoos and it did not work… I wouldn't get them to make them again, I'd get them to just make drums or something, I think I'd just forget the whole straw thing. Other things I suppose…instructions. In the first week, because I did the cars, and I'm not kidding, I had kids have drops like literally a straight vertical drop and it was more to see if they could get it from one side of the room to the other. NOT with a tape measurement! Which I suppose I should have done an example. Like I drew it up on the board and they all set it up right except the angles were a bit bigger than I would have thought.*
>
> (Barbara McClintock, Round Table Discussion 1)

These experiences helped preservice teachers consider how to avoid repeat problems where they discussed having back up experiments, having additional equipment, and thinking about the difficulty a particular task might present for children of different ages (e.g. if it requires fine motor skills these might not be well developed in younger children). For example:

> *These tasks were very complicated in that it was tricky to assemble, and I had trouble getting it to work. It really is a task that should be done with a small amount of students at one time, and involved plenty of teacher assistance. It is probably better for an older class, who won't need too much assistance, except for the candle wax melting which should only be done by the teacher.*
>
> (Linda Buck, Online Discussion August 31, 2007)

Maria Mayar also offered her idea of using failed experiments as an opportunity for further exploration which offers students an opportunity to learn about the nature of science:

> *And if their crystals don't form over the holidays, the teacher and I think it will be a good opportunity to talk to the students about experiments not always working, what could have gone wrong, and try again!*
>
> (Maria Mayar, Online Discussion September 19, 2007)

Stemming from these experiences of failed experiments, came awareness that it was important to try experiments before conducting them with children in the classroom:

> *This week we decided to experiment with making crystals with our grade 5/6 class. During the week I attempted to make some crystals at home with salt (didn't work!) and copper sulphate (I got a tiny crystal!) I am glad I attempted to grow these crystals, as we could revise our methods with the students to hopefully grow crystals more successfully.*
>
> (Maria Mayar, Online Discussion September 19, 2007)

> *A critical moment for Marie was when she attempted the paperclip experiment. We had not previously tried these experiments, and despite how she put the paperclip in the water, it would not float. An obvious way to avoid such situations is to attempt all experiments prior to the lesson*
>
> (Anita Roberts, Online Discussion September 13, 2007)

Overall, experiences in running experiments provided teachers with a range of insights into how to be more effective in planning and conducting practical work. These insights included how to use simple concepts and simple equipment, use role-assigning to help manage ‘mess’ and safety, to consider alternative equipment/processes if safety is an issue, always trial experiments before class, try to have back up experiments/equipment in case things go wrong, and plan, as much as possible, age and level appropriate activities. Collectively, they contribute to enhanced PCK development.

Curriculum Integration

The sixth sub-theme for the PCK development category came from comments preservice teachers made about how their lessons were integrated with other areas of the curriculum. Partners had been encouraged to try to plan some integrated lessons, although this was not a stipulation or even a primary goal of the project. Seven of the preservice teachers representing five different partnerships described the integration they achieved in their lessons. Some of the examples given include:

> *This week I did submarines with my grade1/2 class at Europium Primary. We integrated the lesson with art.*
>
> (Anita Roberts, Online Discussion September 4, 2007)

> *I think from the start when we were looking at it, it was always in mind that it was directly tied in with music. It's both at the same time.*
>
> (Gerty Cori, Round Table Discussion 1)

> *And with literacy we read Green Eggs and Ham by Dr Seuss and the kids loved that…then we made green eggs and ham one week and the kids had to write the procedure of what they did as a part of their literacy.*
>
> (Linda Buck, Round Table Discussion 2)

There were also three occasions where preservice teachers recognised the potential for integration, with comments made similar to this example:

> *This lesson could also be used as the basis for a maths lesson in terms of presenting and recording data.*
>
> (Barbara McClintock, Online Discussion August 29, 2007)

While this increasing ability to integrate science with other areas of the curriculum or recognising potential for integration was evident, some of this appeared to be realisation subsequent to the planning and implementation of the science lesson rather than deliberate planning for integration. However, the explicit questioning and discussion around integration raises awareness so that it does form a greater part of preparation rather than incidental noting at the end that was characteristic of most examples from the data. This also demonstrates the crucial role structured reflection has on learning opportunities.

Application of Theory

The online discussion topic asked preservice teachers to discuss the application of theory in their science planning and implementation. A number of preservice teachers did this in regard to general theories or teaching strategies they had been exposed to over time at university. For example, Linda Buck discussed '*social constructivism, working together with others'* (Linda Buck, Online Discussion September 13, 2007) and Dorothy Hodgkin, Barbara McClintock and Maria Mayar all mentioned the application of discovery learning as they prefaced their comments with phrases like '*This lesson was based on discovery learning …*' (Barbara McClintock, Online Discussion September 5, 2007).

Links to certain strategies like Predict, Observe, Explain (POE) were also made:

> *During this unit Rosalind I focussed our lessons on the 5Es and POE module which gave me practical experience on how to use these models.*
> (Barbara McClintock, Online Discussion September 13, 2007)

Alongside this was mention of the Technology design brief:

> *The phases in Technology (the design brief) we investigated and explored in Dynamic Decorations; Investigate, Design, Construct/Produce and Evaluate could also be used by the students or in planning by us in this lesson.*
> (Dorothy Hodgkin, Online Discussion September 13, 2007).

> *The lesson also strongly linked to the technology planning as the students progressed through each of these stages.*
> (Lise Meitner, 4 September 2007)

A number of preservice teachers discussed the benefit and importance of hands-on learning experiences:

> *We chose this lesson because we realized that the students really enjoyed the hands-on experiments.*
> (Anita Roberts, Online Discussion September19, 2007).

> *A strength of this activity was that it was extremely hands-on which creates a fun stimulating learning experience.*
> (Helen Dunbar, Online Discussion September19, 2007).

The discussion of a range of strategies and theories is important in evidencing the preservice teachers' ability to make links between different models that are being used concurrently in their teaching and planning. This demonstrates their deepening understanding of the similarities and differences between strategies and frameworks that are given different names, but which often contain over-lapping principles. Their recognition and discussion of these were all done within the overarching framework of the 5Es which was the model used for explicit planning.

Dorothy Hodgkin provided a long posting that is reported in full here because it demonstrates this beginning ability to synthesise ideas she had been learning at university:

> *Firstly, throughout the unit so far I feel I have come to a much better understanding of the different types of learning theories that can be applied to science lessons. The teaching experience that I have had the opportunity to be involved in as a part of this unit, has ensured that I am able to make the links between the theories and the application, which I now believe is an opportunity that should be available in all units. Learning about theories is one thing and you could know a teaching theory/model thoroughly through explicit teaching, but without being able to adapt it and implement into lessons then it really is a pointless task, as it will most likely be forgotten by the time you have your own classroom, and at that point you will have to study the theories again.*
> *Using the theories and teaching models I have looked at in my research task and throughout the unit in our science lessons has ensured I can see which of the theories I prefer and which are applicable to different grades/lessons etc... Lise and I have planned each of our science lessons around the 5E model, we both find it great as a planning tool for one or multiple lessons as it shows us how we will cover each area in the topic, it's also a good way of looking at your focus for the lesson. (i.e.: Explore is heavily focused on-therefore the focus may be children's creativity and innovation.)*
>
> *Having the opportunity to see how the 5E model works in practice has shown Lise and I, that the 5E model isn't strictly based to science it's a model that can be adapted for each Domain. Other theories and models Lise and I have looked at and implemented into our lessons (with adaptations), include the POE model, discovery/inquiry based learning and the interactive/collaborative learning theory, all which have worked well for us in our lessons. We found that before even knowing about these theories, we have always used bits and pieces of the theories in our lessons.*
>
> *Although now our research and awareness of each theory to date can ensure for us a proper framework to be implemented for lessons with a clearer planning structure and clearer and outcomes. Lise and I also found that implementing the theories with adaptations to suit your students learning abilities and interests helped in achieving a more structured lesson.*
>
> (Dorothy Hodgkin, 26 September 2007)

In this posting Dorothy highlights how the teaching experience has helped her bridge the theory-practice gap that the literature shows is an often criticised area of teacher education. I believe this was only made possible for Dorothy because of the formal reflection sessions that were run as a part of the academic course work concurrently with her teaching experience, and that expert facilitated questioning that focused her thinking and reflection in order to achieve these realisations.

In addition to the general theories and strategies preservice teachers identified through online discussion were the comments both practising and preservice teachers provided to demonstrate application of the 5Es. This discussion was encouraged more explicitly through interview and round table questions that asked participants to describe how they applied the phases of the 5Es in their planning and implementation. The following areas explore the responses gained from this enquiry.

The 5Es Framework

The 5Es framework was a significant focus of discussion due to the number of questions designed to target this model in practising teachers' interviews, preservice teachers online and round table discussions, and as a feature of the final participant workshop. Contributions revealed both how the framework is related to effective teaching and learning through its use to plan a lesson or unit of work; which of these is more effective for children's learning; and how partners believed they were applying the phases of the framework. Each of these links to evidence of PCK development.

The manner in which the framework was applied helped discern the extent of pedagogical knowledge development. Four of the practising teachers discussed the 5Es model as an informal planning framework. They indicated that it had been a useful structure through which to plan and that it provided rigour to lessons. This was recognised through comments such as:

> *We went back to the 5Es and used it as a quick checklist on where each E was occurring in what we planned. We made sure what we did fitted the framework which really gave the lessons rigour.*
>
> (Ms Virginia Apgar, Interview)

And:

> *Somewhere to sort of go, a framework you'll use when you're not sure of your topic and your material, and a framework for a quick reflection.*
>
> (Ms Annie Easley, Interview)

The use of the framework to guide planning appeared to inspire teachers' confidence in the lessons they had planned indicating a belief that the framework provided an effective structure for learning. This is indicated by Ms Apgar's comment '*we made sure what we did fitted the framework which really gave the lessons rigour*' and Ms Easley's '*a framework you'll use when you're not sure of your topic and your material*'. Ms Apgar also indicated her faith in the framework with the comment '*If they're all there* (5Es phases) *you can say 'this lesson's ok*' (Ms Virginia Apgar, Interview).

These results reflect that the 5Es framework was a useful model for planning that teachers had faith in to help them plan and deliver effective and rigorous lessons.

Effective Use of 5Es – Teaching a Unit

One of the areas of focus for preservice teachers' reflections was the application of the 5Es framework to a thematic unit, compared with individual, disconnected lessons, an approach which is more effective for children's learning. Some of the contributions that demonstrate the thinking about this include:

> *We have been aiming at addressing the 5Es over the whole four weeks, however they seem to be getting neglected quite a bit as we haven't really gone back and reassessed how we are working with it. I think it would be better if we planned on trying to address all 5 in one lesson because then we could reflect more on how effective each section had been.*
>
> (Gerty Cori, Online Discussion September 6, 2007)

> *We did follow the 5Es but it made it easier to spread the steps out over two lessons, because the concepts have been thoroughly explored and understandings of concepts grasped.*
>
> (Linda Buck, 3 Online Discussion August 1, 2007)

Here Gerty, having implemented the 5Es across a four week topic has indicated that she would like to trial incorporating them within each lesson. On the other hand, Linda indicated that the spread of particular stages within the framework over multiple lessons had enabled more effective learning to take place. It is interesting to note that Gerty qualified her statement with reasoning associated with her uncertainty in how the 5E phases are being implemented. The lack of formal reflection undertaken in her partnership is likely to have had an effect here and her 'knee-jerk' reaction is to try to adjust the application of the model so it is easier for her to keep track. This appears to speak more about the challenges she faced in her partnership than her beliefs about the model.

Maria Mayar helped us understand her changing perspective as time progresses in the partnership as she described the challenge time presents when all 5Es are attempted within the one lesson:

> *Yeah, it still fits in but it's just over a smaller timeframe. It's just a bit harder to fit everything in. Like on Monday we ran out of time in our 1 hour lesson to do the Evaluate at the end, but after recess, Virginia was going to do that with the class. So it was still done, but just with the tighter timeframe you can't explore each area very well.*
>
> (Maria Mayar, Round Table Discussion 1)

By the end of the research period, through listening to others and from her own experience, Maria had this to say about how the 5Es framework should be used:

Maria Mayar	*I reckon it would have been better if we had have done some of the stuff that we did over two or three sessions and just on a couple of the 5Es at a once would have been better than trying to cram everything in at once.*
Mellita	*Better for what?*
Maria Mayar	*Better for the kids, for their learning. To have time to be able to explore and discuss and then to have time to reflect and maybe think about it and tie it all back in at a later stage. But rush, rush, rush, you know - get it all done, we've got 5 minutes to go.*

(Round Table Discussion 2)

These excerpts show a development in Maria Mayar's thinking about the use of the 5Es framework. Early in the experience she was vocal in defending the use of the 5Es within individual, disconnected lessons, indicating that it can be applied effectively, but time is perhaps a little more challenging. Towards the end of the experience her thoughts had moved and she acknowledged that it might have been better to take a number of lessons connected to a topic/theme in which to apply the 5Es. She appeared to have a greater appreciation for the need to discuss and reflect with children that the tight planning she had been doing previously did not allow for.

This was a very encouraging example of how the experience and sharing was able to convey more than direct teaching was able to. The notion of connected lessons for developing meaningful learning had already been introduced to preservice teachers early in the unit when the SIS components were explored. SIS component 2 deals directly with the notion of connecting learning across time and context. In spite of this, Maria was unable to own that knowledge in a way that impacted on her practice until she had a number of experiences where reflection, discussion, and, she felt, student learning, was compromised by the rushing through the framework in a single lesson.

The discussion with others who shared similar experiences of disconnected learning, different experiences of connected lessons and thematic teaching also helped the meta-cognitive thinking preservice teachers undertook in relation to how best to apply the 5Es framework. Some of these discussions are highlighted by the examples provided below.

Dorothy Hodgkin	*With ours only because our lessons didn't flow at all. He would just set a topic…*

Lise Meitner	*Just at random yeah.*
Dorothy Hodgkin	*So they were one off and they were crammed.*

(Round Table Discussion 2)

Mellita	*So if you guys were going to go and teach science to your own class and you got to choose, how would you approach it?*
Rachel Zimmerman	*It probably depends because some things you can knock over in one lesson, but some things might take three or four. So it's something you'd have to use your judgement on.*
Dorothy Hodgkin	*I'd choose a topic, like water and go with that for however long I needed.*
Gerty Cori	*From what I've noticed I wouldn't rush it and rush to give the explanation.*
Maria Mayar	*I wouldn't do the one offs either. I'd go over several weeks and try to develop those understandings and get them to do some linking and find the meaning and just let them come up with some stuff before I give them explanations.*

(Round Table Discussion 2)

These excerpts show that through experience and sharing, preservice teachers were able to articulate a need to spend meaningful time on topics rather than one off disconnected lessons. They were influenced in particular by the experience of rushing learning experiences and not allowing students enough time to develop intuitive understandings before being pushed to the next stage of formal learning and explanation, or to the next lesson.

Application of the 5Es Phases

The 5Es framework was also discussed in relation to the application of each phase in the classroom implementation period. Data on the application of phases were collected from practising teachers through interview questions, round table and online discussions where preservice teachers were asked to describe their application and in the final participant workshop. Figure 4.5.1 shows the display created from the records each partnership wrote for the different phases of the 5Es. The presentations from these partnerships provided insight into their understanding of the 5Es framework and how the partners worked together to plan and implement lessons. These data were important in helping the identification of participants' understanding of the framework and their accurate application of the phases within it. This in turn helped to assess participants' developing knowledge of science content and pedagogy.

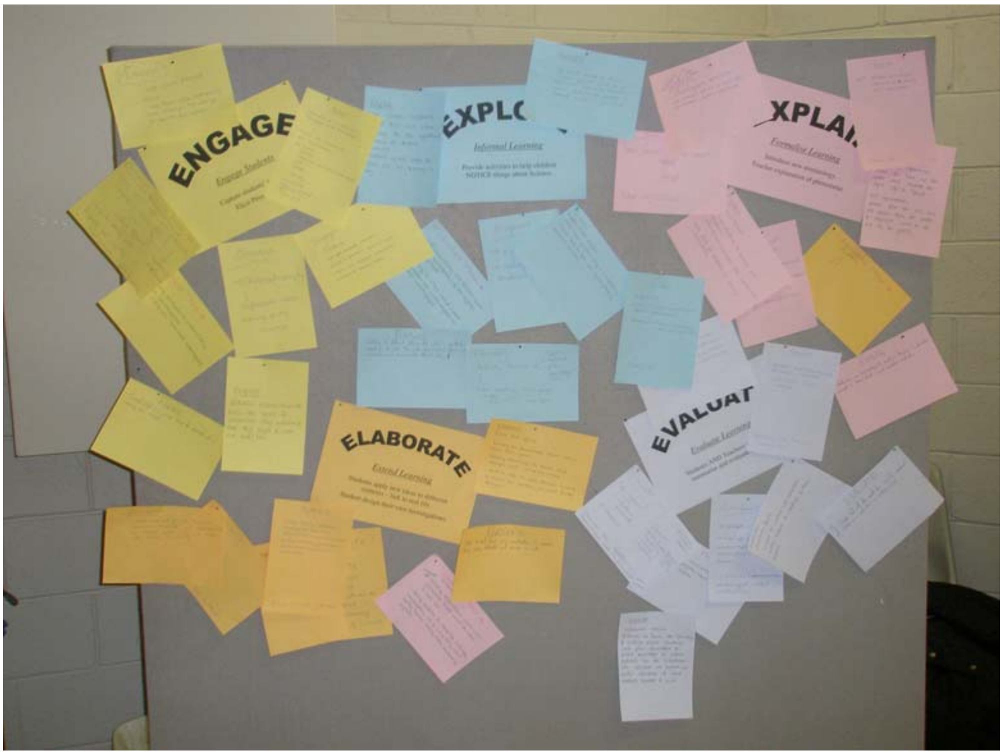


Figure 4.5.1: Partnerships' Sharing of 5Es Framework

Application of the Engage Phase

The participants reported on a range of activities that linked to the Engage phase and in total, offered 18 comments/descriptions that linked directly to this phase. They highlighted ways in which students' interest in the topic/lesson was captured and how students' prior knowledge was elicited for diagnostic assessment. For example:

> *We started off with the engage phase, creating a mind map with students, what they know about water and what they would like to know - this will guide us for future lessons. To engage the students we used a large bubble wand to blow bubbles over their heads, asking them to think about how bubbles are formed.*
>
> (Rachel Carson, Online Discussion August 30, 2007)

> *I had used finding prior knowledge, but not under the 5Es tag. It's similar to Kath Murdoch's steps but easier to remember.*
>
> (Ms Virginia Apgar, Interview)

Other examples that did not explicitly mention the term 'Engage' also fit this phase: through their mention of one or other or both of the defining elements of the Engage phase: eliciting students' prior knowledge and/or engaging their interest in the topic. For example:

> *Before the children started the stations we led them in a discussion about previous learning experiences. This provided us with their knowledge and helped us to understand what level they are up to.*
>
> (Gertrude Elion, Online Discussion August 29, 2007)

> *To get the students thinking about what we were about to explore, though, I had them all attempting to draw a diagram of how to make the circuit using one wire, one battery and one globe. As this was also one of the work stations, they all had the opportunity to test out their theories.*
>
> (Maria Mayar, Online Discussion September 3, 2007)

These examples show that brainstorm discussions were a favoured tool for engaging students, as was the use of the closely associated mind map. Only one partnership explicitly identified the separation of the two components of this phase: eliciting prior knowledge which they did through the mind map, and waving bubble wands to capture their interest and curiosity. This same partnership was also the only one who indicated that the information they obtained through the mind map would be used as diagnostic assessment and thus be useful for informing their subsequent planning. This indicated a high-end use of this stage of the 5Es framework for this partnership. One partnership mentioned use of students drawing diagrams to show how a circuit works as an Engage activity. This particular activity was taken from a tutorial session held with preservice teachers before the partnership experience began.

Some of the preservice teachers demonstrated their understanding that accessing prior knowledge and experiences was important for children's learning, as reflected by these comments:

> *Next week it would be beneficial if we repeat the activity we could draw on aspects of what we did in this lesson when getting children to respond.*
>
> (Gerty Cori, Online Discussion August 29, 2007)

> *In doing the lesson again I would find out what knowledge they have and then plan the stations and make modifications from there, some of the stations were too basic considering the background knowledge of some students.*
>
> (Dorothy Hodgkin, Online Discussion August 30, 2007)

It was disappointing then that so many of the partnerships failed to recognise this component of the Engage phase when presenting their 'best' examples of this phase in the final participant workshop. Here, five of the eight partnerships presented their best Engage lesson as one that focussed only on capturing students' interest rather than achieving both this and eliciting their prior knowledge. For example, Ms Marie Curie and Anita Roberts reported on their final lesson with their Grade 1/2 class on building volcanoes as their most engaging. They wrote that students knew the shape of volcanoes, understood that they erupted and what eruptions look like. They did not communicate how they accessed this prior knowledge. When presenting, Ms Curie focused on engaging students' interest as the critical achievement of this phase:

> *With engaging my kids basically, they're grade 1/2s and they wanted to blow something up the whole time, the whole four lessons. So the very last lesson we did was a volcano which is what they wanted to do. …So out of all of them that was the most engaging one.*
>
> (Ms Marie Curie, Final Participant Workshop)

Two partnerships did achieve both components of the Engage phase as indicated by the example presented by Linda Buck and Rachel Carson. The activity was one conducted with preservice teachers in an earlier science tutorial involving 'oobleck' - a mixture of cornflour, water and food colouring that creates a non-Newtonian fluid mixture. They used it as an introduction to a lesson on solids and liquids. They reported the activity to *'really engage students' interests'* (Rachel Carson, Final Participant Workshop), and that it provided a new and different experience that related well to the lesson topic. Tapping into the unique non-Newtonian characteristics of the oobleck, where viscosity is dependent on the rate of movement of the liquid, they were able to pose the question 'is this a solid or a liquid?' to help elicit students' prior knowledge on this topic. Students' interest and curiosity was stimulated, as reported by the partners, and the questioning 'is this a solid or a liquid?' linked to the scientific concepts being explored in the remainder of the lesson and the unit.

Only one partnership, represented by Jocelyn Burnell on her own, presented on an activity where she inaccurately applied the notion of eliciting children's prior knowledge. In her activity, she asked students to pretend they were seismologists. She indicated that this task was set '*because … that made them think 'well what is a seismologist?*' (Jocelyn Burnell, Final Participant Workshop). She reported that a class discussion was held around this question. Students then made their own seismographs which added to the engagement of students' interest. Whilst Jocelyn's description of the questioning 'what is a seismologist?' was an attempt to incorporate the Engage phase component of eliciting students' prior knowledge, however it actually served as another example of stimulating their curiosity. The reason it did not fit with the notion of accessing prior knowledge is that the questioning did not relate to the scientific concepts she went on to teach which was about how seismographs operate.

Overall, the descriptions partnerships provided on the Engage phase demonstrated a strong emphasis on stimulating children's curiosity and interest which, from partner's reports, appears to have been successful. Less emphasis appears to have been placed on its constructivist aim, that is, to elicit students' prior knowledge, during this phase. Two partnerships demonstrated a high level of understanding and application of this where their attempts were to discover children's knowledge of scientific concepts linked directly to the lesson/unit. Two partnerships alluded to accessing prior knowledge, but described examples where the focus of these attempts was not related to the concepts explored in the remainder of the lesson(s). Accessing prior knowledge was not apparent at all in the remaining four partners' descriptions of how they best applied the Engage phase.

Whilst preservice teachers did focus on the eliciting of prior knowledge component of the Engage phase in their online discussions, it was a rare feature in partners' best examples of 'Engaging' students. These results suggest that overall, partners were more focussed on the 'interests' component of engaging children than the diagnostic assessment that is enabled through eliciting their prior knowledge, which further suggests that partners generally have a limited understanding of the Engage phase and the importance of finding out what students know as a basis for further learning.

Application of the Explore Phase

The Explore phase was the most strongly represented phase in the discussion of the 5Es. A total of 37 contributions, mainly through preservice teacher's online discussion, were focused on descriptions associated with the Explore phase. They were typically offered as descriptions of lessons undertaken. Some of the examples included:

> *Students had 20 minutes to create their pod, which was the explore segment of the 5Es, the explore phase was also the main focus of all the 5Es in this lesson. Some ideas created were wrapping it in newspaper, making a parachute, wrapping it in foam and as much material as possible and putting straws around to try to make it stand.*
>
> (Dorothy Hodgkin, Online Discussion September 6, 2007)

> *Our activity involved cutting a potato in half and placing one half in a dish of freshwater and another in a dish of salt water. Students observed the experiment every ten minutes, drawing or writing a record of any changes. While we were waiting for the potatoes (they take at least 30 mins) we had two basic experiments to show the students. The first was floating a paperclip in a glass of water to show the invisible 'skin' that holds the clip. The second was placing matches in water and watching them move when detergent is added.*
>
> (Anita Roberts, Online Discussion September 13, 2007)

These two examples demonstrate an awareness and application of the Explore phase as a period of time for students to gain hands-on experience of science. They represent the typical responses preservice teachers provided about the application of the Explore phase. The following excerpts, whilst also demonstrating an awareness of Explore as a 'hands-on' experience of science, communicate an understanding these teachers had of letting students come to their own informal understandings of phenomena before formal explanations were provided in regard to the science behind their observations. This is a critical component of effective use of the Explore phase and reflects well on the pedagogy of the teachers involved in this early stage of the 5Es framework. It was, however, a feature of only a few contributions:

> *I thought with what we did we were exploring the properties of surface tension but we never actually used the word and we sort of let them come up with ideas and theories about what it was. So we were exploring so we didn't tell them 'this is surface tension, it's a property of water'.*
>
> (Rachel Carson, Round Table Discussion 1)

> *And it was really good because at each stage, as they'd done one, they were formulating ideas in their mind, so as they come to the next one they were beginning to predict what was going to happen and they were starting to formulate ideas as to why. So it was really good to keep questioning them and to try to get more explanations out of them. You know, they were really getting it.*
>
> (Maria Mayar, Round Discussion 1)

> *The first week we presented a lot of just hands on experiments for kids to explore. Our focus was about water and we wanted to get across the idea of water surface tension and things like that and Properties of Water it was basically. And I didn't want, we didn't want, we purposely didn't explain about water surface tension until probably late in the second week. Because we wanted the kids to come and explore and come up with some ideas for themselves - which they struggled with, which is fair enough. They sort of got the ideas but it was very interesting to hear their observations, or their explanations of their observations I suppose.*
>
> (Mr Robert Boyle, Interview)

One further comment worth highlighting demonstrates an awareness of the need for formative assessment to help gauge when students are ready to move on to formal explanation, but demonstrates the difficulty that can exist in knowing when and how to make this judgement:

> *I knew we were doing the explore level and all that but when does the explanation come into it? Because I was sort of thinking, well there's only so much that some of them will get without being...some of them will go 'ohh' and it will just click, but what about those ones that it just doesn't make sense to? When do we say 'well this is what happens'?*
>
> (Gerty Cori, Round Table Discussion 1)

Both inexperience in teaching generally and teaching with the model contributed to the doubt Gerty expressed in this excerpt. It does, however, highlight how the experience of working with the 5Es model in the authentic classroom context brings questions such as this to the preservice teacher's mind. This would be very difficult to replicate if the concurrent classroom experience and academic coursework were not occurring and helps to affirm the approach adopted in the present study in achieving, at least in part, effective science teacher education.

When individual partnerships shared their ‘best’ examples of the explore phase in the final participant workshop, again the notion of formative assessment was not always apparent. This limited partnerships in their ability to judge whether children were ready to move onto the Explain phase of the 5Es. For example, Barbara McClintock and Ms Rosalind Franklin reported that all of their experiments were linked to the explore phase as they explored what it is to be a scientist in their inquiry unit. They reported that this involved helping children understand the processes scientists use to pose questions and discover answers, and the processes they might use to discover these answers. They discussed their use of a common science teaching strategy, the Predict, Observe, Explain, Teacher explanation (POET) framework, which they applied within each lesson. In this framework, after having an activity described to them that they have to complete, children predict what they think would occur; observe what occurs during the activity; form explanations for their observations which they then share with one another before the teacher provides a formal explanation. They did not specify a particular ‘best’ example of this process or indicate how formative assessment might have been implemented. This leads to the risk that they moved children through a series of activities with little consideration of children’s readiness to do so.

A similar example came from Gertrude Elion and Helen Dunbar. Again, these partners did not specify one ‘best’ Explore session. They indicated that all of their sessions on forensic science ‘*allowed the children to experience it and explore real life situations, where like detectives, go out and do their forensic science work. So every single one (lesson) they got to go out and explore for themselves*’ (Gertrude Elion, Final Participant Workshop). It is unclear whether or not formative assessment was used in these Explore sessions as it is not mentioned whether or not children’s understanding of the processes they were undertaking were judged in any way as a means of determining the flow of the lesson or the unit.

All but one of the partnerships demonstrated this same lack of awareness of the place of formative assessment in the Explore phase. The one partnership that did demonstrate a high understanding of this phase was again that of Linda Buck, Rachel Carson and Mr Robert Boyle. Linda reported on their ‘best’ explore session:

> *For our explore we thought surface tension was the best one because the kids were able to form their own theories about it and we didn't actually give them what it was, what was happening. So I think the best thing was when one of the kids came*

> *up and said force field to us and we were just amazed that from all the experiment experiences that he had, that he came up with this idea on his own.*
>
> (Linda Buck, Final Workshop Presentation)

In their written notes, these partners also recorded that in these surface tension stations they made the students question 'why it was happening' and allowed them to form their own opinions/hypotheses. This provides strong evidence of children being able to explore the phenomenon of water surface tension and test their ideas and hypotheses for why they were observing the results obtained in theses explorations. The use of formative assessment is not acknowledged here, but was clearly present as this partnership describes deliberately waiting for students to reach this level of communication of what was happening before they entered the Explain phase. In order to make the judgement of when to make this move, the teacher partners had to have been engaged in formative assessment. Linda demonstrated her awareness of this in one of her online postings:

> *The main strength of this activity was that students had a chance to discovery for themselves, make observation about what they believe was happening.*
>
> (Linda Buck, Online Discussion August 25, 2007).

Overall, partnerships demonstrated a sound understanding of the hands-on nature of the Explore phase and letting children learn through discovery. Their ability to recognise and articulate children's readiness for formal explanation however, was less evident in the descriptions and postings provided. However, the one strong example of this from Linda Buck and Rachel Carson was able to be used in round table discussions to focus reflective thinking and discussion around this important pedagogical component of the 5Es framework.

Application of the Explain Phase

There were a total of 21 contributions from participants regarding the application of the Explain phase. A range of comments that represented these contributions include:

> *I believe that 'explain' was enhanced in this lesson as we had asked students to predict what would occur before each experiment. Students were able to explain why they had made their prediction, discuss what had happened and why they thought this may be so. Marie and I were also able to aid the 'explain' element, talking about how our experiments had worked and how forces existed such as the 'water skin.'*
>
> (Anita Roberts, Online Discussion September 13, 2007)

> *After this and tidying up, we had a quick discussion about the science involved. The students suggested ideas such as design, gravity, and protection.*
>
> (Lise Meitner, Online Discussion September 4, 2007)

> *The informal probably occurred more (than formal explanation sessions) while the kids were doing the work and our roving scenarios, and then we'd draw it together towards the end and try to couch it in grade two language.*
>
> (Mr Robert Boyle, Interview)

These examples highlight how the Explain phase was generally conducted through class discussions taking place after Explore activities. Students were required to offer explanations '*They then had to explain …'* fitting with the student explanation component of this phase and teachers provided scientific explanations and the introduction of scientific vocabulary fitting with the teacher explanation expectations of this phase.

There were two instances where preservice teachers communicated the difficulty in achieving appropriate explanations. These were:

> *The kids didn't understand though that the atoms in the paper were picking up the colours, like the surface water thing, we explained it. Like you know how it's got the arms on the atoms. I tried to get the kids to notice that the same thing's happening with the clips and stuff and how it's joining onto the other stuff and the same thing is happening with the paper and it's picking up the colours that way. But they didn't pick up on that one at all. It was a bit hard.*
>
> (Linda Buck, Round Table Discussion 1)

> *And Robert even went into the hydrogen and the oxygen in the water and have you ever seen H_2O on a bottle and some of it was sort of above their heads but it was also really difficult to explain it in a way that they can understand. I mean, you don't want to dumb it down for them but...*
>
> (Rachel Carson, Round Table Discussion 1)

These examples demonstrate the difficulty in achieving scientific explanations, particularly ones that are 'age' or 'level' appropriate when those involved in the teaching themselves lack strong background knowledge in the area. This was also exacerbated by the content areas involved which were more abstract in nature and it was difficult to provide real-life concrete examples.

Ms Marie Curie reinforced this when describing her and Anita Roberts' 'best' example of the Explain phase indicating that they '*found it really hard with 1/2s to sit down and explain why this is happening, what's going on'* (Final Participant Workshop).

There were three contributions that suggested some partnerships spent very little time in the Explain phase. Gertrude Elion communicated this by reflecting on how her partnership ran out of time and what she would do differently next time: '*If we did it again we would sacrifice something different and we'll leave the explain in'* (Gertrude Elion, Round Table Discussion 2). Her comment here acknowledged that, in hindsight, she at least appreciated the importance of the Explain phase. There was also this comment:

> *I also felt that because the kids were younger and it was more of an exploration rather than getting those terms right, … but they still got a lot out of it - the concepts anyway.*
>
> (Rachel Zimmerman, Round Table Discussion 2)

Here Rachel infers that for younger children the exploration is more important than the associated explanations that might accompany activity, particularly in regard to building vocabulary. Whilst it is true to an extent that the younger year levels are exploring more, if there is no accompanying explanation, children may not notice the science we were hoping to expose them to through the exploration in which they were engaged. The tendency to under-estimate children's capacity to form explanations and learn appropriate terminology exemplified in this excerpt is of some concern.

Also of some concern was Ms Marie Curie's comment that '*these kids really don't care why it's happening*' (Final participant Workshop). This highlights the risk that if the Explain phase is overlooked, or undermined, as was the case in this partnership, children in the class can be engaged in just a series of 'fun' activities without understanding or noticing the science behind them.

Jocelyn Burnell drew a sad face on the paper provided for her Explain example. In presenting and explaining this to the group she reported '*for the explain phase I drew a big sad face because I wasn't very good at explaining'*. When asked what things she might work on to improve her Explain sessions, Jocelyn responded '*My own knowledge and understanding. Like it did come down to the fact that I hadn't done enough research to be able to answer the questions*'. By her own admission here, Jocelyn indicates that the Explain sessions were not a very successful component of her teaching experience which she linked directly to her lack of content knowledge in the area, something on which the Explain phase relies.

A good example of the Explain phase was provided by Ms Rosalind Franklin and Barbara McClintock. This partnership utilised the Predict, Observe, Explain, Teacher Explanation (POET) strategy in each lesson they taught. Their account indicated that children were given the opportunity to explain before formal explanations were introduced by the teacher which corresponds to the expectations set out in the Explain phase of the 5Es.

The best example of the Explain phase was however offered by Linda Buck and Rachel Carson as they presented their surface tension lesson. They highlighted that they gave time for students to develop their own explanations and then they reinforced and developed these explanations. An excerpt from their presentation highlights what these preservice teachers learnt from this experience:

Rachel	*Our explain, sort of what we really learnt from the explain was giving time for the students to develop their own explanations…from what the students came up with we then went and took their explanations and reinforced them or developed them a little bit more.*
Mellita	*Sorry I'm going to interrupt you there because I've had the benefit of talking to you more extensively about this particular example. So one of the big things from our discussion that I think I've picked up on is that you've noticed that if you let kids notice for themselves before you rush into those formal explanations, they make the connections much more easily*
Rachel	*Yeah*
Linda	*Yeah*
Rachel	*And particularly with the surface tension ones went over like a 3 hour period – over two lessons and I was thinking, 'gosh this is a long time, when are we going to tell them…'*
Linda	*We decided to let the first lesson be all about the experiments, don't explain it to them, get them thinking about it, jog their memory at the end of the lesson so that during the week they could look for other examples.*
Rachel	*And they actually went home and repeated a lot of the experiments.*
Linda	*The next week we let on what it was all about after we first let them have another experience so that they could recall everything.*

(Final Participant Workshop)

It is in this excerpt that evidence of the formative assessment conducted throughout the sessions on surface tension of water was evident. Rachel explained in her introduction to their description of this phase that what they learnt was to give students time to develop their own explanations, which they then took to reinforce or further develop. This demonstrates that as students were exploring water surface tension phenomena through the Explore activities the partnership provided, the partner teachers must have been listening to the explanations children had for their observations and using them as a guide to judge when to move into formal explanation. It was not until '*one of the kids came up and said force field to us and we were just amazed that from all the experiment experiences that he had, that he came up with this idea on his own'* (Linda Buck, Final Participant Workshop), that the partners introduced the vocabulary (surface tension) to reinforce this notion of 'force field' on the water. This is one of the strongest applications of the Explain phase described by the partnerships. It contained clear evidence of allowing children to explore, test, form and share their own explanations for surface tension phenomena, followed by formal teacher explanation and introduction of relevant vocabulary that linked to the words and ideas that children had already posed.

Overall, the Explain phase was applied reasonably well by most partnerships. Four partnerships indicated having provided students opportunities to form and share explanations before teachers introduced formal explanations. The strongest example of this was evident in the partnership between Mr Robert Boyle, Rachel Carson and Linda Buck where the exploration and formative assessment of children's readiness for formal explanation extended across a number of lessons and provided explicit evidence of what children did as a sign of their readiness to move on. Two partnerships indicated providing formal explanation which included introduction of relevant and appropriate scientific terminology, but these partners did not provide evidence that they allowed for student formation and sharing of explanations before these formal explanations were presented. One further partnership appeared to approach it in the other direction where there was evidence of children forming and sharing explanations but no mention was made of how these were followed up with formal teacher explanation. Finally, Jocelyn Burnell, who, as noted earlier, did not really experience a partnership, reported little that provided evidence of student or teacher explanation of the focus of their explorations.

Application of the Elaborate Phase

The Elaborate phase appeared to be the most poorly understood and implemented phase from the framework, as highlighted by the mere six contributions from the different sources of data that accurately dealt with this phase. The Elaborate phase involves the higher-order teaching and thinking skills where teachers provide opportunities for students to apply and extend their learning to different contexts and student designed investigations. It also contains an element of summative assessment of the investigative outcomes. There were some accurate applications including:

> *The last station, students had to create a boat and get it to move by using detergent. This worked well; students had fun getting it to move. Little teacher assistance was required.*
>
> (Linda Buck, Online Discussion August 31, 2007)

> *The assessment task was their own experiment type project.*
>
> (Ms Rosalind Franklin, Interview)

These contributions show how examples of the Elaborate phase involved application of new knowledge to a different context in Linda's description of how children had to create a boat and make it move using detergent. This followed a series of Explore sessions where one activity explored the movement of coloured food dye in milk when detergent was added. Student-designed investigations were not a strong feature but did have some consideration in the application of Elaborate described by Ms Rosalind Franklin. Here students had to pose their own question for investigation and set about answering it through research or experimentation.

There was acknowledgement from a number of the practising teachers that the Elaborate phase was not a strong feature in the implementation of the framework. This was stated in the following ways:

> *Well probably the last stages are missing to an extent.*
>
> (Ms Jane Goodall, Interview)

> *We haven't included Elaborate as much but I'm more conscious of this now, about taking the kids further.*
>
> (Ms Virginia Apgar, Interview)

> *We noted last week that Elaborate and Evaluate we've barely used, but we think that's just the age group. You can't really go into depth with it because they just don't understand.*
>
> (Ms Marie Curie, Interview)

Of these comments it is Ms Curie's that is the most concerning. Here we see another example of the children's age being used as a reason for limiting the types of experiences they have in science learning. I believe it is a reflection more on the lack of ability of the teachers, rather than of the children, that appropriate examples of Elaboration are not built into the learning sequence for these students. It also highlights that this is an area where greater support may be required for teachers with low GCK and low confidence.

There were a total of six instances where the phases of the 5Es were inaccurately identified, and each one of these involved the Elaborate phase. This apparent misunderstanding of the Elaborate phase was also characteristic of the 'best' examples partnerships gave in the final participant workshop. For example, Ms Curie and Anita Roberts related the Elaborate phase to a discussion element that they used to help explain how volcanoes erupt. They had linked the '*eruption of a volcano to the shaking of a coke bottle causing it to overflow*' (Anita Roberts, Final Participant Workshop). This was really an analogy used to aid the explanation of how a volcano erupts rather than an extension of knowledge to a new context or connection to additional concepts through student designed investigation.

Jocelyn Burnell touched on the notion of Elaborate when she described its application as '*holding discussions about when centripetal force would be used in real life'* (Jocelyn Burnell, Final Participant Workshop). This draws on the definition of Elaborate by applying knowledge to new contexts, but she did not apply the phase fully as there was no investigation into these contexts, just brief discussion, and there was no assessment of the investigative outcomes. She also went on to inaccurately identify students forming explanations of why their seismographs would not register the simulated earthquake movements as an example of Elaborate, when this is actually an example of the sharing of informal student explanations of phenomena associated with the Explain phase.

Helen Dunbar and Gertrude Elion described how they explained how the forensic activities they had explored linked to real-life forensic investigation as their example of Elaborate. Similar to Jocelyn Burnell's example, this touched on an element of the Elaborate phase – applying knowledge to new contexts – but does not properly have students engaged in the investigation of these contexts or provide some form of summative assessment of that investigation. Other partnerships continued in this vein, presenting similar inaccurate examples of how they applied the Elaborate phase in their lessons. Again, examples presented tended to be more closely associated with the Explain phase, as highlighted by the above examples. Some also related to the Explore phase rather than Elaborate.

Ms Rosalind Franklin and Barbara McClintock's was one of the only partnerships to accurately apply the elaborate phase. After a series of lesson exploring 'What is a scientist and what do they do?' the grade 3 children individually or in pairs formed their own scientific question and researched and investigated its answer. In carrying out this activity, children had to draw on their experiences from the first 5 weeks of the inquiry unit which introduced different scientific processes through experimentation and research, and apply them in their own context. This is consistent with the notion of extending knowledge to a new context. Summative assessment of the investigating outcome was also included when children had to perform an oral presentation supported by a written presentation on their question and process they used to find the answer.

Overall, partnerships applied the Elaborate phase of the 5Es quite poorly. There were few examples of engaging students in student-designed investigations, and where this was mentioned by one partnership, no evidence for developing fair testing within the investigation was provided. Whilst three of the partnerships made reference to extending children's thinking by applying knowledge to new contexts, these appeared to be conducted in short discussion sessions towards the end of the lesson rather than through dedicated investigations into different contexts. Three partnerships were either very vague or inaccurate in describing their application of Elaborate, their examples matching instead to Explore or Explain phases. Only one partnership, that of Ms Rosalind Franklin and Barbara McClintock, accurately applied the Elaborate phase by encouraging students to design a question for investigation, apply knowledge acquired through the unit about scientific processes to answer their question, and present their findings in an oral and written form.

The Elaborate phase was almost always included in the sweeping comments made in the general discussion of the 5Es. For example:

> *All 5Es were looked at with particular focus on Explore, Elaborate and Explain.*
> (Dorothy Hodgkin, Online Discussion September 26, 2007)

These results, together with the number of inaccurate examples presented of this component of the 5Es, suggest that partners were least confident and least capable in applying the Elaborate phase to their teaching. It is likely that time constraints within the project contributed to its lack of prevalence, but these finding also suggest that a lack of clear understanding of what is intended by this phase was a major contributing factor.

Application of the Evaluate Phase

Participants offered a total of 14 responses that related to the Evaluate phase in the different sources of data. Their comments were generally descriptions of how the Evaluate phase had been achieved in the partnerships, some of which are included below.

> *During this lesson students were involved in evaluate from the 5Es module as students were presenting their knowledge and at the end students had to reflect on their learning, contribution and cooperation with other group members.*
> (Barbara McClintock, Online Discussion September 26, 2007)

> *After the brainstorming students were required to design a poster to demonstrate their learning. … It was good to see some students writing down what they had learnt, and showing some understanding of the topics.*
> (Rachel Carson, Online Discussion October 4, 2007)

> *We did try to draw up some assessment today, the kids did posters and tried to draw things together…*
> (Mr Robert Boyle, Interview)

> *They're presenting tomorrow, their findings. As part of that they have to do a report and a speech type thing, which could be an experiment, depending how into it they got. And we've used a rubric, so they're going to evaluate the speech, the report, so the written and the performance of the speech as well as the collaboration - because they do it with a partner. So they'll evaluate their own collaboration, and we'll evaluate their collaboration as well.*
>
> (Ms Rosalind Franklin, Interview)

The first two contributions, from two of the preservice teachers, demonstrate what appeared to be an overall understanding of the Evaluate phase. This was demonstrated in two ways. Firstly, there was evidence that activities were included that enabled students to reflect on their learning: '*… at the end students had to reflect on their learning'* (Barbara McClintock) and *'… students were required to design a poster to demonstrate their learning* (Rachel Carson). They also alluded to the summative assessment opportunities for teachers where students were '*presenting their knowledge'* (Barbara McClintock), and the student-designed posters Rachel referred to show examples of student-produced work that could be used for teachers' summative assessment of conceptual outcomes.

The practising teachers demonstrated a similar understanding and achievement of this phase through the descriptions they offered in interviews. Both Mr Robert Boyle and Ms Rosalind Franklin highlighted examples of student reflection and teacher assessment. This was particularly strong in Ms Franklin's contribution, describing how students performed a self-assessment, followed by the teacher assessment of the report and speeches students gave.

Given these sources of data demonstrated reasonably sound examples of the Evaluate phase, it was surprising to see the number of examples suggesting a less than satisfactory understanding of this phase when partners presented their 'best' examples of each phase in the final participant workshop. In fact, four of the eight partnerships highlighted examples of Evaluate that were actually examples of the Explain phase. The examples from Helen Dunbar and Gertrude Elion, and Mr John Dalton and partners below, highlight how this inaccurate identification was communicated.

> *One we felt went really well was after dusting for fingerprinting. We got to have a fair bit of time with them explaining it and the teacher got involved in explaining it as well and the children got right into the nitty gritty of it.*
>
> (Helen Dunbar, Final Participant Workshop)

Their description here matches the Explain phase more closely than the Evaluate phase because it specifically refers to the role of the teachers in explaining the 'nitty gritty' of fingerprint dusting. There is no evidence that children were involved on reflecting on their learning about forensic science as a whole and the teachers did not appear to be engaged in summative assessment of conceptual outcomes associated with the unit of work. Rather, as they explicitly communicate, they spent the time 'explaining'. Even though aspects of the Evaluate phase may possibly be met through a class discussion, it would not be a strong example of implementing the Evaluate phase of the framework.

Mr John Dalton, Dorothy Hodgkin and Lise Meitner explained the use of 'Mr Charge overheads' to explain electric circuits to students as an example of the Evaluate phase:

> *And for evaluate we just did Mr Charge and just sort of explained what was happening in relation to the stations they did. Just so they could see what was happening behind it all and see if they had any questions.*
>
> (Lise Meitner, Final Participant Workshop)

This inaccurate identification of Evaluate is also an example of the Explain phase. Lise states explicitly in her account that they used the Mr Charge analogy to explain what was happening in relation the electric circuit stations the students completed. There is no indication that students reflected on the concepts learnt, nor of any teacher summative assessment of conceptual outcomes, as would be expected in the Evaluate phase.

Two partnerships presented partial achievement of the Evaluate phase. The partnership involving Ms Virginia Apgar, Maria Mayar and Grace Hooper discussed the use of graphic organisers and visual representations of what was being learnt to help students reflect on their learning in the Evaluate phase. Ms Apgar described some examples of these: '*We just gave them some prompts like 'I did…, I saw…, I learnt…, I wondered…' that sort of thing just to get them started. We also used an A to Z, just those kinds of graphics*' (Ms Virginia Apgar, Final Participant Workshop). She did not state that the work students produced was used for summative assessment, but the potential to do so would exist, thus providing a reasonable fit with the definition of the Evaluate phase. The second example of partial achievement of this phase came from Ms Annie Easley and Rachel Zimmerman as they described the Evaluate session they implemented with partner Gerty Cori:

Annie	*I'll start with Evaluate. We were in a situation when we were in our fourth lesson and somehow I ended up with two classes. I knew in time fortunately, it was the buddy group of 3/4s. So we used it to help the children explain which is giving out their knowledge, which is kind of evaluation.*
Rachel	*So basically we se up some small stations again and the Grade 1/2s had to tell their 3/4 buddies what they'd done and what they'd learnt about sound.*

(Final Participant Workshop)

This excerpt highlights how students involved in the unit on sound had to reflect on their learning and articulate it to their older 'buddies' who had joined this class for a one-off session. The re-use of stations that had been used to teach the unit helped initiate explanations about particular aspects of sound that they had explored. This clearly links to the component of Evaluate where students reflect on their learning from the unit of work in order to explain the different stations to their 'buddies'. However, on their written record of the Evaluate phase, this partnership also indicated that incidental observation, questioning and feedback were strategies used by the teacher partners to assess students' learning as they 'taught' their older 'buddies' what was going on at each station. This particular description is an informal application of the summative assessment of conceptual outcomes associated with the Evaluate phase, and it is difficult to imagine that each child's full understanding could be assessed in this manner.

There were, however, two accurate representations of the Evaluate phase shared in the final participant workshop. These came from Ms Marie Curie and Anita Roberts, and Ms Rosalind Franklin and Barbara McClintock. Ms Curie and Anita Roberts communicated that their best Evaluate session was when students used knowledge of floating and sinking to select materials to build a submarine. Students were provided with an empty bottle/carton and had to select which materials they would use to make it sink. They reported that '*this selection was based on careful reflection of which materials floated and sank*' (Ms Marie Curie, Final Participant Workshop). This example also provides a product that teachers could use for summative assessment that children had produced by reflecting on and applying their learning, thus fitting with the definition of Evaluate within the 5Es framework.

Ms Rosalind Franklin and Barbara McClintock's Evaluate example had two components. Barbara described the first component where '*we did an evaluation at the end of the unit where they drew another picture of a scientist and wrote their ideas about scientists'* (Barbara McClintock, Final Participant Workshop). They brought in some 'before and after' samples to help demonstrate how they used this strategy to assess growth in the students' ideas and understanding of scientists. This partnership also used an initial and final lotus diagram (an organisational chart commonly used in Victorian schools) which they described: '*We did it together at the start and then again at the end and the difference was quite big*' (Barbara McClintock, Final Participant Workshop). These examples provided evidence that student reflection on learning and teacher assessment of learning were linked to the broad conceptual framework of the inquiry unit, and consequently provided an accurate example of the application of the Evaluate phase.

Overall, the accurate identification of the Evaluate phase in their teaching was mixed. In the final participant workshop, only two partnerships provided examples meeting the complete definition of the Evaluate phase. This meant providing evidence of how students had opportunities to reflect on the breadth of learning they had undertaken during the partnership period as well as examples of teachers conducting summative assessment. Two further partnerships provided good examples of enabling children to reflect on their learning, but poor indications of teacher summative assessment of the broad conceptual outcomes. The other four partnerships all provided descriptions that inaccurately applied the Evaluate phase, even though in other sources of data collection, the preservice teachers of this partnership had provided some accurate examples of achieving this phase.

These mixed results suggest that there was some understanding of the Evaluate phase, but it was limited in some of the partnerships. Interestingly, the partnerships where it was most limited included those where the practising teachers had indicated reasonable levels of confidence and proficiency in teaching science (i.e. Mr Robert Boyle, Mr John Dalton, and Ms Virginia Apgar). Perhaps their initial belief in themselves as effective science educators limited their capacity to apply the 5Es framework in full.

No Knowledge Development

The final sub-theme concerned with PCK development was formed by interview responses from four practising teachers who indicated that there had been no professional learning benefits from their involvement. The most emphatic of these comments came from Ms Jane Goodall and Ms Diane Fossey whose responses to the question ‘So would you say there have been any benefits in this partnership or this experience for your own learning about science or about how to teach science?’ were ‘*No’* (Ms Jane Goodall, Interview) and ‘*No. They’re not skilled enough. No, sorry*’ (Ms Diane Fossey, Interview).

In addition to these, Ms Rosalind Franklin and Mr Robert Boyle, in spite of having already indicated some growth in pedagogy and ideas respectively, communicated that there had been little benefit for their professional learning overall. Mr Boyle noted that the teaching experience in the partnership was very much aligned with how he already taught:

> *It was probably teaching how I would normally approach it I think. So for me it wasn't anything new. It wasn't really a new approach I suppose, but then see I'm not your average - I've got a strong science background.*
>
> (Mr Robert Boyle, Interview)

And Ms Franklin referred to having relatively recent experience of the types of approaches being undertaken:

> *Coming fresh from uni last year, and I really enjoyed the science component of the course, so I think I already had that knowledge there fresh.*
>
> (Ms Rosalind Franklin, Interview)

The responses from Ms Goodall and Ms Fossey are unsurprising, given they did not participate in the partnership experience. The fact that Ms Franklin had previously indicated having an extended appreciation for how to use the 5Es as a form of pedagogical knowledge and then her response here indicating she felt the ideas were already '*fresh'* in her mind, suggests that the extended thinking she experienced about applying the 5Es had a small impact on her feeling of knowledge development overall. Similarly for Mr Dalton, who expressed earlier that he had gained new ideas for teaching. Perhaps Mr Dalton did not view the gain in ideas as a form of professional learning, or perhaps the gain in new ideas had a relatively small impact and did not contribute to his overall sense of learning.

There was also little knowledge development for one of the preservice teachers, Jocelyn Burnell. Jocelyn had low confidence and ability in science and this, coupled with her feelings of being intimidated by her practising teacher partner, impeded her ability and motivation to succeed. She commented on her own lack of organisation and background research which was likely to be, in part, a consequence of her situation:

> *Something that could be improved was my own organisation and I could have perhaps done more research on the topic because some of the questions the kids asked me really threw me. But all in all I am happy that this lesson wasn't a disaster.*
>
> (Jocelyn Burnell, Online Discussion September 26, 2007)

This demonstrated Jocelyn's fairly traditional thinking about teaching as 'provider of answers' rather than partner in exploring. It also demonstrated a fairly low set of expectations on herself and the outcome of her teaching. It is possible that this 'bravado' is a consequence of Jocelyn's insecurity; it provides her with a security blanket of 'I only failed because I did not try' thinking. Her level of accountability to perform more background research and her general motivation may have also been increased if she had been part of an effective partnership. Reflection and thinking about improvement may also have been more constructive if there had been a greater level of shared responsibility for the aspects of the lesson that did not work.

Jocelyn's experience of science education had also left her thinking about science in a homogeneous manner that included fairly traditional approaches to content and practical work. This, coupled with a lack of collaboration with a partner, meant that her approaches to science teaching were unable to be challenged and changed through her experience. This is, in part, why she struggled with the inquiry approach to science and its conflict with her thinking about effective science teaching, which came through as she discussed her concern in obtaining and retaining students' interests. Unfortunately, her experience in the partnership did little to advance her knowledge or ability in this area.

Summary of Knowledge Development

Overall knowledge development among practising and preservice teachers was evident. However, the extent of this development was different for practising and preservice teachers. Practising teachers appeared to have the least knowledge development and generally speaking, it was more in the development of teaching ideas than in PCK. Small developments in GCK were evident for Ms Marie Curie and Ms Virginia Apgar, although these were focused on basic reactions and use of the interactive whiteboard respectively rather than conceptual knowledge of science. Preservice teachers provided a greater level of GCK development and were able to explicitly identify this in some of the comments they contributed to various discussions. It was apparent that both their experience in the classroom and their sharing with one another contributed to this development.

In total, 12 of the 13 preservice teachers reflected some form of growth in pedagogical content knowledge. Based on the comments offered throughout the research period, this growth was strongest for Linda Buck and Gerty Cori, where insights into the need for exploring and explaining and responding to children demonstrated advanced thinking about pedagogical approaches. Lower order thinking was evident for preservice teachers Helen Dunbar and Jocelyn Burnell whose main focus of thinking was on student engagement through 'hands-on' activities. Whilst an important component of effective science teaching and clearly something strong in their developing awareness of approaches to science teaching, it was not reflective of the more advanced thinking about pedagogy shown by some of the other preservice teachers. The remaining preservice teachers provided data that demonstrated growth in pedagogical knowledge somewhere between these two extremes. Gertrude Elion, partner to Helen Dunbar, was the only preservice teacher not to provide some indication of developing pedagogical knowledge. For practising teachers, growth in pedagogical knowledge was small and only explicitly shared by four participants.

Development of PCK was also evident through preservice teachers’ understanding of the process inherent with the 5Es framework: eliciting prior knowledge and using it to inform planning; exploring sufficiently before moving into formal explanations, and trying to elaborate with opportunities to apply knowledge and allow for evaluation through student reflection and teacher assessment of learning. They appeared to become particularly aware of the benefits of using a framework such as the 5Es with a unit of work rather than in disconnected, one-off science lessons; and appreciated the power of inquiry, hands-on approaches to engaging children in science learning. PCK development was less apparent in practising teachers. A small number of these participants did give general indications that their ideas about approaching the teaching of science had altered, but they were small acknowledgements and were not reflected in later overall assessments of knowledge growth.

Partnerships’ application of the 5Es framework was examined for each phase of the model to help judge their knowledge of pedagogy using this particular inquiry approach. Here there was evidence that both practising and preservice teachers had a reasonable understanding of the Engage, Explore and Explain and appreciated the process of moving from one phase to the next. They appeared to struggle with a full understanding of the Elaborate phase and generally omitted or mis-identified this phase in their descriptions of how it was implemented in their teaching. The Evaluate phase was implemented better than Elaborate, but again there was little evidence to indicate that it was fully understood. Partners appeared to engage with parts of each phase but generally missed the importance of the embedded assessment associated with the framework (diagnostic assessment and formative assessment in particular) and often omitted opportunities for students to reflect on their learning as a part of the Evaluate phase. Overall, knowledge of the framework was enhanced by their partnership experience, but it was still in the developmental stages as the data collection period drew to a close.

The range of comments provided in the data demonstrate that PCK was developed through the experiences preservice teachers had in teaching science to students and the engagement in reflection on these experiences. This was evident through the number of expressions that indicated an emerging awareness. For example, '*I have become aware…*', '*we chose this lesson because we realised…*', and other language demonstrated that reflection on the teaching experience was contributing to pedagogical learning. This is important as it emphasises the design of the research that placed preservice teachers in schools for reflection on an authentic science teaching experience did provide insights into approaches that were and were not effective.

The lack of formal post-lesson reflection between partners may have contributed to the low levels of knowledge development that was evident for practising teachers. Preservice teachers tended to reflect more extensively than practising teachers as there were requirements beyond the partnerships' post-lesson reflection for them to reflect and share their reflections with each other. These requirements became clear in the round table and the online discussion forums. This tended to compensate for the casual reflection that otherwise took place in their partnerships and enabled the knowledge and insight development that came from reflection to take place for this cohort. This again highlights the importance of reflection on practice for effective learning to occur.

Contributions from practising and preservice teachers also revealed a number of benefits and challenges the partnership model presented them. These are explored in the next two sections.

4.6 Benefits of the Model

There were a number of benefits in having practising and preservice teachers work together to deliver science lessons in the authentic setting of the classroom. This section examines these benefits as they emerged from practising and preservice teachers' responses in different data sources.

Students' Engagement in and Enjoyment of Science

Acknowledgement of students' engagement in the science lessons and the associated 'spin-offs' this had was one of the most widely reported benefits participants gained in the project. There was a total of 49 comments from interviews, round table and online discussions, with 13 and 36 contributions from practising and preservice teachers respectively. Participants generally expressed surprise at the level of engagement and enjoyment children had with science. This was particularly evident from preservice teachers and those practising teachers who had reported little prior of experience teaching science. This was communicated through statements such as:

> *I couldn't believe their enthusiasm. Marie bribed them all week by not telling them what we were doing in science. Friday morning she'd finally tell them and they'd hit the roof when I'd walk in with my bag full of stuff. They were just so excited to be doing science because they got to play with things.*
>
> (Anita Roberts, Round Table Discussion 2)

> *Probably seeing that they did enjoy it, because I didn't think kids enjoyed it because I never liked it. So seeing that they actually enjoy it.*
>
> (Gertrude Elion, Round Table Discussion 2)

> *We hadn't realised how much the kids were going to love it. That's one thing that really surprised me. I didn't think they'd be so engaged and now they're just 'oh is Anita coming this week, what are we doing this week?' So they equate science to Anita now. They're sick of me, they just want Anita. Kids loved it. They really did.'*
>
> (Ms Marie Curie, Interview)

It was encouraging to have Ms Marie Curie's response here. As noted earlier, Ms Curie had never taught science before and had disclosed that she has avoided teaching it due to a lack of confidence in the area. Her first response to the question about highlights of the partnership was almost one of amazement. Further comments from practising teachers regarding children's engagement included: '*then there was the engagement of the kids, they were really engaged*' (Ms Virginia Apgar, Interview) and '*And a lot of them were reporting back that they've been trying a lot of the things at home. A lot of them do they're so keen.*' (Mr Robert Boyle, Interview). Even Ms Jane Goodall commented *'But on the other hand, the children, oh, they can't wait when they're coming'* (Ms Jane Goodall, Interview).

For preservice teachers, their amazement of how engaged children were in science lessons appeared to stem from their own experiences of science which had generally resulted in a dislike for the subject. They projected their own dislike of science onto the children they were teaching, so to see such a different reaction came as a surprise. This was most evident from Gertrude Elion's comment above: '*I didn't think kids enjoyed it because I never liked it*'. Linda Buck shared a similar sentiment: *'I'm surprised by how enthusiastic they are about science, because I'm 'ohhh, I hate science' … I was surprised by that'* (Linda Buck, Round Table Discussion 1).

Some participants were also impressed by those children who had taken some of the lesson ideas and tried to implement them at home; reinforcing the enjoyment they had appeared to get from the experiences. For example:

> *… quite a few of the kids had gone and done the experiments we did in their first week at home and shown their parents and siblings.*
> (Rachel Carson, Round Table Discussion 1)

> *And some of them are taking them home too. About the volcanoes this afternoon, one of them asked 'what do I need, I'm going to make it in the holidays'.*
> (Ms Marie Curie, Interview)

Of the practising teachers, it was again Ms Curie, the teacher with no prior science teaching experience, who communicated her wonder at this engagement of children. Another feature preservice teachers attributed to the engagement of students, was the lack of classroom management issues during the science teaching period. Contributions recognising this included:

> *Well even Virginia's class, she's got a lot of very hyper boys that don't settle, but we had no behaviour problems at all because they were just really engaged and right into what they were doing and they just wanted to do more, they were just really having a lot of fun.*
> (Maria Mayar, Round Table Discussion 1)

> *There's this one kid who does have a problem, he's just easily distracted, doesn't like working with anyone. He and his partner made a volcano and it was so good, that he had someone surfing in the river down the bottom and he had people on the side of the volcano, he put so much time in.*
> (Barbara McClintock, Round Table Discussion 1)

> *It was kind of surprising how well the kids took us on board. I mean for a first lesson, normally they're a little bit testing you, but they were straight into it, it was like 'yep'. Like the fact that they sat down like I was just blown away.*
> (Gerty Cori, Round Table Discussion 1)

The engagement students had with science seemed to relieve some of the anxiety inexperienced participants had about its teaching. This was best expressed by Rachel Zimmerman:

> *I feel a lot better about teaching science. I know it doesn't have to be as elaborate… and as fancy as I thought before. You can do simple things and you're still going to engage them and you're still going to get the message across.*
> (Rachel Zimmerman, Round Table Discussion 1)

In the final participant workshop, student engagement was also noted when participants were asked to record the highlights of the partnership. Two participants noted student engagement as the main highlight of their experience with comments like: '*Students were always engaged!*' (Benefits Leaf B17).

Teachers' enjoyment of the experience was also a key feature with three of the respondents commenting on this as an overall benefit of the experience. One such comment was '*Having lots of fun teaching science to the stud*ents' (Benefits Leaf B16). Enjoyment was also expressed by a number of practising teachers in their interviews. One example from Ms Virginia Apgar included:

> *I love it. It should be used more often. It's been a wonderful experience. I got so much out of it and was sad when it finished, and the kids were too. It was so fantastic to offer a science lesson when there were three of us in the room. Everyone was receiving quality.*
>
> (Ms Virginia Apgar, Interview)

The benefits participants realised by both their own and students' engagement in the science were important. Teachers who enjoy their teaching are more likely to plan for similar teaching experiences so this result may translate into increased science teaching for these teachers once the project is over. This is encouraging in terms of the sustainability of the science teaching once the project has concluded. The insights into how engagement in science learning can encourage children to go home to talk about and repeat experiments, how it can overcome behavioural issues and how it can result in enjoyment for children and teachers in the classroom may also encourage further science teaching beyond this research project. In addition to realising how engaged students could become in science learning, participants also grew to realise how much prior knowledge and capacity for new learning children had with regard to science. Thus student content knowledge formed the second area of benefits of the model, and is explored below.

Awareness of Students' Content Knowledge

Nine contributions, all from preservice teachers, expressed surprise at the level of prior knowledge children had, or their capacity to learn science concepts that the preservice teachers thought to be difficult. Insights into the level of prior knowledge children can bring to a new topic or lesson was revealed as the Engage phase was implemented in the beginning of the teaching period. Coming out of their first lesson, three of the preservice teachers reflected surprise in the amount of prior knowledge students seemed to have with comments like:

> *There was this one kid and he just blew me away like before we had even done anything he could tell me that when we blew into the bottles it would be that the air was moving in there and the one with the most air would have the lowest sound. And I'm thinking 'this isn't grade 2'. Apparently he's the brattiest kid ever and I was just sitting there going 'Whoa'. I didn't expect that.*
>
> (Gerty Cori, Round Table Discussion 1)

> *Like they were giving words like tectonic plates and it was fairly amazing considering they haven't done it as a unit.*
> (Jocelyn Burnell, Round Table Discussion 2)

This was a key insight for preservice teachers as it emphasised the importance of the diagnostic assessment component of the Engage phase. It highlighted that the different backgrounds and experiences children bring to the classroom need to be kept in mind to ensure that the learning experiences created are beneficial for all students. It also reminds teachers that they should not make assumptions about what children do and do not know, and what they can and cannot do.

Linked to this was the insight preservice teachers gained into the capacity children demonstrated to learn new concepts. Two comments representing this insight were:

> *I was impressed by the creativity of some of the responses, but even more so by the intelligence and reasoning behind them.*
> (Gerty Cori, Online Discussion August 29, 2007)

> *During these presentations I was amazed at student's level of maturity in that they listened to each other and spoke clearly and professionally during their presentations. It was evident that students had put a lot of effort into their assignments and took the time to research their questions to the extent that they could answer most questions that students asked.*
> (Barbara McClintock, Online Discussion September 26, 2007).

These comments reflect the insight preservice teachers gained about both the knowledge children bring to the classroom but also their capacity to understand and retain knowledge in a unit of work. The authentic classroom teaching experience was again critical in developing preservice teachers' belief in the capability of children to learn science. This particularly applies to the notion of prior knowledge which is discussed a number of times in lectures and tutorials in science education units as well as other units about learning in general in the university course. But it was not until the preservice teachers had to plan and implement lessons that explicitly dealt with eliciting students' prior knowledge that they seemed to believe the truth of these teachings.

Insight into Preparation Time

A significant area of growth in understanding and awareness came through preservice teachers' round table and online discussion contributions about the preparation of science experiments. Preservice teachers became aware of the time it takes to set equipment up and the implications of this if the classroom is already in use, or if an alternate space is required. Some of the comments reflecting these issues included:

> *I think you realise the time it takes to set up because in tutes everything is already set up, well I don't really think about you doing that, but we got there at 8.00 this morning to set up the stations, well to help set them up, like you don't really think about that time that goes into that. It is more time consuming.*
>
> (Barbara McClintock, Round Table Discussion 1)

> *Because we're actually planning it, it takes on a whole different context. And also, having to actually do it in the school, you're more aware of the context and you know, how it's going to work in the school.*
>
> (Maria Mayar, Round Table Discussion 1)

Having to be responsible for the organisation and setting up of equipment provided this insight into the time and organisation. This is something preservice teachers may experience in peer micro-teaching at university to an extent, but again, the authentic experience of the real classroom with real children adds a deeper insight into what and how much can be used for effective learning to occur.

Engagement with Partners

When partnerships were collaborative, the engagement between partners led to a feeling of being supported, opportunities for sharing ideas and reflecting together, and an overall enjoyment of the experience. For example, in the Tree of Knowledge activity in the final participant workshop where participants were asked to record the overall benefits they had gained from their experience, over half of the participants (nine) commented on the support and/or collaboration they experienced. A typical comment from these leaves included '*Having each other there for support and to back each other up*' (Benefit Leaf B3) and '*Working together and feeling supported. Sharing goals'* (Benefit Leaf B9).

The engagement with participants in a collaborative partnership was also reflected through the sharing of ideas they reported as a key benefit in the tree of knowledge activity. Sharing ideas and having someone to bounce ideas off was seen as a particular strength of the model. Seven of the 17 respondents made some comment about this in the Tree of Knowledge activity in the final participant workshop through contributions such as '*A number of different perspectives – bouncing off each other for ideas'* (Benefit Leaf B1) and *'Having other adults to share new ideas and give new direction'* (Benefit Leaf B14).

The benefit of sharing ideas also emerged strongly in other data collection sources. In fact it was such a strong area of their development, that it was established as a theme within the knowledge development data where practising and preservice teachers demonstrated a number of occasions where their sharing supported their knowledge development about ideas for teaching science. The usefulness of sharing and the impact on knowledge development was expressed by one preservice teacher in particular:

> *It's good that we're reflecting online. We read everyone's things and yeah, we got all excited about Maria Mayar's one. We were like 'Oh yeah, this can relate'. But it's good to get ideas and build up a collection of ideas from what other people are doing.*
>
> (Helen Dunbar, Round Table Discussion 1)

The sharing with others led to learning experiences that a further four participants noted through the Tree of Knowledge activity through comments such as '*Watching and learning from others'* (Benefit Leaf B9). This is something that can be difficult to achieve in teaching given its isolated nature where it is rare for two teachers to teach together, unless their classes are joined and team teaching is conducted.

One participant also identified how sharing in a reflective way was a benefit of the model. This was expressed through the contribution: '*Having a partnership allows for formal reflection of your teaching'* (Benefits Leaf B11). This was also mentioned by Ms Rosalind Franklin who commented on the strength of the collaborative partnership in offering an opportunity to reflect on her practice and the subsequent improvement this brought about in her teaching:

> *It forces you to reflect on your own practice and I think that's good for any teacher, and having a student there really makes you think 'What am I doing - How is this going - what can I improve'. So it improves yourself as well as hopefully the student.*
>
> (Ms Rosalind Franklin, Interview)

This opportunity for reflection was also highlighted by Mr John Dalton:

> *'I haven't had a student teacher before, I've never really had anyone in the classroom besides a few parents, so it's made me really think about how I deliver it.'*
>
> (Mr John Dalton, Interview)

These contributions, along with the evidence that sharing ideas helped knowledge development described in Theme 1, highlights the strong benefit of sharing this partnership model enabled.

Use of time and resources

The model was seen to provide effective utilisation of time and resources, particularly in comparison to more traditional teaching rounds. For example, Ms Annie Easley, Ms Virginia Apgar and Mr Robert Boyle expressed how they felt more able to contribute to the planning and implementation in this model, and their preference for working in this way. This is clear from each of their comments below.

> *When I've worked with student teachers and I've had to sit and watch, I've sometimes felt this is wasting both our time, really, very much. They're teaching knowing I'm writing about them.*
>
> (Ms Annie Easley, Interview)

> *It should be a model for preservice teachers - work with teachers rather than for teachers. It gives what they're doing more credibility to teachers instead of sitting down at the back of the room while they teach. That's such a waste of resources.*
>
> (Ms Virginia Apgar, Interview)

> *I'm more free to share from my experience or my resources rather than requiring them to come up with their own things. So that's a bit more freeing. That's another strength.*
>
> (Mr Robert Boyle, Interview)

These comments highlight the benefit of utilising the available human resources and expertise of practising teachers in the partnership model. Ms Easley also implied that the teaching conducted by preservice teachers whilst being observed and assessed is different from the teaching that took place in the partnership model, with her reference to ‘*They're teaching knowing I'm writing about them*’.

Mr Robert Boyle suggested that the partnership model provided a safe environment for preservice teachers to experiment with own practice and trial different strategies.

> *I was encouraging them to you know if you see something and you want to have a go at doing it, then this is a good chance to do it. Although I say that to student teachers too but not many do.*
>
> (Mr Robert Boyle, Interview)

Here, Mr Boyle is indicating that he encouraged student teachers in a traditional professional experience round to experiment in this way also but that ‘*not many do*’. Perhaps it is the safety of removing the threat of assessment of preservice teachers’ teaching and the creation of a team approach that links back to the shared ownership and responsibility benefit already identified in this theme that allowed these preservice teachers to more willingly experiment with strategies and practice. This was acknowledged in one of the contributions to the Tree of Knowledge activity where it was stated on one of the benefit leaves, clearly from a preservice teacher: *Being in a classroom and not being assessed – I felt much more relaxed when teaching*’ (Benefit Leaf B8). Here representatives from each of the participant cohorts highlight the capacity to provide better teaching and learning opportunities for both practising and preservice teachers when collaborative partnerships are established.

The effective use of human resources was also recognised in contributions acknowledging the benefit of having a number of teachers in the room. This was featured in four participant responses in the Tree of Knowledge activity in the final workshop with contributions such as '*Engaging children in small groups for explore and explain – a teacher for each group'* (Benefit Leaf B5) and '*More people in classroom to facilitate learning'* (Benefit Leaf B2). This was also noted in three of the interviews with practising teachers with comments such as: '*It's always helpful to have more adults in the room*' (Mr Robert Boyle, Interview).

Participants viewed the partnership model as offering better opportunities to effectively use both practising and preservice teachers together in the classroom which both strengthened learning opportunities for children and saw a more effective use of each participant's time. This decreased ratio of children to teachers was also recognised as a benefit for students' learning and suggests that better learning is afforded with lower student to teacher ratios, perhaps adding to the argument that class sizes should be lowered. The collaborative model used in this project increased the student - teacher ratio, providing teachers with more opportunity to observe each other which, coupled with post-lesson reflection (even if it were informal), provided better learning opportunities.

Focus on Children

Another key benefit that emerged from practising teachers' discussion of benefits of the collaborative partnership model was linked to the shift in focus from assessing student teachers' performance to a focus on children's learning. This emerged from comments such as:

> *The focus was on what was being learnt by the kids, not on assessing student teachers, so there was more opportunity for reflecting on performance, but not in a bureaucratic way. The focus was on active learning for the kids in the class and for them.*
>
> (Ms Virginia Apgar, Interview)

This links strongly to the previous theme that considered the effective use of time and resources, particularly in relation to how practising teachers used their time as active participants in the planning and implementation, rather than passive observers '*sitting down at the back of the room while they teach'* (Ms Virginia Apgar, Interview). The shift to active participation in planning and implementing of the lesson, meant that assessment of lesson structure and components was removed. Teachers' immersion in the planning process removed the need to assess it as an external observer. Assessment of the delivery of the lesson was undertaken by both partners, of themselves and of each other, through reflection. This reduced the threat of assessment and made the process inclusive. With the emphasis taken from these two components of the preservice teachers' performance, and which characterise all other models of practising and preservice teacher partnership, the collaborative planning, teaching and reflecting allowed the focus to shift onto students' learning.

Further evidence of the strong focus on children came from preservice teachers in comments they offered relating to how the model enhanced their understanding of children's needs and interests. This was represented by remarks such as:

> *I think that's where working with the teacher has been really good for us because like we've had ideas but she knows what the kids will be engaged with, because she knows the kids a lot better, then you know, she knows what's going to work better.*
> (Maria Mayar, Round Table Discussion 1)

Preservice teachers also noted differences in planning and implementing that arose due to the authentic teaching experience that contributed to the development of their understanding of children's needs. This was evident through comments and exchanges such as:

> *I did the cars one in the tutorial and then taught it in the classroom, it was completely different. I suppose that was useful, because you learnt the instructions needed to be clearer, that they need more time and that type of thing. It changed it.*
> (Barbara McClintock, Round Table Discussion 1)

Gertrude Elion	*You don't really know either, which way the kids are going to go. Like with us, being older, we know more information, we know a lot of different stuff, but the kids don't. So you don't know what they know and what they don't know so you've got to create a way so everyone is going to learn something from. They're not repeating something they know really well.*
Mellita	*So would you say it is the time in the school that is helping you realise that or is that something you feel you would have known?*
Gertrude Elion	*I think it has, because some of the things the kids have come up with, I would never have come up with. They had different ideas, different things that they wanted to explore themselves compared to what I would explore and I think it also helps in understanding how kids learn in that environment, how the different stations impact their learning or what could be done better, because in an older situation, we know how we learn, well most of us do anyway.*

(Round Table Discussion 1)

The structure of the model was significant in helping preservice teachers experience of these benefits. Only through working with a practising teacher could they gain such immediate insight into some of the needs and interests of the students they were working with. It was also the opportunity for teaching in an authentic context that helped them to learn the types of ideas and directions children take which the preservice teachers favourably compared with the peer micro-teaching situations they would normally experience in discipline-based units such as this.

> *I think you remember it better, like you know how there are other units where we have done bits and pieces, examples, you know, but you don't remember what they were. …if you've taught something before and you remember 'oh I wouldn't do that again, or I'd do it this way next time'. You don't take it on board the same way when someone's demonstrating it.*
>
> (Gerty Cori, Round Table Discussion 1)

This collection of participant responses shows how the partnership experience enabled a greater focus on children and their learning. In particular when partnerships were collaborative, the focus of practising teachers moved away from assessment of preservice teachers on to the children and the learning experience because they were actively involved in the planning and delivery of each lesson. Through the collaborative partnerships, preservice teachers were more quickly attuned to children’s needs as the teacher assisted the planning process as an equal contributor. This meant ideas and strategies that may not work were able to be noted and changed earlier in the planning sequence than would occur in a more traditional partnership where practising teachers often do not see a lesson plan until it has been completed and is soon due to be taught.

Preservice teachers also gained a deeper insight into appropriate instruction, scaffolding and children’s thinking about topics. They were quick to compare their experience with that of the peer teaching they knew colleagues not part of the research group were experiencing. This insight was due more to the authentic teaching experience than the collaborative partnership, but added to the overall benefits of the model.

Being Seen as a Teacher

Some of the preservice teachers also felt that this model provided them with the higher status of being seen as a teacher rather than a student teacher. Three comments from preservice teachers highlighted this as a benefit. For example:

> *We were introduced as teachers, not student teachers. I think that made a bit of a difference too.*
>
> (Maria Mayar, Round Table Discussion 1)

> *Considering they were a really, really naughty class, the kids gave me a lot of respect really, which is what I was scared of really. But yeah, they've been really good and I think sort of establishing myself as not being a student teacher helped that.*
>
> (Jocelyn Burnell, Round Table Discussion 2)

The collaborative partnership model and the context of teaching in schools not associated with formal teaching rounds both contributed to this view of the preservice teachers. The fact that preservice teachers were in and out of the classroom also seemed to reinforce students' view of them as 'the science teachers'. It certainly appeared to give Jocelyn a boost in confidence which she needed, both in her ability to teach science and in her thinking of herself as a teacher. Maria's comment was also taken from the context of discussing student behaviour and she too felt that the children's view of her as the teacher helped with classroom behaviour management.

Helping Participants Achieve their Goals

The model also appeared to enable participants to achieve a number of personal goals through their involvement in the project, along with other worthwhile goals that had not necessarily been identified prior to the partnership experience. These goals and achievements were recorded in initial and final questionnaires and are described for each of the practising and preservice teacher cohorts below.

Preservice Teachers' Goals and Achievements

In the initial questionnaire, preservice teachers were asked what they were hoping to achieve/obtain through their involvement in the project. Responses were collated under common categories that showed the frequency with which each goal occurred for the 12 preservice teachers who completed and returned this questionnaire. Most preservice teachers listed more than one achievement goal.

As shown in Table 4.6.1 confidence and content knowledge were the two greatest goals expressed by preservice teachers. The remaining four goals they listed all have to do with their desire to gain experience and increase their repertoire of strategies and ideas for teaching science. These goals indicate that preservice teacher participants generally had low levels of experience and confidence in their ability to teach science in an engaging and effective manner.

When asked what they had achieved through their involvement in the project in the final questionnaire, preservice teachers gave a number of responses that fell into eight general categories. Most preservice teachers reported having gained more than one achievement. Their responses and corresponding frequencies are summarised in Table 4.6.2.

Table 4.6.1: Frequency of Preservice Teachers' Desired Goals

DESIRED GOALS	EXEMPLAR COMMENT	FREQUENCY (N = 12)
Confidence	I'm hoping to become far more confident in science teaching because currently I would prefer to not teach maths and science if it were possible (Rachel Carson).	9 (75%)
Science content knowledge	I hope I will gain a lot more science knowledge because I currently feel like I do not know much (Gertrude Elion).	8 (67%)
Teaching approaches to science	Being able to discover more approaches to teaching science (Rachel Zimmerman)	6 (50%)
Classroom experience teaching science	I have never observed or taught a Science lesson before, so I feel I need that experience (Dorothy Hodgkin).	5 (42%)
Ideas for activities/experiments	New ideas/experiments (Anita Roberts)	4 (33%)
Insight into engaging students	Learn more about how to make science fun and engaging for both students and teachers (Maria Mayar).	3 (25%)

NB. Frequency calculations represent the proportion of preservice teachers who identify each area of achievement and hence add to more than 100% since most preservice teachers identified more than one goal for the project.

Table 4.6.2: Frequency of Preservice Teachers' Areas of Achievement

AREA OF ACHIEVEMENT	EXEMPLAR COMMENT	FREQUENCY (N=12)
Confidence	Confidence with teaching science (Dorothy Hodgkin)	7 (58%)
Insight into students' enjoyment of science	I realised how much students enjoy science (Helen Dunbar)	6 (50%)
Classroom experience teaching science	Knowledge of how to teach science in a real classroom (Jocelyn Burnell)	5 (42%)
Learning to team teach/collaborate	Learning about team teaching/collaboration (Maria Mayar)	4 (33%)
Science knowledge	A more solid understanding (Rachel Zimmerman)	4 (33%)
Variety of ideas and approaches for teaching science	Exposure to a variety of ideas (Barbara McClintock)	3 (25%)
How to integrate science	I now understand how to integrate science into literacy lessons (Rachel Carson)	3 (25%)
Realisation that science is not difficult	It has shown me that science is not difficult to teach (Gertrude Elion)	2 (17%)

NB. Frequency calculations represent the proportion of preservice teachers who identify each area of achievement and hence add to more than 100% since most preservice teachers identified more than one achievement for the project.

It is encouraging to see that the most desired goal preservice teachers had to increase their confidence was also the most prevalent response regarding what was achieved, as indicated in the final questionnaire. Here seven respondents acknowledged their increased confidence to teach science. The second most prevalent desired goal was to increase science content and knowledge followed closely by gaining ideas for teaching science. Results in Table 4.6.2 show that increased science knowledge was achieved in a reported four cases and ideas for teaching science in three cases.

An insight into students' love of science was the second highest reported gain with six respondents acknowledging this new knowledge. This surpassed the three preservice teachers who had initially identified a desire to find out how to engage children in science. Children's natural interest in science was a surprise for most preservice teachers and they did not have to work very hard to capture their interest. The only other item that five preservice teachers had identified as wanting to achieve was general experience teaching science. All five reported having achieved this goal. In addition to their original goals, preservice teachers reported having achieved how to team teach/collaborate with a practising teacher in four cases, knowledge of how to integrate science with other curriculum areas and in two cases, preservice teachers commented on their realisation that science is not difficult.

These results indicate that preservice teachers were generally able to achieve the goals that they had initially hoped to gain through their involvement. They also indicated additional achievements that had not been considered prior to the commencement of the project. It is important that the main goal of increased confidence was achieved in most cases. Further increases in GCK would have been beneficial to better meet the aspirations of a number of preservice teachers.

Practising teachers' Goals for the Project

Ten different areas of aspiration were recorded in practising teachers' initial questionnaires. Table 4.6.3 shows these responses and their corresponding frequencies. Professional learning was the key goal expressed followed by a range of goals referring to different components that teachers had been informed that the project would address. This included working collaboratively, working in science teaching action-reflection cycles and working with the 5Es model. The goals of working collaboratively, increasing children's understanding of and exposure to science, reflecting on teaching and access to ideas all align with the initial information teachers received. This reflects well on their understanding of the initial project proposal and the chances of achieving these goals. Table 4.6.4 presents what practising teachers felt they had achieved on completion of the project, communicated through final questionnaires or interviews.

Table 4.6.3: Frequency of Practising teachers Desired Goals

DESIRED GOALS	EXEMPLAR COMMENT	FREQUENCY (N = 8)
Science PD	Increase my knowledge in up-to-date theories in teaching science (Mr John Dalton)	5 (63%)
Collaboration	To work collaboratively (Ms Annie Easley)	3 (38%)
Increase Exposure to Science	Good for my kids to experience different approaches to teaching science (Mr Robert Boyle)	3 (38%)
Access to Ideas	Ideas – sharing' (Ms Rosalind Franklin)	3 (38%)
Reflection on Teaching	I am hoping to engage in some reflection upon my teaching (Ms Virginia Apgar)	2 (25%)
Reason/excuse to do Science	To have a reason to indulge in a science area/topic (Ms Annie Easley)	2 (25%)
Assist Preservice Teachers	Involved to help preservice teachers teach science in the classroom and build confidence for them (Mr Robert Boyle)	2 (25%)
Have a 'Science Expert'	Having a student who I thought would have been sort of a slight specialist in the field (Ms Diane Fossey)	2 (25%)
Better student supervision	Students working scientifically will be better supervised (Ms Annie Easley)	1 (13%)

NB. Frequency calculations represent the proportion of practising teachers who identify each area of achievement and hence add to more than 100% since most practising teachers identified more than one goal for the project.

Table 4.6.4: Frequency of Practising teachers' Areas of Achievement

AREA OF ACHIEVEMENT	EXEMPLAR COMMENT	FREQUENCY (N = 8)
Opportunity for Collaboration	Collaboration experience (Ms Annie Easley)	3 (43%)
Increased Confidence	Increase in confidence, not afraid to teach science now (Ms Marie Curie)	2 (29%)
Sharing Ideas	Great ideas (Ms Virginia Apgar)	2 (29%)
Learning on 5Es	Reminded of the 5Es (Ms Rosalind Franklin)	1 (14%)
Reflection Time	Reflection of own teaching (Ms Rosalind Franklin)	1 (14%)
Access to Resources	Some access to specific equipment. Some access to good primary resources (Ms Jane Goodall)	1 (14%)
Inspiration from Preservice Teachers	Inspiration from very competent preservice teachers (Ms Virginia Apgar)	1 (14%)
Motivation to Teach Science	Became more motivated to teach science (Mr John Dalton)	1 (14%)
Optimism about Science	Optimism for the future of Science Education in Primary Schools (Ms Annie Easley)	1 (14%)

NB. Frequency calculations represent the proportion of practising teachers who identify each area of achievement and hence add to more than 100% since most practising teachers identified more than one achievement for the project.

There were some discrepancies between the goals teachers had hoped to achieve what they reported as having gained from their involvement in the project. Most teachers had wanted some science professional development but only one teacher reported having achieved this. In addition to this discrepancy, six areas of achievement identified as goals were not mentioned at all in responses to what had been achieved. These included the goals to: increase children's understanding of and exposure to science; have a reason/excuse to do science; assist preservice teachers; have a science expert; to have a clearer focus and purpose; and have better student supervision.

Some goals were achieved however, with two of the three practising teachers who identified a desire to work collaboratively reporting that they gained this experience. Access to ideas had also been a goal for the project for three teachers, and two of them reported this had been achieved. One of the two teachers who hoped for reflection on teaching reported attainment of this goal.

In addition, a number of achievements were reported that had not been set out as initial goals. These unanticipated achievements included increased confidence; access to resources; inspiration from preservice teachers; and an increased motivation to teach science. Thus some worthy achievements were attained from practising teachers' involvement, even if they had not been anticipated.

The desire for science professional learning was able to be measured through another question on the final questionnaire. Practising teachers were asked to rate, using a ten-point scale, whether the project experience had any benefits for their professional learning. This scale is shown in Figure 4.6.1.

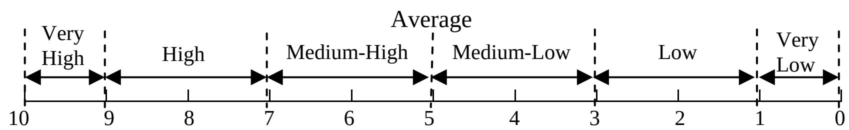


Figure 4.6.1: Values and Measurements for the Scale – Benefits of Project Experience on Professional Development in Science

Teachers' assessment of the model using this scale ranged from a score of a Very Low 1 (Ms Jane Goodall) to a Very High score of 10 (Ms Virginia Apgar). Individual teacher's responses are reported in Table 4.6.5. These findings, along with teachers' responses to the items asking what would be needed to improve professional learning capacity within the model, are summarised for each practising teacher below. Coupled with their self-assessed confidence and STEBI self-efficacy measurements, these results help depict the level of impact the model offered as a form of primary science teacher professional learning.

Table 4.6.5: Score for Benefits of the Project Experience on Professional Development in Science

PRACTISING TEACHER	SCORE
Ms Virginia Apgar	10
Ms Marie Curie	8
Mr John Dalton	8
Ms Annie Easley	7
Mr Robert Boyle	6
Ms Rosalind Franklin	5
Ms Jane Goodall	1
Ms Diane Fossey	-
AVERAGE	6.4

This table indicates the mixed results the project had for impacting on practising teachers' professional learning. In some cases it aligns with other findings about practising teachers' knowledge development, but in some cases it is inconsistent. For example, Ms Curie reported a high level of impact of the project on her professional learning with a score of 8 out of 10 on this scale. This is consistent with other findings that indicated Ms Curie experienced growth in GCK, PCK and self-efficacy belief. She captured some of this in her statement where she articulated that she achieved an '*increase in confidence*' that meant she was '*not afraid to teach science now*' when responding to the open-ended section of the final questionnaire. Mr Dalton, the other practising teacher found to have benefited in knowledge development and self-efficacy beliefs, also rated the project High when responding to this item on the final questionnaire, stating that he had become '*more motivated to teach science and allow others into the classroom*' (Mr John Dalton, Final Questionnaire).

The only other finding from this response item that was consistent with other data sources came from Ms Goodall who ranked her experience at a Very Low 1 for impact on professional learning. This was consistent with other data indicating that she experienced little to no gain from her involvement.

More inconsistent findings occurred for the remaining practising teachers who rated the project between a Medium 5 and a Very High 10 points for impact on professional learning. Other data sources from these practising teachers had however indicated little change in self-efficacy beliefs and little to no knowledge development except for a few valued ideas for science lessons. This suggests that either these ideas were very highly valued by practising teachers, or that they were using this scale to rate their overall enjoyment of the project rather than how it had benefited their professional growth. A positive relationship with me may also have influenced higher ratings to be given if practising teacher participants felt concerned that marking this at a low would adversely affect my feelings.

Practising teachers did qualify their ratings, providing some evidence to support their assessment of learning. For example, Ms Rosalind Franklin reported having gained '*time for reflection on own teaching'* and a '*reminder of the 5Es'* (Ms Rosalind Franklin, Final Questionnaire). Ms Annie Easley appreciated having had the '*opportunity to share (both ways)'* (Ms Annie Easley, Final Questionnaire), while Ms Virginia Apgar responded having gained '*great ideas; wonderful support; and inspiration from very competent preservice teachers*' (Ms Virginia Apgar, Final Questionnaire).

Overall, the average score of 6.4 for the benefits of the project experience for practising teachers' professional development in science is of a medium-high, level according to the scale developed in Figure 4.6.1. These summary results from practising teachers are encouraging and show that the model could be beneficial for professional learning for those teachers who have little experience and/or confidence in science if they are willing to participate in the collaborative nature of the partnerships.

Summary of Benefits of the Partnership Model

Overall there were a number of important benefits of the partnership model. These included important insights that helped preservice teachers gain valuable experience in a range of facets linked to effective science teaching and learning, especially the realisation of how much children are engaged with hands-on science lessons, and an awareness of students' prior knowledge and capacity for learning. Participants recognised the benefits of the opportunities for collaboration and discussed how the model allowed for more effective use of time and resources. The sharing of ideas and focus on children's learning were also highlighted as benefits emerging from the partnership approach. These experiences appeared to contribute to the building of preservice teachers' confidence to teach science through successful mastery experiences.

These insights however, were almost exclusively associated with preservice teachers rather than practising teachers. This may be due to the nature of the questioning and the number of opportunities preservice teachers had to contribute compared to practising teachers. Alternatively, it may be due to the authentic science teaching experience that preservice teachers had coupled with the fact that they had little to no science teaching experience prior to their involvement in this project. In contrast to this, the majority of practising teacher participants, except for one, reported having had a number of prior science teaching experiences.

Practising teachers did report a number of benefits, and these appeared to be linked to the level of collaboration achieved. Collaborative partnerships were reported to offer practising teachers an opportunity to build collegiality reflective of authentic teaching experiences, to enhance practising teachers' teaching performance and standards, and create shared accountability. They supported better use of time and expertise by utilising the available human resources of both practising and preservice teachers in the classroom and enabled a shift in focus away from preservice teacher performance to children's learning. They also provided an enjoyable model of preservice and practising teacher partnership, an opportunity to reflect on practice, and encourage greater risk taking and experimenting with strategies which helps preservice teachers discover and trial approaches that suit their personal styles. The partnership model also appeared to enable personal goals of participants, as well as a number of additional achievements, to be attained.

Alongside these benefits, however, participants also reported a number of challenges and weaknesses with the model. These are explored in the next section.

4.7 Challenges and Weaknesses of the Model

Participants voiced a number of experiences that emerged as challenges or potential weaknesses of the partnership model. These ranged from minor challenges to significant ones and included areas such as time, timing, timetabling and continuity; unexpected situations arising; perceived lack of experience; communication, and, for two preservice teachers, a lack of collaboration.

This latter challenge, coupled with responses from partners who did experience a collaborative partnership of some sort, revealed an apparent weakness with the model: its success depends on the partners within the partnership and their willingness to collaborate. These challenges are explored below.

Time

Time was consistently identified as an issue throughout the data and when participants were asked to discuss challenges explicitly, it was no surprise that it emerged as the major theme. A total of twelve comments were made by seven of the eight practising teachers regarding the challenge of time concerning a range of associated issues as described below.

Finding Coinciding Time

Some of the comments referred to the difficulties of finding coinciding time within partners' competing schedules as is demonstrated in these excerpts:

> *Time is one thing. The girls have LOTE beforehand and Lise goes to work straight after. So she's pretty limited and that only leaves us with the hour.*
>
> (Mr John Dalton, Interview)

> *…it just happened that the one time that they were both available seemed to be Tuesday afternoons and it was my second last choice of all the times in the week. And they finished lectures late, and I've got yard duty, so they arrive and we've only got about 20 minutes in which to sort of get together and set up.*
>
> (Ms Annie Easley, Interview)

> *Time to meet and discuss – conflicting timetables.*
>
> (Challenges Leaf C1)

There was a suggestion that greater direction from the researcher at the beginning of the project may have helped participants think about some of these issues:

> *Yeah well I guess if you did it again perhaps you could say 'think about when you're going to have your sessions with the kids, and think about the consequences of having it wherever you do place it. Whether you want to have a post discussion you might have to have it last hour of the day rather than the first hour or something'.*
>
> (Mr Robert Boyle, Interview)

Here Mr Boyle implies that had his partnership had time either side of the implementation session, better planning and reflection may have resulted. Because they had not considered this when deciding the timing of the implementation, and the partners ended up rushing off to other activities once the classroom session was complete, planning and reflection suffered. Emphasising this in the initial participant workshop may help partners plan better times and consequently improve opportunities for formal planning and reflection.

Time for Planning and Reflection

Linked to the issue of finding coinciding time, was an acknowledgement of the challenge of finding time to plan and reflect effectively:

> *You don't really have time to sit down and do the thorough plans it's kind of a both planning and reflection on the run.*
>
> (Mr Robert Boyle, Interview)

> *Probably at the end of the day we're rushing we could probably spend a little bit more time so that when Thursday comes around its just ready to go.*
>
> (Mr John Dalton, Interview)

> *Finding time to plan and reflect together.*
>
> (Challenges Leaf C2)

Ms Rosalind Franklin indicated that directing a focus for reflection might help improve reflection sessions with her comment:

> *Perhaps a specific focus before the lesson, possibly … Like 'today could you watch my instructions', or that sort of thing possibly.*
>
> (Ms Rosalind Franklin, Interview)

Each of these teachers alluded to the challenge of finding time to plan lessons more systematically. They also presented the notion that greater structure in the directions might assist partnerships in avoiding some of the challenges that arose. Mr Robert Boyle's idea of explicitly discussing the placement of planning, reflecting and teaching sessions in the initial workshop could be particularly beneficial, as partners tended to focus their planning of coinciding time around when lessons would be conducted, neglecting the planning and reflecting that they perhaps thought would 'just fit in somewhere' without really considering when and how.

Duration of Project

Some ideas for improving time included extending the overall project time so that it went longer than the 5-6 weeks:

> *And even to go longer. Because I think my girls have got better, and I'm sure today, they're coming at 12, I'm sure today will be an even better lesson than last time'.*
>
> (Ms Jane Goodall, Interview)

> *I would have liked to have had more time with Barbara because it was so short to help each other out.*
>
> (Ms Rosalind Franklin, Interview)

> *Short amount of time in schools.*
>
> (Challenges Leaf C6)

Each of these comments indicates that participants believed that improvements in lessons were, at least in part, a product of time and experience. They each indicated that if the project duration could be extended, further improvements would be gained.

Prior Notice

A sub-set of the issue of 'Time' was 'Prior Notice'. This emerged when two participants in the final participant workshop recognised that the timing of the project had not been ideal. Their reasoning for this was that the science unit in the school had already been planned and implementation had begun, so the preservice teacher was not able to help shape the topic of the unit and was not there for the first few weeks of its teaching. This was linked to the amount of notice practising teachers were given prior to the project's commencement: *'If given more notice and to be planning together from the onset would have been better'* (Ms Rosalind Franklin, Interview).

Continuity

A further sub-set of the category dealing with time challenges was the issue of continuity. Practising and preservice teachers commented on this including this comment from Ms Diane Fossey:

> *… I guess the fact that if you have a student here during the time of the unit, they would be more in tune with what you would hope the outcomes of the whole unit would be. So perhaps the fact that she is removed from the thematic unit or the integrated unit means that she doesn't really know where we're going or what we're looking for.*
>
> (Ms Diane Fossey, Interview)

This excerpts touches on the challenges associated with the practising teacher coming in and out of the classroom for the 'once a week' science lesson. Also discussing this issue, Ms Easley noted the difficulty preservice teachers had in learning children's names and developing a strong sense of their abilities. It also detracted from the preservice teacher's ability to gauge the approaches and routines that the children are comfortable with, which may help with classroom management and grouping of students. Ms Fossey also discussed how this fragmented experience of the class unit theme can impede the preservice teacher's sense of how the learning is connected to other classroom experiences, and inhibits a connected approach to teaching and learning which may be avoided if the preservice teacher had been present for a full week/round.

Some of the preservice teachers highlighted this as an issue too:

> *I think the disadvantage of going into the school like as a specialist type teacher is that if you were the classroom teacher and you ran out of time it wouldn't matter you could continue after lunch and it wouldn't matter but going in like this you've got those time constraints and if you can't get it done or squeeze it all in you have to sacrifice something.*
>
> (Maria Mayar, Round Table Discussion 2)

These comments indicate how the lack of continuity in the classroom can present as a challenge and can be a potential weakness in a model such as this. The issue of finding coinciding time discussed previously would also be reduced if preservice teachers were in the schools on a more continuous basis. But then, as also discussed earlier, some preservice teachers felt that the periodic time in the classroom for science lessons encouraged students' view of them as teachers, so there appears to be two sides to this challenge.

Certainly the difficulty of finding coinciding time and the desire for the experience to have a longer duration shows the disadvantages of operating a partnership model in a periodic, discontinuous manner. This is likely to have impacted on partners' ability and desire to fulfil formal planning and reflection sessions, as any coinciding time that was found was utilised firstly for the implementation of lessons, then for planning, and finally, if available, for reflection.

Unanticipated Situations

Partners reported on a number of situations that arose unexpectedly during the partnership period which presented a range of different challenges. For example, the partnership involving Ms Virginia Apgar, Maria Mayar and Grace Hooper was influenced by a period of convalescence taken by one of the preservice teacher partners. This was recognised by Ms Apgar: '*Grace wasn't well. It was at an unfortunate time, a third person would have been good to bounce ideas off.*'

Three of the partnerships also experienced an unexpected need to combine classes, effectively doubling their class sizes for a lesson. These situations created challenges in adapting respective lesson plans as the following comments indicate.

> *On Tuesday the 18th of September we conducted our final lesson on sound with the grade 1/2s however an extra challenge was added to the mix another class grade 3/4, the buddies of our 1/2s. Admittedly this made some aspects of lesson more complicated as it was difficult to asses what the grade 1/2s have discovered about sound as some of the 3/4s got a little excited and were calling out the answers before the grade 1/2s were given time to consider their responses.*
>
> (Rachel Zimmerman, Online Discussion October 1, 2007)

> *We had a change to our lesson plan today, having a grade 5/6 class join our 1/2 class. This changed things, as we had such a large group. We did not introduce the lesson as we had planned since the group was so loud and unsettled. The older class was able to assist the younger students in this activity which was helpful.*
> (Anita Roberts, Online Discussion September 21, 2007)

In the case of Linda Buck and Rachel Carson this challenge appears to have been managed quite well:

> *We decided that we would use a whole class approach to this particular lesson. We ended up with the other grade two class who had a CRT, sure our resources were stretched, but it was a good experience working with other teachers.*
> (Linda Buck, Online Discussion September 13, 2007)

The difference for this partnership however, is that it did not occur in the final session where the Evaluate phase was to be implemented and summative assessment was to be conducted. Having what were older 'buddies' join the group in both of the other cases, made it challenging for these partnerships to focus assessment on what the younger 'buddies' knew.

The other unexpected situation that presented a challenge for two of the partnerships occurred when the practising teacher partners were unable to be in class at the scheduled time. Lise Meitner and Dorothy Hodgkin and Linda Buck and Rachel Carson faced this situation with different outcomes. For one partnership the challenge came in unexpected classroom management issues that had not emerged when their practising teacher partner had been present, while for the other everything went smoothly:

> *Lise and I faced a few challenges. John had rang to inform us he had a meeting that he couldn't get out of and that there would be a substitute teacher there for our science class. … The children were extra "rowdy' and weren't doing what they were told throughout the duration of the lesson, they were testing both Lise and I and the substitute teacher which was very difficult to handle. This would be the major weakness of the lesson as the students did not achieve the learning objectives planned, which was disappointing for both Lise and I.*
> (Dorothy Hodgkin, Online Discussion September 24, 2007)

> *I found the lesson to be very successful, our classroom teacher was absent but the CRT* [casual replacement teacher] *seemed please with our efforts. The students were enthusiastic and engaged, and seemed to grasp the concepts well.*
> (Rachel Carson, Online Discussion October 4, 2007)

It is difficult to conclusively attribute reasons for why one partnership had a more successful experience of this than the other without further data, but it is likely the age of the children had some influence. The class who became 'extra rowdy' were older – Grade 5/6 compared with a straight Grade 2. This may have contributed to a sense of 'free time' within the older class group that the younger students did not have. It may also stem from the dynamics of each class and the particular routines and expectations of each classroom teacher.

Barbara McClintock also experienced an unexpected situation when the time of her class was changed and she could not be there:

> *Unfortunately due to circumstances beyond Rosalind's or my control I was unable to complete my science visit this week as Rosalind had to reschedule the lesson to a time where I could not possibly make it.*
>
> (Barbara McClintock, 19 September 2007)

These unanticipated situations can be frustrating, and for Dorothy, Lise and Barbara, they were particularly so. However, they arise frequently in school settings and learning to manage these can only contribute to increased learning, experience and ideas on how they might be managed better or differently. Thus, whilst presenting participants with a challenge, these circumstances were not insurmountable and in fact enabled potential for positive learning experiences.

Preservice Teachers' Feelings of Inexperience

A feeling of inexperience was established as an issue for two of the preservice teachers: Rachel Zimmerman and Barbara McClintock. Rachel commented on her anxiety of conducting her first lesson in the project. This anxiety clearly stems from her inexperience and fear of the 'unknown' as is reflected in her comment:

> *I have to admit I did not know what to expect with this first lesson and of course I had the usual concerns running through my mind would the lesson go as planned? What if the students ask me a question I do not know the answer to?*
>
> (Rachel Zimmerman, Online Discussion August 25, 2007)

Barbara's inexperience was reflected in her description of struggling to plan a timeframe she felt confident with due to her lack of experience with a particular activity. Her students were to pose an investigative question and research its answer, then present an oral and written presentation of their findings. Barbara had this to say:

> *… as I have not planned an assessment task using this format or style I am unsure of the time frame needed.*
>
> (Barbara McClintock, Online Discussion 13 September 2007)

Whilst each of these preservice teachers described situations that arose from their lack of experience, they are not necessarily challenges to be considered in a negative light. Once they had the experience of these occasions, they had something on which to base reflection and planning for improvement. Whilst Rachel did express some anxiety associated with her inexperience, it was quickly overcome once she taught that first lesson. Barbara expressed less anxiety and appeared to be more stating a fact. The supportive, collaborative partnership may have helped her both with the planning and with the feeling of shared accountability if it did not succeed, thus reducing any anxiety. Again whilst a challenge at the time, this expression of inexperience really highlighted the overall potential the teaching experience had for preservice teacher learning, and to overcome inexperience and develop ability and confidence in teaching science.

Communication

Both practising and preservice teachers commented on communication as a challenge of the partnership model, but in quite different ways. Practising teachers were concerned about the communication from the university in regard to some of the expectations, whereas preservice teachers were concerned about communication challenges between themselves and their practising teacher partners.

> *And just to have a clear idea you know we're going to have 5 weeks and we're going to cover this or that.*
>
> (Mr Robert Boyle, Interview)

> *I don't think they realised or fully understood how much recording they were meant to do. They weren't sure that the documents we had, the blank documents, plenty of room for writing in, just what they were meant to write.*
>
> (Ms Annie Easley, Interview)

Communication presented as a significant issue for three preservice teachers in particular: Jocelyn Burnell and Helen Dunbar and Gertrude Elion. These three were involved in partnerships with their practising teachers that I have already described as not very collaborative. Some of these issues this created in terms of communication were expressed through comments such as:

> *Unfortunately we feel as if the teacher has left us on our own to plan … so we are left feeling wary about what we are completing. … We were unaware that they had already completed a type of invisible ink.*
>
> (Gertrude Elion, Online Discussion August 29, 2007)

> *We were led to believe that the teacher had already undertaken lessons about fossils but upon discussion with the children we found it was a new concept. To improve on this we need to establish better communication with the teacher.*
>
> (Helen Dunbar, Online Discussion September 4, 2007)

The experiences of Helen and Gertrude indicate how a lack of communication in a non-collaborative partnership leaves preservice teachers unsure of what to cover and of what has already been done. Both of these preservice teachers acknowledged that they needed to communicate better with the teacher, but they also blamed the teacher for this. They felt intimidated by Ms Goodall's vocal assertion of how science should be taught and resented her lack of guidance and collaboration in what was meant to be a collaborative partnership. This did not help either preservice teacher initiate more open communication.

The situation between Jocelyn Burnell and Ms Diane Fossey was even worse. This is depicted through a number of excerpts taken from Jocelyn's lengthy contribution to the online discussion on September 14, 2007:

> *…our planning session consisted of me going into her class and her handing me a sheaf of papers with possible 'experiments' for the class to complete and telling me to turn up at two every Thursday. So I have planned some lessons but my knowledge isn't great in some areas.*

Unfortunately this initial meeting set the scene for what was to become poor communication between Jocelyn and Ms Fossey for the entire partnership. Neither partner appeared to have very good communication skills, which was further highlighted during the first lesson when Jocelyn felt belittled in front of the class. Jocelyn offers an account of this:

> *…when I attempted to have a discussion (*with the class*) I was looking to her for clarification and later on, in front of the class, she told me that I needed to do more research because she didn't know anything about it. I mean isn't the whole point of this study to work collaboratively?...Needless to say my confidence completely diminished when she said that and I'm sure the students lost any respect they had for me.*
>
> (Online Discussion, September 14, 2007)

Jocelyn acknowledged that she may have contributed to what became a tense relationship:

> *I suppose in a way it is also my fault because I have been too meek when it comes to telling her that we are meant to be planning together but it is very hard. She already has a fourth year to look after and the last thing she needs is me in her way.*
>
> (Online Discussion September 14, 2007)

Jocelyn's situation demonstrates the need for good communication to ensure effective teaching can occur as well as its importance in establishing a safe and supportive environment. She was able to recognise that communication and enthusiasm were needed from both herself and her practising teacher partner to improve the situation when she expressed this need:

Jocelyn Burnell	*Communication. And enthusiasm really. Because after that first week I didn't want to go back. And I still don't…I used my 21st as an excuse not to go back. Yeah just communication and enthusiasm.*

Mellita	*On both parts?*
Jocelyn Burnell	*Yeah definitely. Because I'm not the easiest person to work with, so maybe I wasn't as open as I could have been.*

(Round Table Discussion 2)

These comments suggest that both partners needed greater enthusiasm and commitment to the collaborative intention of the project, which would likely have resulted in better communication between them. Each partner's negativity, Jocelyn's lack of conflict resolution skills, and Ms Fossey's apparent lack of concern for Jocelyn, contributed to what became a destructive partnership.

Two of the other preservice teachers also shared issues stemming from communication challenges. Barbara McClintock indicated how effective communication in partnerships could assist activities such as effective grouping of students:

> *Students were divided into three groups which I picked (this was difficult as I have only seen this class once so was unsure of certain personalities that should not be working together.)*
>
> (Barbara McClintock, Online Discussion September 5, 2007)

Gerty Cori also felt challenged by communication in her partnership when the activities she thought had been planned took a different direction during implementation:

> *This week didn't go quite according to plan. I don't know whether we had misinterpreted each other at the planning stage, or whether things just changed as we went along.*
>
> (Gerty Cori, Online Discussion September 6, 2007)

Her practising teacher partner later indicated in her interview that she had forgotten the process they had agreed on and had consequently altered the planned routine. Once she realised, it was too late, which affected the lesson's structure. This partnership tended to plan immediately following the lesson just taught, and this timing may have contributed to the 'slip up' when the lesson was conducted one week later, showing that the timing of communication is also important.

Anita Roberts shared an issue of students' lack of understanding stemming from a lack of clear communication with the Grade 1/2 class she and Ms Marie Curie were teaching:

> *Another problem we had not expected was that the students assumed this lesson was going to be about floating and sinking. Students were asked to predict what would happen in the experiments. Many pictures showed the materials either floating or sinking. We needed to clearly state to the students that we had moved on.*
>
> (Anita Roberts, Online Discussion September 13, 2007)

At times, partners used email to stay in touch and this too was not always successful: '*It's sort of hard to communicate over email*' (Rachel Carson, Round Table Discussion 1).

Communication also featured as a challenge in the final participant workshop when participants reflected back on their experiences. Five respondents commented on communication challenges in a general way '*Communication was at times difficult'* (Challenges Leaf C15) and specifically: '*Different ideas could sometimes make it challenging to choose a topic or stick to it – one of the cons of working in 3s?'* (Challenges Leaf C9). There was a suggestion that to improve this issue stating: '*get everyone's idea first and maybe compromise and brainstorm*' (Challenges Leaf C9). One of the practising teachers wrote: '*Challenges: Speaking – knowing when; not interrupting; supportively waiting'* (Challenges Leaf C11) and to aid this challenge suggested *'Class teacher not dominate decision making'* (Challenges Leaf C11).

Whilst communication was clearly an issue for some partners, it was only a negative experience or weakness of the model in those partnerships that were not collaborative.

Dependence on Individuals

The lack of collaboration in some partnerships highlighted how the approach of individuals within a partnership was a key determinant in the partnership's success. This was reinforced by some of the comments from successful collaborations also, were the nature of individuals involved were credited for the partnership's success. For example, Ms Virginia Apgar and Ms Marie Curie discussed the quality of their partners:

> *There were many highlights. Firstly the quality of the two students I received. And because of the committed approach to the project, we all wanted it to work.*
>
> (Ms Virginia Apgar, Interview)

> *Yep, definitely* [in recommending involvement in future projects like this one]. *And if they've got someone as nice as Anita it would be easy. If you don't get along with the person it would be hard.*
>
> (Ms Marie Curie, Interview)

> *I think it also depends on the teacher that you're working with or in charge of the class. If they've got enthusiasm for the science then everybody else kind of gets enthused as well. Our teacher's ace, she's right into it, she just wants to do science and wants them to explore and experiment and she's been really supportive which has made it a lot easier for us to be enthusiastic.*
>
> (Maria Mayar, Round Table Discussion 1)

In contrast to this:

Gertrude Elion	*I think I've got scarder.*
Helen Dunbar	*Especially with the expectations of the teacher.*

(Round Table Discussion 1)

> *Because it's sort of lots of people and you've all got your different ideas and you're trying to bring it together and then they sort of don't gel.*
>
> (Gerty Cori, Round Table Discussion 1)

And, when asked if he had any further comments he would like to make at the end of his interview, Mr John Dalton intimated that older teachers, who are more set in their ways, would not be suited to a collaborative partnership model:

> *It would probably suit some teachers more than others. Aaaaaaammmmm, I don't want to sound mean here, but probably younger teachers. Teachers that aren't … some teachers are set in their ways and they think this is the way you do it and you are going to do it this way you do it like this and you do it like that not, you know, flexible. You know how other people do things. They don't like to involve other peoples' ideas.*
>
> (Mr John Dalton, Interview)

Ms Easley also recognised the difficulty some teachers have in letting go of the control:

> *If it had been just the student and me, it would have had more domination from me. It's a challenge for a teacher to do that, especially when you know what works for you and what doesn't, but that doesn't mean to say it's the same for them, it could be quite different.*
>
> (Ms Annie Easley, Interview)

These comments represent some of the different experiences and ideas practising and preservice teachers had that depended on their partners' approach. The experience can be positive as it was for Ms Virginia Apgar, Ms Marie Curie and Maria Mayar. Gerty Cori had a good relationship with her teacher, but the risk characterised by her experience is the frustration that may occur when teaching ideas and philosophies differ significantly between partners, making it difficult to compromise on common approaches. The worst situation, as expressed by Helen Dunbar and Gertrude Elion, arises when the relationship becomes so intimidating that fear rather than collaboration and joint learning drives the experience. Their situation provides a strong argument for preservice teachers working in pairs with a practising teacher, as they have each other for support.

Whilst I find it difficult to agree with Mr Dalton that it is only older teachers who can be set in their ways, he does raise a valid point in that teachers who are less flexible and who do not like team approaches to teaching, would find the model more difficult to implement. My experience, however, suggests that this can occur with teachers of any age, as can excellent practice and flexibility. Ms Easley also referred to the tendency of practising teachers to 'dominate' and that in this instance having to work with a team involving two preservice teachers made it easier for her to better manage her tendency to dominate. She also acknowledged that just because a particular ‘known’ strategy ‘works’ for one person, does not mean it will work for everyone. Together these experiences present a potential weakness in the model: it is dependent on everyone involved being committed to the notion of partnership and collaboration.

Lack of Structure

One final area of concern came from three of the practising teachers who discussed the less formal structure they felt this model represented compared with a traditional teaching round and the drawbacks this presented in terms of being able to appropriately support the preservice teacher. For example, Mr Robert Boyle noted that lesson planning was more *ad hoc*:

> *… for the student teacher maybe with that discipline of having to write a formal lesson plan and things like that, that might be a good procedure. I don't know.*
>
> (Mr Robert Boyle, Interview)

Ms Jane Goodall and Ms Diane Fossey expressed concerns that feedback on performance was less formal and structured and that there was less of a sense of what was going to be taught:

> *Well I guess I haven't done any written reflections …. Usually I would sit down and do a written reflection when the lesson was happening. Probably look in more depth at their plan before they do it.*
>
> (Ms Diane Fossey, Interview)

> *I would normally talk to them more fully about what they are going to do first.*
>
> (Ms Jane Goodall, Interview)

However, overall these concerns have less weight in considering improvements needed in the model, which is discussed in the next section. This is because, in particular, Ms Fossey and Ms Goodall did not participate in a collaborative partnership. If they had, their concerns are unlikely to have presented as issues. It essentially means that the concerns they expressed here were not comments associated with the intended model, as they did not implement it in the manner intended.

Mr Boyle’s comment has more credence. Although a planning and reflection booklet was provided to encourage a structured and systematic approach to planning, it was only used extensively by one of the eight partnerships. Had Mr Boyle and other partnerships utilised this resource, his concern regarding formal lesson planning might have be minimised. His concern does, however, raise awareness that either the accountability for using these documents was insufficient to encourage widespread use, or that the framework they provided for planning and/or reflection did not sufficiently meet planning and reflection needs and was hence abandoned. The lack of any feedback or comment on these documents, except from the one partnership that did use it and commented on its usefulness, makes the former more likely than the latter.

Summary of Challenges and Weaknesses of the Model

Overall there were a number of challenges experienced by partners that highlight how a collaborative partnership model can be challenging and have its own weaknesses. Issues of time to do with duration, finding coinciding time and continuity of students' involvement in the classroom all presented obstacles that were difficult to overcome and which affected the extent of planning and reflection. Unexpected situations arising also presented challenges but served more as learning opportunities than negative experiences. This was also the case for the challenge some preservice teachers felt in regard to their inexperience in teaching science.

Communication was a significant challenge for some partnerships and served both as a positive experience for the learning it provided as well as a negative one. Positive learning experiences emerged as partners faced communication issues and worked to negotiate and operate as a team. Negative experiences were characteristic of those partnerships that were lacking collaboration where this lack of collaboration impacted on communication and led to some preservice teachers feeling overwhelmed and intimidated. This led to the emergence of the main weakness of the model: it depends on the relationship established between the partners involved as to how successful the partnership experience can be.

With the benefits and the difficulties identified, participants were able to make a number of very useful recommendations for improving the model to ensure more effective science teacher education and professional learning. These recommendations are reported in the next section of this chapter.

4.8 Participants' Recommendations for Improving the Partnership Model

Practising and preservice teachers offered a range of useful recommendations for improvements through their contributions to round table discussions, interviews; in the final questionnaire; and through recommendation statements they formed at the final participant workshop. These are outlined below.

Preservice Teachers' Recommendations for Improvement

In the final questionnaire, preservice teachers were asked what they thought would be needed in a project like this to help them achieve more effective development as a science teacher. Most preservice teachers highlighted more than one area for improvement. Overall, their responses fell into eight main categories which, along with their corresponding frequencies and a sample comment to illustrate the nature of the responses that formed the categories, are given in Table 4.8.1.

Table 4.8.1: Frequency of Preservice Teachers' Ideas for Improving the Partnership Model

AREA OF DESIRED ACHIEVEMENT	EXEMPLAR COMMENT	FREQUENCY (N=12)
More time/experience	Probably more lessons and time in schools (Lise Meitner)	9 (75%)
Greater collaboration	It will work better if all teachers are willing to work in collaborative relationships. If the teacher we were working with worked with us to plan and develop lessons it would have been more beneficial for me.	4(33%)
Resources	More available resources (Jocelyn Burnell)	2 (17%)
Reflection	Reflection (Gerty Cori)	1 (8%)
Ideas for Evaluate	Other ways of evaluating students' knowledge (Rachel Carson)	1 (8%)
Teach different ages	Perhaps try teaching a lesson with a different age group at the same school (Linda Buck)	1 (8%)
Teacher willingness to try new things	Greater willingness from teacher to try new things (Barbara McClintock)	1 (8%)
Teach a unit not one off lessons	Follow up lessons as a part of a unit of work. Not single lessons (Dorothy Hodgkin)	1 (8%)

Nb. Frequency calculations represent the proportion of preservice teachers who identify each area of improvement and hence add to more than 100% since most preservice teachers suggested more than one improvement.

These results suggest that preservice teachers valued the project experience with three quarters of them indicating that more time in schools was the most significant way to improve the project. A number of comments related to the difficulties faced including the lack of collaboration in some partnerships. It was encouraging to see preservice teachers' acknowledgement of some of the key learning they had experienced reflected in some of the comments. For example, the need for reflection, different ways to implement the Evaluate phase of the 5Es, and to teach a unit of work rather than disconnected, one-off lessons.

A series of individual responses followed these suggestions. These included a need for the practising teacher to be more willing to try new ideas, greater reflection, more ideas for evaluating student understanding, to teach children of different ages, and to teach a unit rather than stand alone, one-off lessons.

Preservice teachers also constructed a summary recommendation statement about how to ensure a partnership experience, like the one used in this project, was effective for preservice teachers' science education. Their ideas included the need for equality between partners, willingness to contribute, earlier planning time, availability of resources and clear expectations of what the partnership involves. These responses are listed in Table 4.8.3 alongside those from practising teachers so that similar and different ideas can be compared between the participant cohorts.

Practising teachers' Recommendations for Improvement

Practising teachers proposed a number of possible improvements to the partnership model. These suggestions fell into to four general areas: Set Times for Planning and Reflecting; Lesson Content and Processes; Direction from the Researcher; and Timing and Duration.

The responses practising teachers provided on what would be needed to improve the professional development aspect of the project for practising teachers yielded four key suggestions. These categories and their corresponding frequencies are outlined in Table 4.8.2 along with exemplar comments characterising each area of improvement suggested.

Table 4.8.2: Frequency of Practising teachers' Ideas for Improving the Partnership Model

AREA OF DESIRED ACHIEVEMENT	EXEMPLAR COMMENT	FREQUENCY
More time	This is a wonderful model, I only need more time (Ms Virginia Apgar)	5 (71%)
More ideas/experiments	More hands on ideas for teaching (Ms Rosalind Franklin)	3 (43%)
Reflection with Other Teachers	Reflect with other teachers involved (Mr John Dalton)	1 (14%)
Lesson Plans Provided	Being provided with a range of lesson plans related to my topic (Ms Jane Goodall)	1 (14%)

Nb. Frequency calculations represent the proportion of practising teachers who identify each area of improvement and hence add to more than 100% since most practising teachers suggested more than one improvement.

These results indicate that, similarly to preservice teachers, practising teachers felt that the most important improvement was to extend the length of the project. This would also likely address the next most prevalent suggestion, more ideas for hands-on activities, as more time would result in a broader range of activities being implemented. Mr John Dalton made an excellent suggestion to incorporate reflective discussion between the practising teachers involved. This may indeed enhance the professional learning capacity of the model for practising teachers. The provision of lesson plans requested by Ms Goodall is indicative of her non-collaborative approach to the partnership and lack of understanding of its intent. Including such a suggestion would not only undermine the intention of the collaborative planning component of the model, but would also be impossible to achieve with the range of topics and approaches being implemented by the different partnerships.

The five practising teachers present at the final participant workshop also constructed a summary statement regarding the factors they need to be included to ensure science professional learning could occur. Components such as targeting teachers who do not already teach science, using volunteer students to ensure motivation, longer lead up time, equal sharing and a number of other items associated with levels of participation and compromise. Imagination and innovation were also listed. A complete list of items noted is provided in Table 4.8.3.

Table 4.8.3: Practising and preservice teachers' Recommendations for Successful Learning

Similar Recommendations From Practising and preservice teachers	
PRACTISING TEACHERS	PRESERVICE TEACHERS
• Use student volunteers • Time • Warning time • Equal sharing • Willingness to share	• Volunteering nature of the program • More time • Earlier planning • To be seen as an equal teacher not as a student teacher – respect. • Willingness to contribute
DIFFERENT RECOMMENDATIONS FROM PRACTISING AND PRESERVICE TEACHERS	
PRACTISING TEACHERS	PRESERVICE TEACHERS
• Students to bring their ideas – confidence • Willingness to make time • Optimism • Imagination • Innovation • Encourage more classroom teachers who tend to 'avoid' science to take part and benefit • Timetabling/organisation	• Willingness to learn • Take equal responsibility for mistakes • More support, 'back each other up' – team teaching • Preservice teacher pairs with teacher (also depends on individual students and teacher) • Clear expectations of what is involved • To be a positive experience as a negative experience can lead to a negative opinion of science teaching • Available resources

As seen in Table 4.8.3 the areas identified by both practising and preservice teacher cohorts as necessary for successful professional learning and teacher education are focused around time, partnership equality and the volunteer nature of the project. Practising teachers also included the need for flexibility, imagination and attitude, and the notion of targeting teachers more in need of science professional learning to improve the professional learning results.

Preservice teachers were particularly focused on aspects that might contribute to the creation of equality in the partnerships. Given this was only an issue for three of the 13 practising teachers involved in the discussion, it is significant that this recommendation came through in the overall set of criteria, indicating that all preservice teachers were affected by the notion of partnership and found it important. They also highlighted the need for resources.

The experiences of practising and preservice teachers provided an excellent source of information to engender these recommendations. They were also able to identify that barriers still exist for the implementation of science teaching. These barriers were listed in response to an open-ended question on the final questionnaires, and are discussed in the following section.

4.9: Intention to Teach Science and Perceived Barriers

In the final questionnaire participants were asked whether their involvement in this project has influenced the frequency with which they intend to teach science, and what they saw as the barriers to their science teaching. This addressed the final research sub-question: *What barriers are perceived to exist to increasing the priority of science in primary school classrooms?* The responses to these open-ended items are reported below.

Perceived Barriers to Teaching Science

When asked what barriers existed to increasing the priority of their teaching of science on the final questionnaire, both practising teachers and preservice teachers gave a range of responses that were generally very similar. Practising teachers offered five main types of responses: curriculum constraints; access to resources; school policies; background knowledge; and the time it takes to organise and set up lessons. The first four of these were also identified as barriers by preservice teachers, along with the further four areas of lack of confidence; uncertainty on how to integrate; a lack of support in schools, and cost. Responses from both practicing and preservice participant cohorts are summarised with corresponding response frequencies for each item in Table 4.9.1.

Table 4.9.1: Practising and preservice teachers Barriers to Teaching Science

Practising teachers' Response Categories	Frequency (N = 7)	Preservice Teachers Response Categories	Frequency (N = 12)
Curriculum Constraints	3 (43%)	Curriculum Constraints	8 (67%)
Access to Resources	3 (43%)	Access to Resources	7 (58%)
School Policies	2 (26%)	School Policies	2 (17%)
Background Knowledge	1 (14%)	Background Knowledge	5 (42%)
Time to Organise/Set up	4 (57%)	Confidence	5 (42%)
Money	1(14%)	Cost	1 (8%)
		Lack of Support in Schools	1 (8%)

One of the most significant barriers participants saw to their teaching of science (noted by eight preservice respondents and three practising teachers), was concerning constraints imposed by the curriculum. This theme emerged from comments such as: '*The curriculum and the time allocated specifically to science'* (Barbara McClintock, Final Preservice Teacher Questionnaire) and '*Time. Science generally isn't included in the timetable'* (Linda Buck, Final Preservice Teacher Questionnaire). Practising teachers discussed this barrier with reference to the '*crowded curriculum'* (Mr John Dalton; Ms Rosalind Franklin, Final Practising teacher Questionnaires). Ms Jane Goodall noted it in terms of '*relativity to topic'* being taught in a given term's inquiry theme.

Both participant cohorts also identified access to resources as a significant barrier with two practising teachers and seven preservice teachers mentioning this issue. Comments regarding resources were generally short and pointed. For example, Lise Meitner dot pointed '*resource availability'* (Final Preservice Teacher Questionnaire); and '*Lack of equipment*' and '*resources – or lack of*'' were noted by Maria Mayar (Final Preservice Teacher Questionnaire) and Barbara McClintock (Final Preservice Teacher Questionnaire) respectively. Two of the three practising teachers noted access to resources as a barrier without further elucidation but Mr Robert Boyle indicated '*getting the appropriate equipment (especially chemicals)*' (Final Practising teacher Questionnaire). Linked to this were the two participants who noted money and cost as barriers with responses '*money – teachers pay for resources*' (Ms Virginia Apgar, Final Practising teacher Questionnaire) and '*cost'* (Grace Hooper, Final Preservice Teacher Questionnaire). Ms Apgar and

Grace were partners for the project, so if they were having to fund lessons themselves, it is not surprising that both mentioned this as an inhibitor.

The main barrier for practising teachers was actually to do with the time it takes to set up a science lesson. This was mentioned by four of the practising teachers and was typified by comments such as '*time to collect materials/equipment*' (Ms Virginia Apgar, Final Practising teacher Questionnaire). This was supported by some of the responses to Black Hat thinking in the initial participant workshop which included responses associated with a lack of time for organising science lessons: '*No lab techs. Teachers need time to gather equipment*' (Thinking Hats B12). In spite of mentioning the challenge time presented in organising practicals in their online discussions, preservice teachers did not identify it as a specific barrier to their intention to teach science.

Money was also expressed as a concern through the recording of the symbol '*$*' (Thinking Hats B15). However, one respondent at least felt no concerns when he or she wrote '*None!*' (Thinking Hats B19). Two practising teachers and two preservice teachers indicated that some aspect of school policy manifested as a barrier for them. There was no indication of what form or nature these policy barriers took. Perhaps linked to this is the broader policy regarding the reporting of science to parents at some levels of schooling, as highlighted by this comment:

> *Would love to do weekly science lessons yet a 1/2 class we don't need to report on science therefore we seem to allocate time in our program for other subjects. If I needed to report on it, it would be a greater priority.*
> (Ms Marie Curie, Final Practising teacher Questionnaire)

Issues with knowledge and confidence were the equal third major barriers listed by preservice teachers with five mentions apiece with comments such as:

> *Knowledge!!*
> - *Not having enough*
> - *Not having enough time to extend knowledge*
>
> (Gertrude Elion, Final Preservice Teacher Questionnaire)

Most responses in these categories were the single terms 'knowledge' and 'confidence'. One practising teacher also alluded to how a lack of background knowledge can be inhibiting with the comment: '*Not as science literate as I would like to be - used 'Teachers on Primary Science' (TOPS) CD when unsure'* (Final Practising teacher Questionnaire). Two preservice teachers listed a lack of knowledge in how to integrate science with other curriculum areas as a barrier and Maria Mayar (Final Preservice Teacher Questionnaire) indicated that a '*lack of support in schools'* could act as a barrier.

The areas identified in common between preservice and practising teachers were aligned in Table 4.9.1 to show where the similarities and differences occurred in what barriers they felt acted as inhibitors to their teaching of science. This shows that curriculum constraints and access to resources featured in both cohorts' top three barriers, with teachers only identifying time for organisation above these. Preservice teachers were most concerned about their background knowledge and confidence. This arose as an ongoing concern in spite of the many sources of data they provided (reported previously in this chapter) indicating their increases in confidence. In spite of these barriers, participants demonstrated a general willingness to overcome obstacles and increase the amount of science they taught as a result of their involvement in this project. This is reflected in the results concerning participants' intention to teach science.

Intention to Teach Science

Practising and preservice teachers were asked whether their involvement in this project had influenced the frequency with which they intend to teach science. Results indicated that all 12 preservice teachers who completed the final questionnaire intended to teach science often while only two of the seven practising teachers who responded indicated 'yes' to this question. The main reason given by both practising and preservice teachers for feeling an increased desire to teach science was due to witnessing students' engagement in science. For the four practising teachers who responded 'no' to this question, reasons were either not provided or it was stated that science already had a high priority in their teaching.

Overall, seven key themes emerged from the reasons participants gave as to why they intended to include science in their teaching repertoire. A summary of the results for practising and preservice teachers responses to this questionnaire item are summarised in Table 4.9.2.

For those practising teachers who indicated 'yes', the project had influenced the frequency with which they intend to teach science, both of their reasons were linked to students' enjoyment of science with comments:

> *Yes. My students love science lessons (hands on). Would love to do weekly science lessons.*
>
> (Ms Marie Curie, Final Questionnaire)

And

> *Definitely. Science now has a permanent place on the timetable. Students constantly enquire about future lessons and are disappointed when there is a clash and science can't be done.*
>
> (Mr John Dalton, Final Questionnaire)

Table 4.9.2: Practising and preservice teachers Reasons the Project Experience has Impacted on Their Intention to Teach Science

PRACTISING TEACHERS RESPONSE CATEGORY	FREQUENCY (N=7)	PRESERVICE TEACHERS RESPONSE CATEGORY	FREQUENCY (N=12)
Yes		Yes	
Because of students' engagement	2 (29%)	Because of students' engagement	5 (42%)
		Increased confidence	3 (25%)
No		Easy to Integrate	3 (25%)
Science already a high priority	1 (14%)	Easy to teach	2 (17%)
Not Specified	3 (43%)	Increased desire/enthusiasm	2 (17%)
Uncommitted	1 (14%)	Not specified	3 (25%)

Nb. Most preservice teacher participants identified more than one reason as to why the project impacted their intention to teach science hence their frequency calculations add to more than 100%.

Ms Rosalind Franklin and Ms Jane Goodall both gave quite short responses to this question with a '*No'* (Ms Rosalind Franklin, Final Questionnaire) and '*Not really*' (Ms Jane Goodall, Final Questionnaire). Ms Annie Easley and Mr Robert Boyle both indicated that they would not likely increase the amount of science they taught because it was already a high priority for them. This was indicated in their comments '*No. I can teach as much as 19 hours integrated science per week'* (Ms Annie Easley, Final Questionnaire) and '*No. Science is already a very high priority in my class*' (Mr Robert Boyle, Final Questionnaire). Ms Virginia Apgar did not commit one way or another in explicit terms but commented that she '*Need(s) to remain determined to teach science'* (Ms Virginia Apgar, Final Questionnaire).

The most common of preservice teachers' responses with five participants listing it, came from their realisation that children enjoy science. Comments of this nature included '*I will include it frequently when teaching because the students love it so much*' (Barbara McClintock, Final Questionnaire) and '*It has showed me that children do actually enjoy science*' (Gertrude Elion, Final Questionnaire).

There was one comment from Jocelyn Burnell in response to this question stating '*Yes, I'll teach science as much as possible because I've seen the benefit of it in the classroom'* (Jocelyn Burnell, Final Questionnaire). It is unclear from this exactly what she feels the benefit is, but some of her earlier comments from round table and online discussion could suggest that she too is referring to the level of student engagement science lessons engendered in her students.

Three preservice teachers provided comments associated with increases in confidence as reasons they would be more willing to include science in their teaching. For example: '*Yes. I am more confident in teaching it.*' (Helen Dunbar, Final Questionnaire) and '*Because I had never observed or taught a science lesson before I probably would have shied away from teaching it'* (Dorothy Hodgkin, Final Questionnaire). Three of the participants also indicated that they could integrate science and hence teach it more than they had initially thought they might. Rachel Carson's '*I think because I now understand how to integrate science into literacy lessons I will be more inclined to do more science in the classroom'* (Final Questionnaire) showed a specific example of thinking about integration, while Barbara McClintock and Maria Mayar were more general with comments such as '*It is also good to integrate across the curriculum*' (Maria Mayar, Final Questionnaire).

Two preservice teachers discussed their attitudes towards science as an impetus to teach it with comments like '*it has increased my desire and enthusiasm to teach science*' (Barbara McClintock, Final Questionnaire), for example. Two also acknowledged that the project experience helped them see that teaching science was not as hard as they thought and this helped to increase their intention to teach it. This was demonstrated through the comments '*It has shown me that science is not difficult to teach*' (Gertrude Elion, Final Questionnaire) and '*I have found that it is quite easy to teach*' (Maria Mayar, Final Questionnaire).

There were also assurances given from three preservice teachers that science would be a feature of their teaching as a result of their experience, although no particular aspect of their experience was listed in their reason. Linda Buck's comment exemplifies the general nature of these three contributions:

> *Yes. I am not sure I would have taught science at all if I could help it. Now I'm looking forward to teaching science hopefully once a week.*
>
> (Linda Buck, Final Questionnaire)

Overall, most practising teachers did not intend to teach science more often as a result of their experience in the project because they already included science as a high priority in their teaching. All preservice teachers reported that the project had impacted on their intention to teach science more often and other reasons they identified in addition to seeing children's engagement and their own increased confidence were that they had discovered it was easy to integrate with other curriculum areas, it was easier to teach than they expected, and that their experience had increased their own desire and enthusiasm to teach science. This feedback highlights the power of the partnership model and authentic teaching experience to affect teachers' attitudes towards the teaching of science and the priority it should have in their teaching.

4.10: Summary of Results

The collaborative partnership model for preservice and practising teacher science professional learning was effective in a number of ways. It provided preservice teachers with needed mastery experience in an authentic classroom setting that enhanced their knowledge and confidence to teach science and enabled them to develop a range of important science teaching insights. It provided practising teachers who had little experience and/or confidence with science to experience the same mastery experiences as preservice teachers, also building knowledge, confidence and insights into the teaching of science. It offered opportunities for action-reflection that was linked to enhanced learning, particularly for preservice teachers. The impact on these participants was significant, and was signalled through their overwhelming positive response of an increased intention to teach science more often. The next chapter discusses the significance of these results and their links with the relevant literature.

The model appeared to have a number of benefits. The main one was the recognition of children's easy enjoyment and engagement in science lessons. Here, both practising and preservice teachers noted a reduction in classroom behaviour management issues that had existed in other contexts, and for preservice teachers there was a realisation that children actually enjoyed science, contrary to both their beliefs and their own feelings towards it. They also developed an important awareness of the depth of children's existing knowledge of science concepts and their capacity for science learning.

The results indicated that the reflection conducted in partnerships, whilst present, tended to be very informal. Only one partnership utilised the planning and reflection booklet provided to generate structured, formal reflection sessions on which they each reported favourably. Others talked of ‘casual chats’ conducted ‘on the run’ and all highlighted the issue of insufficient time for planning and reflecting properly. It seems likely that the lack of formal reflection contributed to practising teachers’ limited knowledge development. The limited structure evident in partnerships’ post-lesson reflection is likely to have contributed to subsequent limited gains in professional learning experienced by the practising teachers. However, the fact that they were all relatively experienced, competent and confident in their science teaching abilities when they commenced the partnership may have made this an unlikely outcome. Preservice teachers were able to compensate for their lack of formal reflection with practising teachers using online discussions and round table forums for their reflection. The round table forums appeared to be especially significant in encouraging effective reflective practice, no doubt assisted by my additional facilitation.

The role of reflection was clearly important in directing preservice teachers’ thinking about their practice and developing a pedagogy of practice, both for how they teach and how teacher education can enable their learning. This was achieved by the sharing through the online and round table discussion forums, which served to highlight the importance of the connection between classroom-based and university-based learning experiences, through in-depth analysis and a synthesis of practice in light of experience and explicit teaching of theoretical models and strategies. These experiences demonstrated the power of effectively scaffolded reflection to promote metacognition in preservice teachers’ practice, a powerful step in developing a theory-practice nexus.

However, there were also instances of limited success of the model. For example, it had little impact on the professional learning of practising teachers who were already confident in their knowledge and/or ability to teach science. It presented challenges in terms of logistical factors such as organising time, following a formal structure to promote learning, and in cases where collaboration was limited, the risk of actually decreasing participants’ confidence to teach.

Other than the key challenge of time, other challenges were different for practising and preservice teachers. Preservice teachers appeared more challenged by their lack of knowledge and experience, being able to identify their background knowledge, failed experiments and achieving student understanding as key challenges. Those who experienced non-collaborative partnerships noted partnership relationships and communication as key issues.

Barriers to including science as a priority in teaching included the time it takes to organise equipment, access to resources, curriculum constraints and school policies. Preservice teachers also identified ongoing concerns with their confidence and science content knowledge as their significant barriers. In spite of this participants with initial low efficacy expressed their increased intention to teach science.

CHAPTER 5: DISCUSSION

Collaborate: To work jointly with others or together especially in an intellectual endeavour.
From: Late Latin *collaboratus*, past participle of *collaborare*: to labour together.
(Merriam-Webster Dictionary, 2009a)

Partner: 1. One that shares (partaker)
2. One associated with another especially in action (associate, colleague).
From: Middle English *partener*, alteration of *parcener* from Anglo-French *coparcener.*
(Merriam-Webster Dictionary, 2009b)

5.1: Introduction

This study sought to explore collaborative partnerships between practising and preservice teachers in order to develop insight into their impact on their professional learning in science education. This exploration was conducted through a variety of data collection tools to build a rich picture of how the partnerships were approached and the benefits, challenges and learning opportunities that emerged for the partners involved. Interviews, round table and online discussions, written feedback and questionnaires all helped to establish a picture of the partnership experience from both preservice and practising teachers' perspective.

Participants' attitudes, beliefs and self-efficacy towards science were important aspects under consideration and one of the aims of the partnership experience was to examine whether there was any change in these areas as a result of participants' involvement. The other important aspect under consideration was whether development in participants' general and pedagogical content knowledge (GCK and PCK) about science education was influenced through their participation.

In this chapter the research findings are considered and links to the relevant literature are made. The chapter is written in three sections. Section one discusses the findings about practising and preservice teachers' attitudes and self-efficacy beliefs as a result of their involvement in the project. Section two examines the results of the partnerships and how they appeared to impact on development in GCK and PCK. Section three considers the results relating to the barriers participants saw to increasing science as a priority in their teaching and their intentions to increase science in their programs. This discussion will assist the development of the study's conclusion which will be reported in Chapter six along with recommendations and directions for further research emerging from the study.

5.2: Attitudes, Beliefs and Levels of Self-Efficacy

The attitudes, beliefs and self-efficacy of research participants towards science were explored through the ‘thinking hats’ exercise in the initial workshop, the self-assessed confidence levels in the initial and final questionnaires, the STEBI questionnaire results and comments provided during online and round table discussions, open responses in the questionnaires, and interviews.

Attitudes

The data showed that both practising and preservice teachers had positive attitudes towards science from the beginning of the project. This is indicated firstly through their participation in the project, which was a voluntary involvement in the form of recognised professional learning or a voluntary mode of completing their science education unit. In addition to this, both participant cohorts indicated the benefits of science education for children as linking to the world, and they saw science as providing opportunities for hands-on learning. They also communicated a desire to increase their own or their students’ knowledge and understanding of science and, preservice teachers in particular, wanted to increase their confidence to teach it. These desires all reflected a positive attitude towards the place of science in the primary school curriculum.

Attitudes, already good to begin with, appeared to strengthen throughout the project experience. This was conveyed through participants’ increased intention to include science as a high priority in their classrooms. All 13 preservice teacher participants and the two practising teachers with limited prior experience indicated an intention to include science as a high priority of their teaching as a result of their experience. Jones and Carter (2007) report on a number of studies that indicate that intention to perform a particular behaviour is a good predictor of the likelihood that that behaviour will indeed be actioned. Preservice teachers provided a range of reasons as to why they intended to teach science (see Table 4.9.2) which were generally related to having seen students’ keen engagement in science, and increases in their own confidence because they realised it was not as difficult to teach/integrate as they had thought. Howitt (2007) also found that preservice teachers’ efficacy was enhanced by the response they received from children’s reaction to their science teaching, highlighting this as a significant component of the sense of success preservice teachers take from the mastery experience generally and an important benefit of the partnership model.

For the practising teachers, while there was no evidence that Ms Annie Easley or Mr Robert Boyle's attitudes had been enhanced, their attitudes were probably the most positive and strong of all the participants beforehand. Ms Rosalind Franklin, although inexperienced in her first year of teaching, also had a reasonably strong attitude towards science before the project. She had discussed enjoying the science component of her education degree and was acting as the science specialist in the school. Ms Franklin's attitude did not appear to change over the period of her involvement. These already strong attitudes towards science and exposure to science teaching meant that these teachers were unlikely to be affected by children's level of engagement or by increases in confidence to teach science. This is because they were already familiar with children's responses to science and already had the necessary confidence to teach science on a regular basis.

Ms Jane Goodall's positivity towards science did not appear to be affected or enhanced; neither was the attitude of Ms Diane Fossey who was unusual in that she entered the project with a fairly poor outlook towards science. This is likely to be due to a general lack of involvement in the partnerships and teaching experience from each of these practising teachers, discussed in detail in Section 2 of this chapter.

Generally, there was little to no change in the already strong, positive attitudes among practising teachers who were already confident and experienced in teaching science. However, for inexperienced practising and preservice teachers, the experience of successful science teaching was effective in enhancing established beliefs that science is an important area of the primary curriculum.

Participants' Self-efficacy Beliefs

Participants' self-efficacy beliefs regarding their ability to teach science effectively were varied. Preservice teachers had generally low levels of self-efficacy upon entering the project, whereas that of practising teachers was generally high.

Preservice Teachers' Initial Efficacy Beliefs

Preservice teachers expressed a lack of confidence in their science background knowledge (GCK) and feelings of uncertainty, nervousness and even fear about teaching it. These initial feelings and concerns indicate a high level of anxiety relating to a lack of confidence and self-efficacy belief that they could teach science successfully. Initial self-assessed confidence levels and STEBI-B results confirmed this, with medium-low average scores of 4.6 out of 10 and 39.6 out of 65 for their respective self-assessed confidence and the PSTE scale of the STEBI. They also discussed wanting to gain confidence and improved science content knowledge from their involvement in the project. They did report higher levels of confidence in biology than in other areas of science, with chemistry at the lowest end of the confidence scale. Together these results indicate preservice teachers' low levels of confidence and self-efficacy belief upon entering the project.

These findings are likely to be linked to the lack of background knowledge stemming from the large proportion of primary teachers that rarely study science beyond the Year 10 level of secondary schools (Skamp, 1997), and when they do, in 75% of cases it is biology (Schibeci & Hickey, 2004). They also align with Akerson's (2005) report that teachers demonstrate a tendency to only teach biology, if they teach science at all, due to a greater lack of confidence in the areas of physical and chemical science. Preservice teachers reported lacking experience teaching science on previous teaching rounds and in some cases, had not even observed a science lesson in action in the primary school setting. This means they lacked both the mastery and vicarious experiences that Bandura (1977) purports as essential components for building efficacy beliefs.

Practising teachers' Initial Efficacy Beliefs

In contrast to the preservice teachers, most of the practising teachers involved had had extensive mastery experience. As already discussed, many were science specialists in their schools and three had further experience running professional learning for other teachers and/or working in science education units as tutors in the tertiary sector. This meant that not only had the majority of them built extensive mastery experiences through personal teaching experience, but many had also provided the vicarious experience for other practising and preservice teachers. According to Bandura (1977), as long as practising teachers had felt successful in these experiences, high levels of self-efficacy would result. Only two practising teachers reported lower levels of self-efficacy. Ms Marie Curie, who was in her first year of teaching and who reported never having taught science before, and Ms Diane Fossey, who indicated that she tried to avoid teaching science because she felt she lacked expertise. The generally high levels of self-efficacy were reflected in the high self-assessed confidence scores which averaged to 7.7 out of 10 (Table 4.2.6) and PSTE scores of 53.4 out of 65 (Table 4.2.8).

Changes in Self-Efficacy Beliefs

After the project experience, results again varied both within and between the practising and preservice teacher participant cohorts.

Changes in Preservice Teachers Efficacy Beliefs

Generally, preservice teachers experienced gains in levels of self-efficacy and confidence to teach science. Preservice teachers asserted growth in their knowledge and/or confidence to teach science and in fact, they reported growth in confidence as the most prevalent benefit of their involvement in the project. Increased confidence was also the second most prevalent reason given as to why they intended to include science in their own teaching in the future.

These results were confirmed with preservice teachers' STEBI and self-assessed confidence scales. Self-assessed confidence levels grew by an average of 1.4 out of 10 points with results increasing by as much as 6 points out of 10 in some cases. Similarly, results for the PSTE scale of the STEBI questionnaire showed an average increase of 7.5 (out of 65) points, with five individuals reporting increases in self-efficacy belief of more than 10 points after their experience. The average growth in efficacy beliefs of preservice teachers measured by the PSTE scores was in line with other studies into science self-efficacy where mastery experiences were a prevalent methodology (Morrell & Carroll, 2003; Wingfield et al., 1998; Cantrell et al., 2003).

While the data showed that confidence and self-efficacy levels of preservice teachers increased overall, there were some instances where decreases were evident. Reduction in confidence in individual areas of science could be attributed to not having taught particular areas of science during the partnership experience which coincided with the development of greater insight into the challenges of science teaching. This added insight could lead to a realisation that, given their inexperience in a particular area, it could be more challenging to teach than they had initially assessed. It could also be related to the impact of the partnership experience on preservice teachers' assessment of competence; it is interesting to note that each of the preservice teachers reporting decreases in confidence also reported a partnership experience that was less collaborative than those experienced by the other preservice teacher participants.

In spite of the reduction in confidence of these preservice teachers, there were also comments provided through other data sources contrary to this evidence. This appeared to be linked to the fact that two preservice teachers, while in a non-collaborative partnership with their practising teacher, had each other for support and encouragement. There was also the case of Maria Mayar where the initial PSTE score was so high (61 points out of a possible 65), that she was well above the level at which Morrell and Carroll (2003) indicates the ceiling effect comes into consideration. It was not surprising then, that all other data sources indicated that her confidence had indeed increased.

The other important case to consider regarding drop in confidence was that of Jocelyn Burnell. Each of the data sources revealed adverse changes in Jocelyn’s self-efficacy belief. In her discussion responses she attributed her decreasing confidence and increasing anxiety of teaching science to the very negative experience in a non-collaborative partnership with her practising teacher partner, Ms Diane Fossey. These findings resulted in spite of Jocelyn reported having experienced some level of teaching success, i.e. mastery experience. Her situation highlights the extent of the socio-cultural influences that Jones and Carter (2007) discuss where efficacy changes in preservice teachers can be inhibited if the classroom teacher does not support or share the vision of the preservice teacher. It also demonstrates how much impact the affective state described by Bandura (1977) can have.

This finding also supports those of Howitt (2007) who demonstrated the importance of safe and supportive environments for developing science self-efficacy. Generally it describes just how important the nature of the partnership can be in contributing to outcomes in efficacy beliefs, as in this case, the negative experience with her ‘partner’, Ms Fossey, over-shadowed the mastery experience success she reported. Bandura (1977) asserts that mastery experience is the most influential efficacy-building factor. Jocelyn’s experience, compared with those of the other participants in this study, suggests that this may not be the case, and that supportive relationships in a positive environment are far more influential.

Although personal science teaching efficacy (PSTE) scores increased overall, the science teaching outcome expectancy (STOE) scale actually showed an overall slight decrease. This finding is consistent with findings others have reported with STOE results, including Riggs and Enochs (1990). As already highlighted in Chapter 3, these include the general difficulties that exist in trying to measure general teaching efficacy beliefs as reported by Morell and Carroll (2003), and the greater difficulty Posnanski (2002) discusses in regard to affecting outcome beliefs, which he says are ‘more stable and not as easily influenced as self-efficacy beliefs’ (p. 213).

Whilst the evidence indicated that confidence had improved overall, it was still reported as a possible barrier to these preservice teachers’ placing science as a higher priority in their teaching. This suggests that whilst a project such as this one can enhance preservice teachers’ confidence to teach science, it remains an area of concern for them.

Changes in Practising teachers’ Efficacy Beliefs

For practising teachers, there was little overall change in levels of efficacy belief towards teaching science. Self-assessed confidence scores rose by a negligible amount (0.8 out of 10 points). STEBI results reflected small increases overall on the PSTE scale (1.8 out of 65) and no change in the average score on the STOE scale. Given the very high results practising teachers scored on the initial questionnaire, it is highly likely that these results were subject to Morrell and Carroll’s (2003) ceiling effect. Morell and Carroll were able to corroborate this effect by showing significant increases in scores for participants who scored less than 50 in the initial administering of the questionnaire in their study. Similar analysis could not be replicated in this study as all practising teacher participants scored over 50 in the initial questionnaire results.

In interview data, changes in confidence emerged in responses from two of the practising teachers when they were asked about any learning they had experienced. Ms Marie Curie indicated an increase in confidence to teach science and Mr John Dalton reported an increase in his confidence to have other adults in the room as well as an increased confidence in his ability to help children understand science concepts. It is likely that this increased confidence in helping children understand is linked to his confidence in having other people in the room who could be judging this aspect of his teaching. These statements in interview data were corroborated in the final questionnaire when practising teachers were asked to record anything they had achieved/obtained from their involvement in the project. Ms Curie and Mr Dalton both recorded confidence as a part of their responses.

These particular cases again support the place of Bandura's (1977) mastery experience in building self-efficacy beliefs. Ms Marie Curie had reported having never taught science prior to her involvement in the project and Mr John Dalton reported never having had other adults in the room since he became a qualified teacher. The successful mastery experiences each of these practising teachers appeared to have, built the necessary confidence and belief in themselves on which they reported. Of all the practising teachers, these were also the only two who indicated that their involvement in the project had increased their intention to teach science more often. Others reported that science already had a high priority in their teaching programs.

Summary

Overall, the data indicated that, if in collaborative partnerships, preservice teachers will gain in their confidence and self-efficacy beliefs in regard to their ability to teach primary science. The findings also suggest while mastery experience (Bandura, 1977) is important in building efficacy beliefs, the nature of the partnership may actually have an even more significant role for preservice teachers who have low efficacy to begin with.

Furthermore, practising teachers who already have high levels of self-efficacy belief in their ability to teach science successfully are unlikely to experience changes in their confidence levels through their involvement in a partnership such as the one in this study. If teachers are lacking confidence in teaching science however, involvement in a project such as this is likely to provide the mastery experience opportunities that do result in increased efficacy beliefs which is in turn, likely to increase their intention to include science as a priority in their future teaching.

Experiences teaching science in a collaborative partnership may help strengthen existing attitudes towards science and its place in the primary curriculum. It is difficult to judge whether attitudes would be changed completely as all participants entering this study indicated reasonably positive attitudes to begin with. However, the level of amazement at how engaged children became in science lessons reported by the participants of this project suggests that if changes were to occur, they would be positive.

5.3: The Impact of the Partnerships

A key construct of this study was the use of partnerships that emphasised collaboration rather than the more traditional mentoring or supervision approaches to practising and preservice teacher partnerships. One of the most fundamental goals of this research is thus tied to the exploration of these collaborative partnerships and their impact on the primary aspects of development: attitude towards, self-efficacy in and knowledge about science education. This section explores these aspects as they affect the practising and preservice teacher participants.

As reported in Chapter 4, most of the partnerships in the study engaged in moderately high to high levels of collaboration. One partnership had a slightly lower, moderate level of collaboration due to the timing of the partnership experience which began 3 weeks after an inquiry unit had been implemented at the school. Two partnerships showed little to no evidence of collaboration, apparently stemming from a lack of understanding or a lack of willingness from the practising teachers involved. The contrast between these non-collaborative partnerships and the successful collaborative partnerships is useful in helping to explore the impact of the partnerships on participants' attitudes, self-efficacy and knowledge development.

Impact of the Partnership Model on Attitudes and Self-Efficacy

In the discussion on attitudes and self-efficacy earlier in this chapter, it was evident that preservice teachers had generally gained in confidence and self-efficacy belief towards teaching science as a result of their involvement in this project. The impact of the partnership model is considered for each of these participant cohorts below.

Preservice Teachers

All but one of the preservice teachers reported some growth in confidence from their involvement in the project. Some of the development in confidence would be attributable to the fact that preservice teachers had exposure and experience of teaching science in the classroom, regardless of the partnership. It is also likely to be linked to an overall satisfying sense of achievement in terms of the University science education unit's requirements. Biggs (2003) notes how the experience of understanding is satisfying and links to efficacy and esteem. The structure of the project helped preservice teachers develop deep understanding of the theoretical components of the units of study as they put them into practice and received positive responses from the children they were teaching.

While again this may have occurred regardless of the partnership, there are a number of examples in the data that suggest the nature of partnerships is significant in influencing changes in self-efficacy for preservice teachers.

In each instance where the partnership was supportive and collaborative, indications of growth in preservice teachers' confidence were recorded. This is supported by recent findings released by Kenny (2009). He found indications "that a good relationship with their colleague teacher had a direct bearing on the preservice teachers' confidence … and tended to lower their anxiety levels" (p. 12).

The two instances where the partnership was non-collaborative and preservice teachers felt unsupported and even threatened by their practising teacher partner resulted in some instances of decreased confidence. Critical feedback delivered in an insensitive manner and communication of high expectations alongside the withdrawal of support tended to create threatening environments in which these preservice teachers struggled to achieve. These cases demonstrate the power of the social-cultural environment that Jones and Carter (2007) discuss. Bandura (1997) also discusses social persuasion and affective states which in this case were both very negative and consequently, so were their impact on these preservice teachers' self-efficacy.

However, one of these preservice teachers did report successful mastery experience which influenced the frequency with which she intends to teach science in the future. In spite of this, her confidence decreased overall due to the nature of the partnership she experienced. This reveals that even with successful mastery experience, the component Bandura (1977) highlights as being the most significant factor for building efficacy belief, without a supportive, safe environment, self-efficacy levels may still be adversely affected in a significant way. This suggests that the collaborative partnership is of central importance if there is to be even an opportunity for successful mastery experience to be gained.

The other non-collaborative partnership that helps illustrate this argument was that between Helen Dunbar, Gertrude Elion and practising teacher, Ms Jane Goodall. These preservice teachers experienced a small net increase in confidence in spite of the negative experience with Ms Goodall because they had each other for support. This case further emphasises the role of collaborative partnerships on efficacy building. Even though the practising teacher was non-collaborative, the preservice teachers in the partnership were. As a result they experienced far less detrimental impact of the experience than Jocelyn Burnell, who lacked direct collaboration with anyone.

These three preservice teachers also gained support and ideas from their colleagues through both the online and round table discussion forums. These forms of vicarious experience and social persuasion were sufficient to help Helen and Gertrude attain improvement in self-efficacy. Their confidence was established through these media which provided ideas and directions to pursue and the assurance that these ideas worked in other classrooms (Bandura's (1977) vicarious experiences). This highlights the importance of establishing a supportive network between preservice teachers during an extended off-site activity. Koballa and Tippins (2001) verify the use of strategies such as online discussions in providing opportunities for 'fellow learners' to discuss and debate and thus create meaningful learning.

Further evidence that the collaborative partnerships could be a key feature of efficacy building opportunities is demonstrated when the results of this study are compared with those of other studies using mastery experience. When the STEBI results from the three preservice teachers who reported non-collaborative experiences with their practising teacher partners are excluded from the average results, an average increase in PSTE score of 11 points is returned. This is considerably higher than the average increase of 7.5 points yielded when their scores are included. This average increase is also higher than those of most research results concerned with the effects of science mastery experience opportunities for preservice teachers, where averages of around 5 points (Morrell & Carroll, 2003), or 7 points (Wingfield et al., 2000; Cantrell, Young & Moore, 2003) occur. Palmer (2006b) reported high increases of 11 points in a project involving mastery experience in science teaching but his preservice teachers taught only one primary aged child rather than a whole class. This situation does not reflect the true nature of the classroom environment which Stajkovic and Luthan (1998) warn can produce inflated judgements of self-efficacy compared with actual performance.

Preservice teachers also discussed a new awareness of how equipment and experiments can be simple yet still be very effective for learning. They came to realise that basic household items could be utilised which are easily accessible and safe for young children's use. The simplicity of experiments that both engaged students' interest and assisted their learning was communicated almost as a reassuring discovery that put successful science teaching within their grasp. These insights were highly likely to have been significant factors in helping to build their confidence.

Practising teachers

As noted above, practising teachers displayed little to no changes overall, except in the cases of Ms Marie Curie and Mr John Dalton, whose results did show gains in confidence and self-efficacy beliefs. Mastery experience (Bandura, 1977) appeared to be the main factor affecting the increases in attitudes and efficacy beliefs as partners described their feelings of success when lessons went well; their feelings of success for managing parts of lessons that did not go well, and their amazement at the level of children's engagement in science-based lessons.

It was the latter - children's positive reaction to the science lessons and their level of engagement in the learning activities implemented by partners' - that appeared the strongest factor in strengthening positive attitudes towards science. For practising teachers, this was most evident for Ms Marie Curie, Mr John Dalton, and to a lesser extent Ms Virginia Apgar. Each of these practising teachers discussed the importance of including science experiences for children at the end of the project. This appeared to be due to the exposure and experience of teaching science and witnessing children's reactions to it rather than their involvement in a collaborative partnership *per se*. In Ms Curie's case, it could be argued that only through involvement in a partnership project such as this would a teacher with such a strong tendency to avoid science, place him or herself in a situation where the exposure to science teaching could even occur. According to Appleton (2003), this may not have happened if the project had not involved the notion of sharing the experience given Ms Curie's lack of confidence. This suggests that collaborative partnerships may act as a conduit through which teachers may feel safe enough to initiate science professional learning and teaching in their classrooms, thus making it an important feature in the design of practising teacher's science professional learning opportunities.

The partnership played a more significant role in the development of Mr John Dalton's attitude as this was more strongly associated with having other adults in the classroom than with science itself. This suggests that a partnership model can help a teacher make the transition from sole classroom operator to team teacher and enhance his or her attitude towards involving other supportive adults in classroom teaching experiences.

Changes in self-efficacy are closely linked to changes in attitude. Ms Curie and Mr Dalton's cases illustrate how closely confidence in one's ability is tied to attitude. Ms Curie's attitude towards science was impacted on largely because she began with a lack of confidence. Once this confidence improved, so did her attitude towards science. Mr Dalton's attitude towards having others in the classroom was tied to his confidence in having others see him teach, particularly as he was less confident in his ability to help children understand science concepts. Through the partnership experience he developed ideas and ability in enabling students' conceptual understanding, improving his confidence and thus his attitude to opening his classroom. In each of these examples Bandura's (1977) mastery experience rather than the partnership feature remains the key feature, in influencing change.

Overall the findings suggest that the impact of collaborative partnerships on practising teachers' efficacy will only be of benefit to those teachers lacking skills, confidence and experience teaching science to begin with. It is these teachers who are most in need of the mastery experiences proposed by Bandura (1977), and who will thus gain most benefit from experiencing science teaching success. It is possible that the form of this mastery experience may be more successful if collaborative partnerships are used as a tool to recruit teachers, as those teachers most in need may otherwise avoid situations where they have to teach science due to their lack of confidence.

Collectively, the multiple case-study analysis in this study compared with other primary science mastery experience studies in the literature strongly suggest that the collaborative partnership is the *enabler* of successful mastery experiences that grow increased efficacy belief. This places collaborative partnership models as of central importance to educators designing experiences aimed at developing primary preservice teachers' attitudes and self-efficacy beliefs towards science and its teaching.

Impact of the Partnerships on Knowledge

Preservice teachers were generally concerned with their level of knowledge and, in particular, science content knowledge as they entered the project. Involvement in the partnership experience appeared to address their concern by providing knowledge-building opportunities in two key ways: general science content knowledge (GCK) and science pedagogical content knowledge (PCK). There was also a number of benefits that the partnership model appeared to provide that enhanced general knowledge and insights about science in the classroom. These areas of knowledge are discussed for practising and preservice teachers below along with the components of the model that contributed to their development.

Development of Preservice Teachers' General Content Knowledge (GCK)

As reported in Chapter 4, preservice teachers' reported GCK growth associated with knowledge of experiments and accessing and using equipment. They discussed learning from mistakes, deepening understanding through the experiments they conducted in the classroom, and enhancing their understanding of the concepts they were exploring with children as an exercise in joint learning. They also showed indications of discovering the nature of science, moving from a 'facts and formulae' view of science to an appreciation of how it allows exploring, questioning and creativity.

Preservice teachers also shared specific ideas they had explored with children, indicating their own knowledge development in the process. The range of content knowledge and sharing of it was highly significant for preservice teachers. It allowed them to share their knowledge and learn from one another, and there were a number of instances where other partnerships applied the shared ideas in their own classes. This provided a form of Bandura's (1977) vicarious experience where the sharing of successful lesson ideas instilled confidence in others to trial those same lessons. This was particularly supportive for the preservice teachers who found themselves in non-collaborative partnerships.

This acquisition of science content knowledge and lesson ideas was in some ways achieved independently from the nature of the partnerships with practising teachers. Ideas for lessons and the science behind them were shared equally between those in collaborative and non-collaborative partnerships. General statements of growth in knowledge and understanding of science concepts also came as much from the preservice teachers in collaborative as those in non-collaborative partnerships. Hence the role of the collaborative partnership in developing preservice teachers' content knowledge appears to be supportive, but not necessarily fundamental to its occurrence.

What was significant was the sharing preservice teachers experienced with one another. The importance of this has been noted by other researchers including Brandenburg (2004), Korthagen (2001) and Parsons and Stephenson (2005). They each highlight the need for social construction of reflective practice and emphasise the need for reflective practice to be collegial in nature. Loughran (2002) also points to the importance of sharing experiences in practice-focussed discussions between preservice teachers to enhance meaningful learning. In his most recent work, he further discusses the need for thinking and discussion on practice to overcome what he otherwise identifies as largely tacit knowledge that teachers have about their practice which reduces “the possibilities of understanding expertise in teaching” (Loughran, 2010, p. 13). In line with this idea, in this study, the explicit thinking and discussion of practice appeared to be central to the content knowledge development experienced by preservice teacher participants.

Development of Practising teachers’ General Content Knowledge (GCK)

The results showed that practising teachers experienced limited gains in science content knowledge due to the already high level of knowledge most practising teachers had. However, there was a gain in content knowledge for the three practising teachers who had little to no prior science teaching experience. This increased the potential for learning to occur compared with those with more extensive experience. Here content knowledge development was mainly associated with how to conduct simple experiments; the depth of content knowledge appeared to be limited when the teaching experience was aimed at lower grade levels.

Even with more experienced and confident practising teachers, some limited growth in content knowledge development appeared to occur in the form of expanding ideas for science lessons and use of technology to support science teaching. This links partly to a growth in general ideas for teaching science, partly to development of content knowledge, and partly to pedagogical approaches if they had been used effectively to support learning in the lesson. Where a topic was taught in which the preservice teacher had expertise, the practising teacher reported learning terminology and definitions.

It is interesting that for preservice teachers, gain in content knowledge appeared to be strongly related to their discussion and reflection with one another and was largely independent of the partnership they were in. For practising teachers, the opposite appeared true. The gains, albeit small, in content knowledge development for practising teachers relied each time on the preservice teacher partner. This was supported by practising teachers’ identification of collaboration as one of the main benefits they experienced from their involvement. Here, the potential for the partnership model to enable growth in content knowledge development appears to be more significant.

These findings support other research projects concerned with collaborative partnerships. Murphy and Beggs (2004, 2006) and Berry and Milroy (2002) each report on the potential for practising and preservice teachers to learn from each other when they participate equally in sharing, implementing and evaluating of science lessons. This strengthens the argument that the partnership itself can have an impact on knowledge development, as it was clearly found that in this project, the partnership appeared to affect practising teachers' content knowledge more than preservice teachers'. Preservice teachers appeared to gain content knowledge more from each other than from practising teachers through their involvement in round table sessions. This highlights the critical importance of the role expert facilitated experiences at university has in what might otherwise be considered as an exclusive school-based learning experience.

Development of Preservice Teachers' Science Pedagogical Content Knowledge (PCK)

A number of insights into how students were helped to achieve conceptual understanding was clear from the data and related to growth in preservice teachers' developing PCK. Chapter 4 reported how preservice teachers discussed the impact of group sizes, amount of content, links between lessons, last minute changes to planning, and the importance of clear, explicit instructions and the timing of these with respect to certain lesson activities as important components in helping to achieve student understanding. There was acknowledgement of the importance of 'pitching' lessons at the right level - not too easy, not too hard - of having the appropriate resources so that language of texts and internet sites were accessible for the children; and the importance of experiential learning. The latter was a particular point of discussion for those working in productive collaborative partnerships.

Some of these insights into effective pedagogy were related directly to the authentic classroom experience and the fact that preservice teachers were able to gain mastery experience. For example, timing comes with experience, so the authentic classroom experience in this study enhanced preservice teachers' ability to learn how long children take to perform different activities.

The authentic teaching experience can also be linked to Biggs' (2003) notion of deep learning. For example, preservice teachers discussed, at some length, their learning about running experiments where they discovered limitations caused by children's stage of development (such as fine motor skills), and how important it is to trial experiments before using them in the classroom. This latter awareness was interesting as the need for trialling experiments was discussed extensively in university science sessions prior to the project. This suggests that discussing this issue at university lacked the impact that the authentic experience provided. Establishing this priority in science lesson preparation clearly has links to the potential success of future science lessons, and subsequently to children's learning. This highlights the gap between theory and practice discussed in the literature (Darling-Hammond, 2006; Korthagen, 2001) and how university content is not always successfully retained, especially as this type of learning would be delivered through discussion and/or transmission style approaches. This demonstrates the importance of Biggs' (2003) discussion of surface approaches to higher education and the poor impact these can have for learning. The deeper approaches that came through the authentic experience, as described here, had a far greater impact.

So far, the partnership might appear somewhat incidental in considering how these developments in PCK were possible. However, this was not the case. For example, preservice teachers discussed a range of lesson improvements including how they might better manage the physical environment and 'mess' experiments sometimes create, and whether some activities would be better as teacher demonstrations or stations/rotations. Each of these components can only be discovered through reflection on first hand experiences such as those reported by preservice teachers, and these improvements were based on the reflection they initially conducted with their practising teacher partners.

One preservice teacher commented that she wished she had the opportunity to trial these ideas so she could compare the outcomes. It is unfortunate that the project did not allow time or opportunity for this. Some of the suggestions made, such as moving to teacher demonstration, would have limited students' learning and it would be interesting to see whether this would have become obvious had the partners involved had the opportunity to implement their ideas. Generally though, the ideas for improvement were good and will hopefully remain with the preservice teachers if they have an opportunity to teach the same topics.

When reflecting with a practising teacher partner, the focus of reflection tended to be strongly linked to students' learning and how to improve this. Those in non-collaborative partners tended to be more concerned with their survival and 'getting through' what they planned, with little discussion of how students' learning factored in their considerations. This further highlighted the partnership as important in encouraging the reflective thinking that led to PCK development. The key area where this became most evident was in the action-reflection cycles using 5Es framework. However, it was not the sole factor determining the extent of learning. The other crucial component was the reflection through peer sharing that preservice teachers were involved in throughout the project, and in particular, the expert facilitation of this reflective discussion. The part each of these played in helping preservice teachers' PCK development is discussed below as their knowledge development about the 5Es is considered.

Development of Knowledge in Applying the 5Es

A noteworthy area of pedagogical growth was recognised through discussion of how the 5Es framework, as a model, should be used. In early discussions, preservice teachers demonstrated little insight into the benefits and drawbacks of using the 5Es framework. There appeared to be no ability among preservice teachers to comment on whether they thought disconnected lessons, where they attempted to address all 5Es, or related lessons that implemented the framework across a unit of work, would affect students' learning. They seemed to believe the 5Es could be applied differently, but as effectively, to either approach.

Further into the experience, preservice teachers were able to identify that children needed longer periods of time to work with some concepts. It was acknowledged that time to reflect and then draw ideas together at later stages were needed, and some realised the impossibility of the task of incorporating all 5Es into one lesson. They indicated that they would not rush the Explore stage so that explanations were meaningful and appropriately timed. They acknowledged that students needed time to develop their own understanding and make their own links and meaning before teachers intercepted with formal explanations. The preservice teachers who had been involved in teaching a unit of work were able to relate why this approach worked and understand it from their own perspective. They were able to recognise that connected lessons in a unit of work were more effective for achieving meaningful learning.

The fact that this discussion emerged towards the end of the school experience, after the sharing of different successes and challenges and after some of these preservice teachers had earlier indicated that 5Es could be applied as successfully to disconnected lessons as to a unit of work, makes this a clear development in the understanding of pedagogy that emerged. Preservice teachers had prior university-based experience with the notion of connected lessons across a unit of work when, in particular, the second SIS component (Tytler, 2002a) was used to highlight that meaningful learning is achieved through connection across lessons and contexts. Preservice teachers were reminded of this in the first round table discussion when the use of the 5Es was first discussed in relation to a unit of work or disconnected lessons. Yet it was not until they had experienced and compared stories of the challenges of disconnected lessons, were they able to see lesson connectedness as an important feature for achieving student learning. This learning was not apparent through the time devoted to exploring the pedagogy in lectures and tutorials or even after the early teaching experience in the first round table discussion. It was only after a number of classroom experiences, reflection and prompting of thinking to make links between what had been studied with what had been experienced, did the realisation fully emerge.

This represents a significant advancement of understanding about good pedagogy in science and was established through the sharing of the different practice-based experiences preservice teachers had in round table discussion. It links to Loughran's (2002) notion that meaningful learning occurs when preservice teachers reconsider their own and their peers' experiences. Hence, the round table discussion took on extra significance in achieving this understanding. Not only did it allow preservice teachers to compare and reflect on their experiences, but it enabled the expert facilitation of the discussion that in turn helped preservice teachers examine particular components of their experiences more closely. Without the expert facilitation, preservice teachers may have compared their experiences, but not necessarily picked up on important components that distinguished between poor, good, or better pedagogical practice. The expert facilitator was essential in helping preservice teachers to notice the important components of their collective experiences. This relates to Russell's (2005) assertion that a reflective practice session requires a structure and a scaffold, to ensure preservice teachers' focus is on the sorts of questions they need to consider.

Further PCK development was evident through preservice teachers' discussion of how they implemented different phases of the 5Es. In particular, a growing understanding of the need to elicit students' prior knowledge was recognised as preservice teachers applied the Engage phase in their teaching. Initially, preservice teachers were concerned with engaging students' interest in science due to their belief that their own dislike of science would be mirrored by primary school children. As the classroom experience progressed, comments were more in line with pedagogical thinking than just 'trying to get them interested'.

This was an important development in PCK about science, which is why it is built into the 5Es framework (Hackling & Prain, 2005). It is linked to the constructivist principles that people build knowledge and accommodate and assimilate information given what they already know (Bybee, 1997). Preservice teachers were at the important beginning stages of realising the significance of eliciting children's background knowledge and actually using this to inform their planning rather than going through the motions for no real purpose other than 'ticking a box', which is how their initial approaches appeared. The development in pedagogical awareness lay not in that they used the Engage phase to elicit students' prior knowledge, but that they communicated a developing understanding of why they would do this, how they would use the information elicited and the implications of not using the information to inform planning. This learning was associated with the realisation preservice teachers experienced that children had both deeper prior knowledge and greater capacity to understand scientific concepts than they had initially anticipated.

When discussing the Explore phase, preservice teachers were able to make links to the discovery and inquiry approaches that are associated with effective science teaching and learning. They also demonstrated a growing awareness of the relationship this phase has with the next, Explain phase. Reflecting on experiences, they articulated the benefits of allowing students an opportunity to form their own informal definitions of phenomena before formal explanation are provided. They realised how this helped children assimilate the scientific explanation with their own and made them more attentive and interested in the scientific explanation when it was given by the teacher.

Three preservice teachers from the two non-collaborative partnerships appeared not to experience or appreciate this level of pedagogical knowledge associated with applying the Explore and Explain phases of the 5Es. Here, there was no evidence of waiting for children's understandings to be developed before formal explanations were provided, indicating that while the model can be applied, it cannot be applied effectively without a certain level of pedagogical understanding. This is where the nature of the partnership appears to be an important factor in determining how much time preservice teachers devote to pedagogical thinking if they do not have a supportive guide/mentor in planning and reflecting on lessons. When left on their own, particularly given their low levels of confidence, preservice teachers considered their mere survival through the lesson as success rather than considering their approach, how it was used, and its impact on actual learning. This is reminiscent of Parsons and Stephenson's (2005) discussions of preservice teachers on teaching rounds who are so caught up in thinking about what they should do that they rarely consider the rationale behind their selected approaches.

The round table forum was again significant in addressing how the group of preservice teachers ended up viewing the relationship between Explore and Explain, and the presence of the expert facilitator meant that important points could be focussed on until shared understanding and consensus was reached. This further exemplifies Loughran's (2002) notion of the meaning-making that comes from articulating practice-based experiences. It also further highlights the importance of an expert facilitator to focus the discussion on aspects that preservice teachers need to notice for learning to occur, which they may otherwise overlook; a notion supported by Russell (2005).

Not all areas of the 5Es were applied well. The Elaborate phase received the least attention in lessons and appeared to be the least well understood. Only one partnership effectively applied this phase, using a student designed research project where students were able to pose their own questions and decide how to find their answers. However, the majority of these projects appeared to rely on library research rather than scientific skills and processes that the intended student designed investigation associated with this phase would provide. The Evaluate phase was applied with mixed results where overall summative assessment of learning occurred, but student reflection on learning was often overlooked.

One of the significant factors impacting on the lack of successful implementation of these later phases of the 5Es framework was undoubtedly the short amount of time, an issue noted earlier, so class discussion/explain, elaborate and evaluate phases were all compromised. While time was clearly an important aspect in explaining why the later phases were executed in a haphazard manner, it is likely that experience and confidence were also contributing factors. By encouraging student-designed investigations, the Elaborate phase hands over a lot of the control of what and how something is to be investigated, to the students. This lack of control is threatening for teachers who lack confidence in their ability and background knowledge of science. These are the teachers who tend to rely on reading-based approaches to science teaching or teacher directed investigations as strategies for dealing with their lack of confidence in their science ability and background knowledge (Akerson, 2005; Appleton & Kindt, 1999; Fensham, 2004).

In addition, many preservice teachers were experiencing classroom science from a teacher's perspective for the first time. The period of time provided to them through the science education unit was relatively small, and for most, only four science lessons over a four week period were achieved. This was simply too short a time to be able to make any significant impression on deep levels of knowledge across five key areas of pedagogy.

For the 5Es, the level of success in the Engage and Explore phases were considerable and helped preservice teachers construct knowledge about teaching. Influences were also made on the Explain phase, although these were not as extensive as those for Engage and Explore. To use a constructivist approach to help preservice teachers learn and retain deep insight into the remaining and possible higher-order thinking aspects of the framework, more time is needed to build experiences, to allow for appropriate scaffolding of learning and to build confidence to trial these phases. Thus it is not surprising that whilst the early stages of the 5Es framework were achieved well, the last stages were not clearly attained in all cases. Overall however, progress in PCK was attained.

Further evidence of this came through preservice teachers' increased ability to discuss and link other general theories and strategies they had learnt in the university setting. They recognised a number of theoretical models and teaching strategies (e.g. Constructivism, Discovery Learning, Rich Tasks, Problem-Based Leaning and 5Es) in their reflections on lessons, and linked strategies like POE, and its extended form POET, to different phases of the 5Es. Tied to these general references to realising the importance of different influences on effective learning, came the explicit discussion of applying theories and strategies they had studied both in the Science Education unit and other Educational Studies units at university. This further highlighted how the authentic experience helped bridge the theory-practice gap (Darling-Hammond, 2006; Korthagen, 2001; Loughran, 2002) and the importance of expert-facilitated reflection as a tool for learning (Korthagen et al., 2006, Loughran, 2002).

This range of insights and development of GCK and PCK was linked to the authentic classroom experience, exposure to teaching children science and reflection on this experience. For preservice teachers, this relates to the literature in three ways. They help bridge the theory-practice gap discussed by Darling-Hammond (2006), Korthagen (2001) and Loughran (2002); they provide necessary mastery experience discussed by Bandura (1977); and they highlight the critical importance of reflective practice for learning discussed by Korthagen et al. (2006) and Loughran (2002, 2006). The theory-practice gap is bridged through the opportunities preservice teachers had to apply concepts learnt in university coursework as specified by Darling-Hammond (2006) and exposure to the nuances of everyday teaching as noted by Korthagen et al. (2006).

Mastery experience features not only as an efficacy building tool, but also as a means through which authentic teaching can be experienced where preservice teachers are able to develop knowledge about children and teaching practice. The reflective practice throughout this study was critical though, because as Korthagen et al. (2006) assert, learning does not occur through experience, but rather, through reflection on experience and interaction with others. As Loughran (2002) acknowledged in his own work, only through the reflective practice is tacit knowledge of practice able to become “explicit, meaningful, and useful” (Loughran, p. 38).

The data show that the construction of preservice teachers’ pedagogical knowledge came from the ownership of the experience and the facilitation of the relevant deep thinking to accompany it. This demonstrates the power of and the need for integrating the university and practical experience, as purported by a range of authors (e.g. Darling-Hammond, 2000b, 2006; Korthagen, 2001; SCTP, 1995; Zeichner, 2002). The data also demonstrate the important need for an expert facilitator, such as the university lecturer, to have deep insight into what was being experienced, both in the classroom and at the university, in particular to ensure the appropriate level of scaffolding is provided to support the building of a high-level of PCK. This is supported in the literature by Russell (2005) who indicates the importance of structure and scaffold in reflective practice to ensure important components are ‘noticed’. It also recognises the place of reflective practice as central for meaningful learning (Loughran, 2002). Finally, the nature of the partnership was essential. Those in strong collaborative partnerships spent more time on reflection about students’ learning and demonstrated increased awareness of improvements they might make to improve it. Those in non-collaborative partnerships tended to reflect on important lesson requirements such as classroom management and content, but without articulating the link between these ideas and their impact on students’ learning.

Development of Practising teachers' Science Pedagogical Content Knowledge (PCK)

Growth in practising teachers' PCK, although not a strong element in learning overall, was evident for some practising teachers. Reflection time was reported to have been significant for assisting increased insights into teaching approaches, particularly with regard to the use of the 5Es both within a lesson as well as across a unit of work. This supports the level of learning preservice teachers gained from reflection in their partnerships as discussed above. The experience using the 5Es framework was also discussed in terms of it increasing practising teachers' awareness of the need to ensure opportunities for students to apply knowledge to new contexts are provided in teaching and learning sequences. At times, practising teachers also made general, non-explicit comments about gaining improved ideas about teaching and learning approaches from their preservice teacher partners.

They also reported that their predominant achievement was an opportunity to collaborate with others and share teaching ideas. A number of other 'one off' gains were also noted including just one response that professional learning was, overall, achieved. Most achievement was reported as having come from working in the partnership with their preservice teacher, which supports the interpretation provided above regarding the importance of the partnership for preservice teachers' PCK development. It also supports other research that suggests practising teachers can learn from preservice teachers (Berry & Milroy, 2002; Kenny, 2009; Murphy & Beggs, 2004, 2006).

Similar to the minimal development of practising teachers' GCK, there were only small gains in PCK evident in thesis data due to the already high levels of knowledge and in most cases, extensive experience teaching science. This left little room for any significant improvement in the pedagogical approaches in the short time period available. This further highlights the importance of involving teachers more in need of science professional learning, even though they may tend to try to avoid these very same opportunities (Appleton, 2003). However, the learning that did occur was attributed to the collaboration in partnerships with preservice teachers, highlighting that the partnership model was an important factor in determining opportunity for PCK development to take place.

Summary of the Impact of the Partnerships

Working in a well-functioning collaborative partnership with the practising teacher was significant in being better able to cater for children's needs and interests, due to the practising teachers' existing knowledge of children in the class. The fact the practising and preservice teachers were equal partners in planning lessons meant that particular needs were integrated at the initial planning stages, contributing to a more efficient planning sequence. This makes the collaborative nature of the partnership model important. In more traditional partnerships, the preservice teacher presents the completed lesson plan, and feedback from practising teachers about the suitability of particular activities is not likely to come until this point, if at all. This then requires adjustments and changes and further feedback leading to a more inefficient process.

The partnership would also have been expected to enhance other learning where practising teachers' experience would be beneficial. For example, timing of lesson components and how long children generally take to complete certain activities would have been something practising teachers had more insight into than their preservice teacher partners. However, findings reflected partners running out of time for their planned lessons. Insights into the simplicity of equipment and practical work could have come from knowledge practising teachers already had of their class, given that so many preservice teachers were surprised by this. This could indicate that these simpler types of approaches may not have been tried without the practising teacher partner's input in planning. It was certainly the preservice teachers who worked with two of the most experienced and science competent teachers who appeared to gain the greatest insight into how simple experiments and equipment could be. Most likely, it is both the general exposure to science classroom teaching and the partnership with practising teachers that contributed to the overall development of knowledge for preservice teachers.

The collaborative nature of the partnerships could be attributed more conclusively to the level of learning from prior experiences during the action-reflection cycles. Ongoing contributions from those in collaborative partnerships indicated how adjustments were made to different aspects of lessons as they learnt from their previous experience. Contrary to this, the three preservice teachers in non-collaborative partnerships gave no such indication of developing awareness in their planning. In fact, in these non-collaborative partnerships Explain and Evaluate sessions consistently lacked any real profile or improvement as time in the project progressed. These were also the only preservice teachers who did not discuss ideas for improving the way they conducted or organised practical work. This suggests that without a collaborative practising teacher partner, the subsequent lack of reflective practice contributed to limited improvement over time.

For practising teachers, what knowledge was gained came from the collaborative planning and reflecting conducted with preservice teacher partners. Where there was no collaboration, there was no knowledge development at all. While knowledge development was minimal for most practising teachers even if they were in collaborative partnerships, it was still evident. If the less experienced teachers are considered alone, knowledge development, and self-efficacy were effected significantly. This suggests that the collaborative partnership is important for achieving professional learning for practising teachers, but those teachers have to have a need for the professional development.

These examples indicate how the partnership can be both important and incidental in its assistance to development of GCK, PCK and general insights into teaching science. It appears to depend on the nature of the learning taking place as to how important the partnership is in aiding this learning. The inference can be made that learning from experience and exposure to the classroom occurs, regardless of the nature of the partnership, for realising student engagement in science. However, it does appear to be significant in reflecting on what did not work and ways of improving on these facets, with the purpose of these improvements being focused on student learning. It also appears crucial in successfully building confidence and self-efficacy beliefs about science teaching ability.

5.4 Factors Influencing the Success of Partnerships

The basis of the collaboration between practising and preservice teachers in this study was that they engaged in cycles of science teaching action-reflection to enhance efficacy and knowledge. The action component of this involved the planning and implementing of science lessons which was critical in providing mastery experiences of science teaching that acted as a source of efficacy information to improve confidence and contributed to general and pedagogical content knowledge development. The reflection component of the cycles ensured participants thought about and articulated their ideas and beliefs about the effectiveness of their action, improvements they could make, and informed further planning. A number of factors contributed to the extent of success of the collaborative partnership model and subsequent learning that was able to take place. These factors are considered below.

Formal Reflection

One of the intentions of the reflective practice component built into the action-reflection cycles was to determine whether this would impact on pedagogical growth for either the practicing or the preservice teacher partner. This collaborative reflection was targeted in two ways. Preservice teachers reflected together both online and in round table forums. Round table discussions were particularly successful, as already discussed, due to the expert facilitation of these sessions to appropriate guide reflective thinking and discussion.

The second strategy targeted collaborative reflection between practising and preservice teacher partners through the Planning and Reflection Booklet (Appendix 4) which was supplied to each partnership at the first workshop. In spite of this, responses overwhelmingly indicated a casual approach to partnership reflection. This was disappointing given the emphasis on the importance of formal reflection as established in the literature, as a critical component for effective professional learning for practising teachers as well as an effective component of teacher education. It is also disappointing in that results indicated that reflection was a critical factor in developing PCK, particularly for practising teachers. Had it been more formal between partners, it may have yielded data to indicate the extent of PCK development that might be possible. Those who had limited formal recording of their planning, and more particularly, their reflection, reduced the level of articulation and thinking about the factors contributing and detracting from their success. Loughran (2006, 2010) discusses the importance of articulation for the achievement of reflective practice.

The consequences of not participating in regular, formal reflection were not strongly felt or observed by participants, and hence it lost its priority amongst other more immediately pressing concerns. The fact that reflection was so casual in spite of the framework provided and requests to incorporate it, suggests that the perceived value of reflection was not important enough for partners to overcome the challenge they cited, of insufficient time.

Timing of the lesson implementation also had consequences for reflection. Reflection worked best when it immediately followed the teaching session, so was made difficult for a number of partnerships when the designated teaching time did not take place before a break, or just prior to the end of the school day. However, even then it could be impeded by other commitments participants had, such as yard duty, appointments or for preservice teachers, or classes scheduled at university.

Finding coinciding time for the action-reflection cycles was challenging for partners and this was exacerbated for those partnerships involving two preservice teachers and one practising teacher, where partnerships had to synchronise three separate timetables rather than just two. Since many Victorian schools also have mandated blocks of time for literacy and numeracy which can not be moved to accommodate other activities, these issues compounded the challenge of finding appropriate coinciding time to build in the planning, implementation and reflection components of the cycles. Of these, reflection was the one sacrificed most readily as, for participants, it had the least observable consequences. This attitude towards reflection was expressed by the number of statements about reflection that contained the phrase ‘it would be nice, but...’.

Whilst time was the reason cited for the informal approach most partners took to reflection, it is likely that it is also linked to the demanding process critical reflective practice requires. Loughran (2010) discusses how reflective practice requires the examination of practice in order to learn and respond, and that this can be uncomfortable and difficult, particularly if the findings do not support the individual’s initial, personal and often well-held positions. The effort and potential discomfit associated with formal reflective practice may have been as significant an inhibitor as the time issue teachers cited as their reason for minimal reflection.

Time

There were further challenges associated with time that impacted on the success of the model. For example, the practising and preservice teachers identified the short duration of the project as a disadvantage. Because preservice teachers improved their practice notably over the partnership period, it would be expected that, if it could go longer, further improvement would show. Indeed, for preservice teachers, more time in schools was identified as the most significant aspect that would be required to help them achieve more towards their development as a science teacher.

The timing of organising the partnerships with schools was also identified as an issue. One practising teacher had already planned an inquiry unit when the preservice teacher joined her three weeks after it had been established in the class. This compromised the level of collaborative planning this partnership was able to undertake. There was also considerable pressure on partners, and on myself, to establish the partnerships quickly and for implementation to begin, as the partnership experience started a week after it was initially intended. In a 12 week university semester already half way through, the extra week was a significant time delay.

In addition, there was some difficulty in deciding when to approach schools about the project. The university semester and the school term dates did not coincide in a manner that made for optimum timing. It was difficult to plan the unit structure to enable preservice teachers enough time to establish themselves and acquire enough background prior to commencing the school experience and time this with the school term. Principals communicated afterwards that planning of each term's curriculum focus often occurs in Term 4 of the preceding year, and it is difficult to alter these plans halfway into the year, the time when they were approached for involvement in this project.

Although in his study Kenny (2009) does not specify when he contacted principals in his effort to place students, it is evident that it was at least three weeks earlier than the timeframe adopted in this study. Kenny reported having a response that yielded more practising teachers than preservice teachers in the elective unit the placement was associated with. Whether this response was influenced by the earlier timeframe or because teachers were not explicitly required to contribute to the planning, teaching and reflecting is unclear.

Morrell and Carroll (2003) also had no difficulty recruiting teachers when they asked for active participation from teachers in the collaborative process. They did, however, have funding that they used to support involvement which was used to pay for teacher cover, science equipment for the schools involved and meetings.

Practising teachers also identified the time required to organise and set up experiments as the main factor impacting on their likelihood to conduct science lessons. This is consistent with literature from other research into factors impacting on science education, such as reported by Levitt (2000), Rennie (2001) and Keys (2005). Practising teachers also identified constraints imposed by the curriculum as a barrier to teaching science that also links to time as an issue for success. This was also one of the most common responses from preservice teachers regarding barriers to teach science, demonstrating that even in the short period of time associated with this project, they gained a clear insight into the challenge curriculum constraints can present. This is also consistent with other research findings (e.g. STAV, 2005; ASTA, 2005) that demonstrate how a strong literacy and numeracy focus in primary schools can negatively impact on teaching of a range of other curriculum areas.

Overall time was an important factor in determining the success of a number of the partnership model's components.

Communication

Communication was also identified as a challenge for some partnerships. The partnerships that were unable to achieve a collaborative relationship highlighted this as a critical issue in evaluating the model. This was not unexpected given the difficulties these preservice teachers reported throughout the project experience. There was also an underlying impression that the practising teachers from the non-collaborative partnerships were not committed to the project idea. They did not listen carefully to any of the information presented at the catch-up meeting held for them, instead, rushing through the documents and appearing anxious to leave. As a consequence they failed to fully understand the purpose of the project, and hence were unable to ask the appropriate clarifying questions.

The non-collaborative cases raise a number of questions about using a partnership model. Firstly, the recruitment of practising teachers needs to be considered more carefully. Recruitment was supported by the Catholic Education Office through an Education Consultant. There is no information about whether the principal identified the teachers meaning they had no choice about their involvement, or whether the Education Consultant approached the teachers directly after discussing the project with the principal. In either case, it is uncertain how the project was described to these practising teachers, and possibly initial misconceptions were instigated by an inaccurate or incomplete account of what their involvement would require.

It is difficult to see either the cause or the solution to the failure of some teachers to establish a collaborative partnership, other than the preliminary information would be less likely to be misunderstood had they been able to attend the initial workshop. This was unavoidable however, and thus is a factor that cannot be relied on fully when trying to schedule a meeting with a number of practising and preservice teachers, given so many demands on time. It certainly highlights the need for clear communication.

Preservice teachers also reported wanting clearer expectations of what the partnership involved. This stemmed from both the non-collaborative experiences of three of the preservice teachers as well as the uncertainty some preservice teachers had about the level and accountability of recording required in the planning and reflection books. This further demonstrates the need for clear communication.

Another partnership challenge regarding communication was associated with the partner members themselves. Strong personalities coupled with a relatively abrupt manner, caused some tension between one set of partners, who reported clashes in ideas as well as ideals. All three of these partners expressed difficulty in communicating although they appeared to be able to compromise most of the time. It is possible that tense dynamics in this partnership may have been compounded by having three members rather than two.

The tension in this partnership raises two points for consideration: the compatibility of partnership members and the optimum number of people for an effective partnership. It is difficult to sense whether the tension experienced in this partnership was linked to a personality clash or to a clash in philosophy and educational ideals. Murphy and Beggs (2006) discuss random pairing of co-teaching teams as less than ideal and sought to establish more compatible partnerships through visits to school principals to discuss potential partnering. This would be extremely difficult to achieve on a larger scale however, due to the time-intensive factor and the expense associated with visiting all principals for all student placements in a large university course. This would be further compounded by placements based in rural/regional/remote or even overseas as occurs in some teacher education courses.

Zeichner (2002) discusses the ideal of using compatibility of partners as a criterion for placing students in professional experience placements and the difficulty and improbability of achieving this. While a significant clash in educational philosophies could be detrimental to a partnership experience such as that used in this project, tension can potentially be of some benefit. Tensions challenge partners to remain professional and challenge themselves to keep an open mind to approaches that do not come naturally to them. In situations where a clash is not extreme, this could enhance learning regarding the skills of team work.

The risk of an extreme clash remains an issue in using partnership models such as this one, but as Ms Virginia Apgar posited '*It works if everyone does what they're meant to. There's no such thing as a personality clash*' (Ms Virginia Apgar, Interview). Zeichner's (2002) challenge of finding classroom teachers who identify themselves as learners is also a contributing factor. This also helps to explain why some partnerships were able to work through tensions and achieve collaboration while others were not.

Access to Resources

Preservice teachers noticed that schools had little scientific equipment and consequently access to resources was also a factor they identified as linking to success. It also featured in both practising and preservice teachers' discussion of potential barriers to increasing their science teaching.

This is always a difficulty when a number of groups is potentially planning different topics and it is not always clear what resources will be required. Preservice teachers did have access to university science equipment and a number of them utilised this. Consumable resources had to be funded by students or through the school where they were placed. There were also instances where practising teachers reported having no access to science-specific funds, and in some cases practising teachers were required to fund science classroom resources themselves.

A number of studies discussed in the literature highlight that access to resources is a wide-spread problem and one not easily addressed. Provision of resources without accompanying professional learning is limited (Keys, 2005; Levitt, 2001), but at the same time access to appropriate resources is fundamental to hands-on learning. This is a serious issue for consideration when primary schools are generally science resource poor (Goodrum et al., 2001; Keys, 2005).

Use of Volunteers

A decision to use volunteer participants in the study was required for both ethical and practical purposes. As discussed previously, preservice teachers had to be volunteers as the study was tied to a unit of work in their course. Practising teacher volunteers were used as it is not possible to mandate their involvement in a small scale project such as this. The issue this presented was that most of the practising teachers that became involved were already of a relatively high level of confidence and ability in their science teaching. Appleton (2003) acknowledges how entering such a mode of professional learning could be considered a "risky behaviour unlikely to be adopted by a teacher avoiding science" (p. 3). This limited the ability of the framework to serve as a professional learning model for those teachers. Hewson (2007) recognises this issue and poses the question of how to design professional development programs for participants who are non-volunteers. Perhaps more relevant, is the question of how to help practising teachers in need of professional development in this area to feel safe enough to volunteer.

Authentic Classroom Experience

The authentic classroom experience has already been discussed in relation to a number of findings in this study. It is mentioned again in summary here because it was such a key factor in determining the success of the partnership model. The authentic experience provided practising teachers access to their own classrooms and schools thus increasing the opportunity for enhanced knowledge and skill development (Garet et al., 2001). For preservice teachers, the authentic classroom provided a real experience with children that heightened their awareness of critical factors such as timing, running experiments, children's prior knowledge and capacity for learning. It also meant that students' enthusiasm and engagement in science could be witnessed first hand which had a significant impact on all participants who had little to no prior science teaching experience. These experiences primarily link with Bandura's (1977) mastery experience. They also reflect the authentic rather than simulated environment that Stajkovic and Luthans (1988) tell us is required for reliable increases in efficacy measures.

The high level of engagement of children in science was a significant insight for these teachers to have gained. If they realise how much children enjoy science, they may be more willing to implement science lessons. This helps to overcome one of the first hurdles in increasing the amount of science teaching in schools. The other factor that will help teachers continue to teach science, and utilise inquiry approaches, such as that provided through the 5Es, is the increased efficacy they experienced. Bandura (1977) indicates how efficacy is a predictor of behaviour and Goddard (2003) and Jones and Carter (2007) indicate that higher levels of efficacy can influence the selection of instructional strategies.

Collaboration within Partnerships

The need for equality and collaboration within partnerships was a key factor recognised by both practising and preservice teacher cohorts for successful partnerships. Practising teachers indicated this through their identification of the need for equal sharing and willingness to share, while preservice teachers wanted to be seen as an ‘equal teacher’ rather than as a ‘student’ teacher, and identified the need for a willingness by all parties to contribute. Whilst some element of being seen as a ‘student’ teacher is always likely to exist, a number of the partnerships did illustrate that collaboration in planning, implementing and reflecting could be achieved on an equal basis. This was certainly more authentic when the practising teacher involved was also in need of science professional learning, rather than already being experienced, confident and even expert in this area. This was further recognised by practising teachers who noted that projects of this nature need to target those classroom teachers who tend to avoid science.

The willingness to participate in a collaborative manner was a strong theme in preservice teachers’ responses when considering the factors that influenced the success of partnerships. This indicated their belief in the power of the nature of the partnership in achieving successful learning, and the recognition that a negative experience can lead to a negative view of science teaching. The link to successful mastery experience and the impact of negative experiences in lowering efficacy that Bandura discussed is evident here, presenting an important reminder of why it is essential to be able to identify and minimise risks through studies such as this one.

Practising teachers also discussed the attributes of preservice teachers that they believed were important for establishing effective partnerships, which in some cases also extended to other practising teachers. For example, they felt that preservice teachers needed to bring ideas to the partnership and be confident. It is not clear whether this means confidence to share ideas in the planning or confidence generally to plan and deliver lessons. They saw it as important that partners were willing to make time, and to be optimistic, imaginative and innovative, and from accounts of some of the partnerships, these attributes seem to have been recognised by those practising teachers who experienced and benefited from these factors.

Overall, the message from both practising and preservice teachers was clear. Successful partnerships that result in learning require collaboration and commitment from all partners. The lack of collaboration that existed for some partnerships was a significant limiter given the need for interaction to build trust, shared vision and common ways of discussing intellectual work as described by Kirschner et al. (1996). Jones and Carter (2007) also emphasise the importance of shared vision between co-operating and practising teachers for the achievement of improved efficacy.

This chapter has identified a number of important areas of consideration that emerged regarding factors that impact the success of the partnership model and barriers to increasing science teaching in schools. These ideas inform the final concluding chapter of this study, which presents answers to the research questions. It goes on to offer recommendations for improving primary science education in the light of the study’s findings and concludes with directions for further research.

CHAPTER 6:
CONCLUSIONS, RECOMMENDATIONS AND DIRECTIONS FOR FUTURE RESEARCH

6.1: Introduction

This chapter brings together the rich case study data provided by the research to form four key conclusions that answer the research sub-questions and subsequently, the over-arching research question from which they stemmed. The four research sub-questions are answered in turn in Section 6.2 which then concludes with the overarching research question being addressed.

A number of recommendations are then made drawing from the study's findings. Next, directions for further research that is linked to and informed by the present study are suggested, along with a final reflection, in Section 6.3.

6.2: Answering the Research Questions

The over-arching research question asked:

What is the impact of collaborative partnerships between preservice and practising teachers, using a model of critical reflection for action, on the knowledge, self-efficacy beliefs, and attitudes of teachers towards teaching and learning of science in primary schools?

To answer this question, a series of research sub-questions was developed addressing each of the key areas of the over-arching question that related to attitudes and self-efficacy beliefs of preservice teachers; attitudes and self-efficacy beliefs of practising teachers; and knowledge. A fourth research sub-question was also posed that examined the barriers to increasing effective science teaching in primary schools. This helped to establish whether attitudes, self-efficacy beliefs and knowledge levels were predominant factors inhibiting the teaching of primary science, or whether other factors were also involved.

Research Sub-Question 1: What attitudes and levels of self-efficacy beliefs do preservice teachers have towards science before and after the partnership experience?

This sub-question was relatively straight-forward to answer. The findings of the study indicated that preservice teachers' attitudes, beliefs and self-efficacy can be moderately to significantly enhanced, if a model of collaborative planning, implementing and reflecting on a series of science lessons with practising teachers is used.

Preservice teachers' initial attitudes towards the value of science in education were positive at the beginning of the research period. These attitudes were enhanced throughout the project experience predominantly due to the level of engagement and enthusiasm of students in science lessons that preservice teachers witnessed. Preservice teachers also developed a deeper appreciation of global and social issues from their exposure to teaching science. The authentic classroom setting was fundamental for the development of these enhanced attitudes.

Self-efficacy beliefs were relatively low among preservice teachers upon entering the project. They were concerned with their own level of science background knowledge (i.e. GCK), ability to teach science concepts, and their ability to answer children's science questions. Most participants' self-efficacy beliefs had grown considerably by the end of the project, having been enhanced by successful teaching experiences in an authentic setting, but also linked to the level of collaboration from a practising teacher partner. Collaborative planning, implementing and reflecting benefited preservice teachers' confidence to suggest and trial ideas, to become critically aware of strengths and weaknesses in their lessons and, when shared with a practising teacher partner, were more likely to see themselves as teachers who are learning than preservice teachers still on the cusp of professional practice. Modelling of learning and reflective practice by practising teachers is also likely to encourage positive attitudes to on-going learning once preservice teachers have entered the profession.

Gaining mastery experience (Bandura, 1977) was one of the strongest contributing factors for building efficacy belief in preservice teachers. However, when collaboration in the partnership failed, social persuasion (Bandura, 1977) became a more significant efficacy-building tool, even when successful mastery experiences were achieved. This highlights the importance of Jones and Carter's (2007) assertion that shared vision between practising and preservice teachers is essential for efficacy improvement.

Research Sub-Question2: What attitudes and levels of self-efficacy beliefs do practising teachers have towards science before and after the partnership experience?

Practising teachers' initial attitudes and self-efficacy beliefs were of a high level. After the project there was an enhancement in attitudes and a growth in self-efficacy beliefs only from those teachers who reported low self-efficacy and science teaching experience before their involvement. This showed that attitudes and self-efficacy beliefs can be enhanced in practising teachers using a collaborative partnership model of professional learning in science education if they are able to identify themselves as lacking knowledge and confidence in the science area.

As with preservice teachers, it was exposure to children's enthusiasm for science that most contributed to enhanced positive attitudes towards science and its importance in the curriculum. Successful teaching experiences and overcoming difficulties faced during the teaching experience, both examples of Bandura's (1977) mastery experience, contributed to increased self-efficacy beliefs. For those practising teachers who already had strong positive attitudes and personal self-efficacy beliefs, the project experience had little to no impact on existing attitudes and efficacy beliefs.

The fact that so many practising teacher participants already had a strong sense of self-efficacy and science teaching experience demonstrates the difficulty Appleton (2003) identified about attracting teachers in need of science professional learning to situations they consider 'too risky'. Bandura (1977) also reported on the relationship between efficacy levels and the influence over the types of activities in which individuals elect to be involved. This is a concern that needs addressing and is considered further in the recommendations stemming from the study later in this chapter.

Research Sub-question 3: What are the effects of action-reflection in collaborative partnerships between practising and preservice teachers on knowledge, attitudes and self-efficacy beliefs of preservice teachers towards science education?

The data relating to the effects of action-reflection in collaborative partnerships were rich, diverse and wide-ranging. They are dealt with in this section through separate components for which they were examined: impact on attitudes and self-efficacy beliefs of participants; impact on general content knowledge, and on pedagogical knowledge development.

Attitudes and Self-efficacy Beliefs

The effects of action-reflection in collaborative partnerships and practising teachers had a minimal effect on participants' attitudes to science education and a moderate to significant effect on personal self-efficacy beliefs and knowledge. Attitudes tended to be enhanced in the project, but this was due to the authentic classroom experience of teaching science and witnessing children's positive reaction to it, rather than to the partnership experience. The partnership experience was, however, significant in affecting personal self-efficacy beliefs.

Those partnerships with high levels of collaboration yielded more significant changes in levels of personal self-efficacy belief in preservice teachers as self-assessed by STEBI questionnaires. Those involved in non-collaborative partnerships showed either mild increases or negative changes in efficacy. Supportive, collaborative partnerships with high levels of involvement from all partners tended to encourage preservice teachers' belief in their ability to plan and deliver effective science lessons. The changes in practising teachers' self-efficacy beliefs were more difficult to judge due to both the small number of participants in this cohort and the low response rate for both the initial and final questionnaires. The two practising teachers who were least confident and experienced showed indications of increased self-efficacy through either self-reports and, where it was available, STEBI and self-assessed pre and post confidence scores. The one practising teacher with little experience and confidence who failed to participate in a collaborative partnership did not provide any initial or final data, but did report that the project had made no impact on her attitude towards science and/or its teaching in the interview. Together, these findings indicate that the partnership model is important in assisting practising teachers to develop personal self-efficacy in their science teaching, but only if their efficacy and/or experience was at a low level to begin with and only if they are active participants in the partnership.

Where there were two preservice and one practising teacher, the impact of partnerships had mixed results. When the collaboration failed to emerge, having two preservice teachers within the partnership was supportive and could be considered a necessary and even critical component for success. The preservice teacher who was left on her own when her practising teacher partner failed to participate collaboratively, or at all, in the planning, teaching and reflective process, experienced significant decreases in self-efficacy belief. Where there were two preservice teachers in the partnership, it is likely that this would have been minimised if there had been another colleague with whom to share the planning and teaching experience, confirming Parsons and Stephenson (2005) findings of how this type of solitary experience can produce negative effects for preservice teachers.

The partnerships that experienced moderate to high levels of collaboration generally yielded increases in preservice teachers' self-efficacy beliefs, whether they were in one-to-one partnerships or two-to-one partnerships with practising teachers. One partnership did comment on what they believed to be the additional difficulty an extra person brought to the decision-making process when deciding the ways in which teaching should be approached. The clash of personality between one preservice teacher and the practising teacher in this partnership suggests that such difficulties can influence the level of challenge faced in establishing a collaboration, and while a third team member may exacerbate this, it is unlikely, given the results of other partnerships, that this would be the cause of tension. Professionalism from all partners ensured that this clash was overcome and whilst it made for a more demanding process, it did not impact on efficacy or knowledge growth in these partners compared with other partnerships who experienced a smoother collaboration.

These findings indicate that action-reflection in collaborative partnerships provides a strong base for efficacy-building opportunities for preservice teachers and practising teachers who are limited in science teaching experience and self-efficacy belief.

General Content Knowledge (GCK) Development

The impact of the action-reflection in collaborative partnerships was important in the development of general content knowledge. Practising and preservice teachers both reported the benefit of sharing ideas and developing lesson content. This was the case for both inexperienced practising and preservice teachers who both benefited from broadening their repertoire, as well as for experienced teachers who, in some cases, reported the benefit of learning to deliver concepts in new, different and improved ways. This was particularly evident when preservice teachers brought IT applications to support lesson delivery. The focus on knowledge and skill development in this capacity indicates that some aspects of Ingvarson et al.'s (2005) and Garet et al.'s (2001) guidelines for effective professional development have taken place; both sets of authors identifying the importance of content, particularly in discipline-based areas such as science and mathematics.

Overall however, science background knowledge appears to have been developed minimally, although preservice teachers experienced greater GCK development than practising teachers. At times, the younger grade levels meant that investigation of underpinning science concepts was small, as partners researched little beyond that which they perceived as necessary for the lesson. Links to additional assessment tasks in the unit may have helped increase GCK development for preservice teachers.

Practising teachers showed little content knowledge development, except again in the cases where there were lower levels of experience and confidence to begin with. A stronger focus on content could have been taken in the participant workshops to strengthen the content knowledge factor of professional learning in the model, but this may also have introduced factors that limited the range of schools able to participate. It would be difficult to identify a content area that suited all schools as well as one that worked across year levels. It is more important for the nature of a program such as this that teachers select contexts with their preservice teacher partners that suit the contextualised needs of each classroom and school.

Pedagogical Content Knowledge (PCK) Development

The study provided significant insights into the development of science pedagogical knowledge, particularly for preservice teachers. The use of the 5Es framework and the critical reflection they engaged in through online and round table discussions appeared to be the key components responsible for this, rather than the partnership *per se*. However, those partnerships that were collaborative generally reported more frequently on their use of the 5Es framework, suggesting greater thinking and discussion about it may have taken place. Non-collaborative partners appeared to be more concerned about survival than pedagogical thinking. Links between the 5Es framework and other theoretical models were also recognised by a number of the preservice teachers who experienced collaborative partnerships. Importantly, they noted that the practice actually helped them to connect ideas and feel more confident about them rather than just learning them in the university tutorial room.

A number of factors contributed to the development of PCK. The dedicated science teaching experience was one factor that helped thinking and learning about science-specific pedagogies. The fact that it was linked to science education assessment for preservice teachers also increased the focus on science-specific thinking. The 5Es framework provided a sound approach to pedagogy that aligned well with the nature of science principles, further enhancing science-specific pedagogical learning. The sharing preservice teachers engaged in through online discussions helped them explore their teaching, but it was the facilitated round table discussions where expert guidance helped preservice teachers 'notice' the important components of their pedagogical practice that were more significant.

Reflection with practising teachers was intended to help both practising and preservice teachers develop insights into science-specific pedagogy. It also addressed Goodrum et al.'s (2001) report that teachers feel a lack of time and opportunity to share ideas and reflect collaboratively in professional learning situations, and also contributed to the achievement of Garet et al.'s (2001) call for professional communication to be embedded in professional development programs. The informal approach most partners took to reflection meant that this did not impact on professional learning to the extent that it may have, had all partners approached it more systematically.

One partnership (Ms Marie Curie and Anita Roberts) did approach reflection as intended, and they both reported benefiting from this. They both exhibited progress in pedagogical thinking, but as each of them, and the practising teacher in particular, was extremely nervous about teaching, many of their 'critical moments' for reflection focussed on more basic matters such as classroom and resource organisation. This showed that if these fundamental components are not in place, it is difficult to focus on the higher order thinking levels that pedagogical reflective practice requires. This was true for a number of the preservice teachers who entered the project with low self-efficacy. Their reflective discussions were also far more focussed on basic lesson structure and organisation than deeper pedagogical issues.

Collaborative partnerships heightened the likelihood of successful pedagogical knowledge growth, particularly when there is, as purported by Loughran (2002), formal reflection focussed on practice. Formal, structured and, if possible, expert facilitation of reflective discussions, further enhances the level of pedagogical thinking and development. This is important as effective pedagogies in science are more likely to assist in developing science literacy and helping students gain an understanding of the nature of science.

Research Sub-question 4: What barriers are perceived to exist to increasing the priority of science in primary school classrooms?

The study showed that the barriers that prevented increased priority of science in primary school classrooms included significant concerns about accessing appropriate resources, and the time it takes to organise and set them up, findings consistent with those of Appleton and Kindt (1999), Goodrum et al. (2001), Keys (2005) and Levitt (2001). Curriculum constraints were also significant factors recognised by both practising and preservice teachers which is consistent with Appleton's (2003) and Goodrum et al.'s (2001) reports identifying the impact of an overcrowded curriculum on the frequency of primary science teaching. These were the three most significant issues, which, if able to be resolved or improved, would likely see an increase in the frequency of primary science teaching.

Increases in background knowledge and confidence were highlighted mostly by preservice teachers. The predominance of preservice over practising teachers responding in this way is likely to be compromised by the fact that most of the participating practising teachers already felt competent in their science teaching and ability. Other research indicates that practising teachers' lack of background knowledge and confidence is a serious factor affecting the level of primary science teaching (e.g. Appleton, 2003; Goodrum et al., 2001).

Overarching Research Question: What is the impact of collaborative partnerships between preservice and practising teachers, using a model of critical reflection for action, on the knowledge, self-efficacy beliefs, and attitudes of teachers towards teaching and learning of science in primary schools?

The study shows that the impact of collaborative partnerships on preservice and practising teachers' knowledge, self-efficacy beliefs and attitudes towards science is moderate to significant. It is can clearly be a successful model in providing a supportive professional learning experience for both practising and preservice teachers. When collaborative, partnerships are successful in helping both practising and preservice teachers develop confidence in teaching science, and the experience in the authentic setting helps them realise the impact it has on children's engagement in learning. Collaborative partnerships enhance attitudes towards science through the exposure they give both practising and preservice teachers to the effect of science teaching in the classroom and the links science has to the real world.

The study shows that collaborative partnerships help practising and preservice teachers develop deeper understanding of science-specific pedagogies, particularly when formal reflection on practice is achieved. Expert facilitation of reflection further helps develop preservice teachers' understanding of science pedagogy. The authentic experience also assists preservice teachers to develop insights into general ideas that are important in science teaching, such as accessing and organising equipment, the importance of trialling experiments prior to classroom delivery, and how to integrate science with other areas of the curriculum.

The few insights gained through this study regarding integration of science with other curriculum areas are useful as a part solution to the challenge already discussed concerning how curriculum constraints present a barrier for the wider implementation of primary science teaching. This barrier is emphasised as an issue by ASTA (2005). ASTA notes that while educators associate the delivery of literacy and numeracy with the teaching of English and mathematics, they fail to recognise the opportunities that other curriculum areas offer to deliver literacy and numeracy outcomes and standards, particularly science. The practice some of the partnerships had in explicitly planning for integration in their science lessons should help develop greater integration of these areas in future. This is evidenced by preservice teachers in particular who referred specifically to integration when responding to how the partnership experience had impacted on the frequency with which they intend to teach science. This illustrates the potential that exists for equipping preservice teachers and potentially their practising teacher partners with the experience of integration when teaching science.

The study showed that collaborative partnerships are of significant importance for developing self-efficacy beliefs, particularly when preservice teachers come with very low levels of science confidence. The more collaborative the partnerships are, the greater the impact on developing personal self-efficacy beliefs and knowledge. Collaboration utilises the ideas of two or more people and allows for mutual responsibility for developing and executing these ideas in the classroom. Insight into their effectiveness is thus something that can be appreciated fully by both partners which in turn enhances the authenticity of the reflection and the ownership of ideas for improvement. It removes the 'blame game' where preservice and supervising teachers blame one another for short-comings in the teaching experience that can sometimes detract from reflective practice and thus the opportunity to learn. It is also the factor that helps preservice teachers feel that they are regarded as a teacher, contributing efficacy-building experiences.

Collaborative partnerships help to bridge the gap between theory and practice by providing a combination of reflection on theory and experiential learning in the classroom, something recognised as important in the scholarship of teaching by a range of teacher education researchers (e.g. Darling-Hammond, 2006; Korthagen, 2001; Kreber and Cranton, 2000; Loughran, 2002; 2006, 2010). They achieve this further through the close link established between the university and classroom experiences which is necessary for effective preservice professional experience (Zeichner, 2002) and for the effectiveness of teachers emerging from the system (Darling-Hammond, 2000b).

Collaborative partnerships allow for an authentic experience of science teacher education that is consistent with Bigg's (2003) and Ramsden's (2003) 'deep approaches', focussing on what and how preservice teachers learn rather than what they remember. Assessment closely aligned with the experience further helps achieve the deep approaches purported by these authors. The reflective component of partnerships also encourages thinking about 'why' rather than 'what' is being done, that Parsons and Stephenson (2005) argue for to improve the professional experience. They also help to remove the solitary nature of teaching Parsons and Stephenson tell us that placements can sometimes confer.

Collectively, these significant factors indicate that collaborative partnerships offer an excellent opportunity for enhancing the profile and effectiveness of science teaching in primary schools. They also indicate that collaborative partnerships contribute to efficacy-building opportunities, and provide a basis for general, and even more so, pedagogical learning in science.

A number of recommendations also emerged from the study that might further enhance the impact of collaborative partnerships as a model of science professional learning for practising and preservice teachers. These are outlined in the following section.

6.3 Recommendations

Recommendations linking to and stemming from the present study are presented in this section in three ways. Firstly the recommendations made explicitly by the practising and preservice teacher participants are provided regarding the collaborative partnership model. Linking to and building on these, along with additional insights from my own perspective, are a set of researcher recommendations. Lastly, recommendations for further research are presented followed by a final, personal reflection.

Recommendations from Practising and preservice teacher Participants' Perspective

Recommendations were made by practising and preservice teachers based on what they believed would maximise the potential for science professional learning and education using a collaborative partnership model. A number of these recommendations were similar in nature. For example, both cohorts felt that the preservice teachers involved should be volunteers, recommending against making a program like this compulsory. However, if this model does provide an effective insight into science education and raises the likelihood of primary teachers' inclusion of science in their programs, then it should be something all preservice teachers experience.

Promoting equality within the partnership and recognising that success is dependent on willingness to share and contribute in a collaborative manner were also key factors identified by each cohort. Practising teachers also highlighted the need for optimism, imagination and innovation for effective professional learning to occur and recommended that teachers in need of science professional learning be targeted. Preservice teachers highlighted the need for supportive process, clear expectations and access to resources along side their clear message that the experience needed to be collaborative and positive for their learning to be effective.

Both practising and preservice teachers identified a need for more time and closely linked to this, practising teachers further identified the need for more notice ahead of the commencement of the partnership period. Similarly, preservice teachers indicated that earlier planning was needed. These recommendations relate to the lead-in time and organisation of the project with schools and the duration of time spent involved in the classroom experience.

Recommendations from the Researcher's Perspective

The study revealed a number of areas as needing improvement. These have informed a number of important recommendations from my perspective, including such as organisation of the project, more focussed targeting of practising teacher participants, providing more time in the partnerships, and strategies for enhancing the planning, and even more so, more focussed reflection in partnerships to ensure better learning outcomes.

There were occasional instances of tensions in partnerships which raised the question of how partners are matched. Murphy and Beggs (2006) warn of the difficulty in enacting equal responsibility in collaborative partnerships (or what they describe as co-teaching). They encourage both a shared establishment of the design of the partnership expectations and strongly recommend that participants sign a ‘code of practice’ type of agreement prior to commencing the co-teaching experience. Given the positive responses most partnerships in this study and the strong relationships and levels of collaboration that were achieved within them, this would appear to be unnecessary. Involving a large number of people in the design of expectations would be invasive of time and largely unrealistic. It would also make it difficult to reproduce in different research contexts if it was established as a required practice, as different cohorts may establish different guidelines for collaboration on the planning, implementing and reflecting stages of the framework. Requiring participants to sign a code of practice may also create feelings of participants' professional practice being undermined. The results from most partnerships indicate that collaborative practice can be achieved without these pre-emptive actions. However, the importance of shared understanding of the collaborative practice should not be under-estimated, as two of the non-collaborative partnerships in this study clearly highlights.

Time was identified as the most significant limitation of the present study and the experience of the project highlighted a number of ways its level of impact could be reduced. An early timeframe for organising the project and recruiting participants is recommended to help address the difficulty in recruiting sufficient number of practising teacher partners and the organisation of the project in order to allow for appropriate and sufficient lead-in time.

Alongside this, it is recommended that the researcher/unit lecturer is directly responsible for recruiting practising teachers into a project such as this to better ensure that accuracy of information is communicated to participants. This should overcome some of the issues with non-collaborative partnerships that emerged in the present study. Further difficulties in recruiting appropriate teachers may still be met given the nature of the model which involves working with a university-based science education expert.

High and clear expectations of written planning and reflection need to be implemented. For example, the planning and reflection booklet used in the present study was introduced to participants as a tool that 'might help' rather than as a compulsory item to be submitted as a part of preservice teachers' coursework. It is recommended that the planning and reflection book, or a similar tool, be made a compulsory item, linked to preservice teacher assessment. Increased expectations such as this would add rigour to the project and also increase the achievement of more significant pedagogical growth for partners. This would in turn, help overcome the descriptive nature of the reflection and encourage it to be approached as a more analytical task, as Parsons and Stephenson (2005) warn. Raising expectations would also increase the level of interaction required between partners which would achieve higher levels of learning. This is important, considering that Lord (1997) and Biggs (2003) note that learning is linked to the level of interaction of peers. In establishing future partnerships, participants could also be alerted to the issues of finding common time for planning and reflection and this is better planned to occur either side of the implementation of lessons, and incorporated into partnerships' planning.

As preservice teachers gained more learning than practising teachers through their participation in online and, in particular, round table discussions, indicating the importance of collegial reflection, (as acknowledged by Loughran (2002)), it suggests that including practising teachers in facilitated discussion would increase their learning opportunities and their grasp of science-specific pedagogy. It is recommended that such an approach be trialled with groups of partnerships so that mixes of practising and preservice teachers are present for the round table or conducted with separate cohorts.

The study suggested that involvement in a partnership experience with practising teachers is best conducted in the later years of preservice teachers' course, to ensure that a stage of readiness for reflective practice on pedagogy that requires confidence and competency in the more basic components of lesson delivery, classroom and behavioural management and general lesson planning skills, is more likely to be in place. This links to Loughran's (2006) assertion that learning about practice is driven from what preservice teachers are "ready to attend to" (p. 147). This can also be extended to ideas of professional readiness of practising teachers. Pedagogical content knowledge growth is more likely to occur for those who already have some confidence in both their content knowledge and to deliver science to ensure their thinking moves beyond just surviving the lesson into effective practice to optimise learning.

There is also need for a longer duration of time in the classroom. Preservice teachers who were floundering with basic survival in their science lessons were only beginning to develop capacity to start thinking about pedagogy, when the project concluded. A longer duration would also better address the need for ongoing professional development, a critical factor recognised by Ingvarson et al. (2005) and purported by Garet et al. (2001) as the most significant contributor to effective and lasting professional learning.

Increasing classroom time would also enable partnerships to move beyond the Engage, Explore, Explain phases of the 5Es framework more successfully. The Elaborate phase in particular, was poorly implemented by the majority of partnerships. This meant that the issue of leading student designed instead of teacher-directed investigation, as identified by Goodrum et al. (2001) still presented as an issue in this research. Requiring partners to implement all stages of the 5Es was an attempt to help address this issue. The short time for implementing cycles contributed to its limited success.

Approaches to supporting partnerships to find coinciding time is also needed for effective partnerships and learning. Accommodating the timing of the university semester and the school term dates was a difficult issue. It may be that volunteers in the university program would need to be willing to commence preparatory work prior to the official commencement of the unit, to accommodate this. This is one of the more difficult problems to resolve, particularly if a project like this were to be embedded in a university unit rather than just be available for volunteers from the total preservice teacher cohort studying the unit. Clearly the most significant factor in addressing this issue in future is the early organisation and identification of schools and practising teachers.

Ongoing discussion with practising teachers and principals since the project was implemented has led to the realisation that schools normally plan their curriculum focus for each term in Term 4 of the preceding year. Most Victorian primary schools have dedicated blocks of time for literacy and numeracy in the morning, and in some schools it is mandated that these blocks be delivered at these times. As well, a number of primary schools report specialist subject days to be Wednesdays, Thursdays or Fridays. This information is useful to support planning and organisation of timetables to better ensure enough coinciding time is available for preservice teachers to be able to visit schools for the action-reflection cycles. It is recommended that if a similar model were to be adopted in other teacher education programs, similar investigation into the local schools' needs and availability is conducted well in advance to ensure smoother organisation, planning and running of the program.

Access to resources, finding time to organise them and set them up and general curriculum constraints were all highlighted as barriers for practising and preservice teachers' science teaching. Addressing these issues is beyond the scope of this study, as they are factors that only curriculum policies and government or private funding can address. University partnerships may be able to alleviate some of the problems with accessing resources, as was the case in the present study, but this would not be possible on a wide scale and would introduce further complications such as responsibility for maintenance and safety, linking to occupational health and safety concerns.

If science is the priority in education espoused by government, support for overcoming these major barriers is necessary. Funding for laboratory equipment and general staff to support organisation is needed in primary schools in a similar way to how this is already recognised and supported in most secondary schools. Regional hubs, where equipment and support could be accessed from a point central to a particular region could assist this process in a more cost effective way. This would require the establishment of equipment-borrowing schemes and science officers who could provide designated days in schools local to the region. Science coaches, already supported by the government are another strategy, but at present these tend to be limited to particular schools for limited periods of time. A solution that is on-going and widely accessible is required.

In some ways, the curriculum constraints issues are being recognised by government education policies with science being mandated for reporting to parents in Victorian schools from Grade 3 and upwards as of 2009. This should increase the frequency with which science is taught in middle and upper Victorian primary schools, but does not address lower primary science education. The move to National Curriculum in 2011 could support a more consistent approach across Australia once debates around the nature and extent of science for primary school education are settled, and levels of required reporting are determined.

What is not addressed by these potential solutions is the issue of teacher background knowledge and efficacy, two significant barriers addressed by preservice teachers in this project and recognised in the literature as an issue for practising teachers. These issues were not as prevalent in the barriers listed by practising teachers, but the cohort of practising teachers in this particular study were already generally experienced and confident in science. Broader research has, however, identified the significant impact lack of science knowledge and efficacy has on the inclusion of science in primary education (e.g. Goodrum, et al, 2001). Any solutions to improving access to resources and support must also consider the need for GCK and PCK support. To achieve this it is recommended that professional learning programs be established through partnerships with teacher education institutions to ensure a more widespread expectation and avenue exists for both preservice and practicing teachers to access quality, authentic science professional learning.

Generally there appears to be a number of solutions to the barriers participants in this study list, which align with those identified in other research. Co-ordinated approaches between schools, universities and governments to ensure time, money, priority and appropriate learning support structures are in place can overcome the current barriers impeding a higher level of science teaching and its effectiveness in primary school settings.

With all of these factors contributing to the growth in practising and preservice teachers' science professional learning, it can be difficult to ascertain how important the actual partnership is in the mix. However, in this study, the partnerships that were collaborative clearly yielded greater evidence of pedagogical thinking and growth in pedagogical knowledge, and greater increases in self-efficacy beliefs, signifying they are certainly a contributing factor. A model such as the one reported on in this project that provides a period of time dedicated to science teaching and thinking that can help to address all areas of concern in regard to enhancing teachers' willingness and ability to teach science effectively.

This leads to the final recommendation: the use of collaborative partnerships over other models of practising and preservice teacher partnerships is recommended for practising and preservice teacher professional learning, particularly those dedicated to learning in science education. Collaboration between partners better supports each person in seeking important successful, mastery experience (Bandura, 1977), particularly if confidence is low as is often the case in science. Collaboration better utilises the human resources and expertise in the classroom and allows for a greater chance of shared reflection and thus growth in understanding science specific pedagogies. Careful planning and a high level of involvement from the research/university lecturer can help to ensure that partnerships do operate collaboratively.

Recommendations for further research

A number of key areas for further research emerge from the present study. The collaborative partnership model needs to be tested with a wider pool of participants. In particular, further research into the benefits for practising teachers is needed, and this needs to involve practising teachers who are in need of science professional learning and efficacy building.

An investigation into whether the model is achievable and beneficial if made compulsory in science teacher education units, rather than voluntary, is also required. This would help research-based decisions to be made about how projects such as this one should be offered.

The impact of extending the length of time partnerships are involved in action-reflection cycles also needs to be explored further. This would enable researchers to see whether deeper and more accurate knowledge development would occur in both general content and pedagogical knowledge areas. Involving practising teachers in reflection networks, preferably expert facilitated, could also be examined as a factor for enhancing learning and experience.

Finally, a longitudinal study into the level of lasting impact experience in a program such as this has on ongoing science teaching is needed. Research funding and time is needed to explore these factors further.

Final Reflection

The experience as a lecturer and a researcher in this project has been a rewarding and empowering one. I have become a firm believer in the need for mastery experiences in authentic classroom settings as a fundamental need in science teacher education courses. Never have I witnessed so many ‘ahhhh’ moments from preservice teachers as ‘the penny drops’ as I did in round table discussions with this cohort. This has also firmly cemented my belief in the need for expert-facilitation in teacher education and never again will I entertain the idea that an apprentice-based model of teacher preparation, on its own, has some merit. The importance of both the university and the school in providing a nexus between theory and practice, have become core in my belief regarding the achievement of effective teacher preparation and professional learning.

Despite the risks this study presented in regard to forming successful collaboration between practising and preservice teachers, the findings have also engendered my belief that collaborative partnerships are among the most effective ways of addressing issues of science professional learning and professional experience for preservice teachers. I look forward from here, to managing the challenges and improving the process, so my preservice science teaching improves further and my preservice teachers experience success in science teaching that I hope translates to better and more frequent and effective learning experiences for children that is so direly needed.

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Appendix 1: Information Letters

INFORMATION LETTER TO TEACHER PARTICIPANTS

TITLE OF PROJECT: THE INFLUENCE OF COLLABORATIVE PARTNERSHIPS IN SCIENCE TEACHER EDUCATION AND PROFESSIONAL DEVELOPMENT ON THE ATTITUDES, CONFIDENCE AND SELF-EFFICACY OF PRE-SERVICE AND PRACTISING TEACHERS TOWARDS THE TEACHING OF PRIMARY SCHOOL SCIENCE.

NAME OF SUPERVISOR: CAROLINE SMITH

NAME OF STUDENT RESEARCHER : MELLITA JONES

PROGRAMME IN WHICH ENROLLED: Ph.D

Dear Participant,
You are invited to participate in a project which is being undertaken as part of a PhD study for Mellita Jones. The purpose of the project is to investigate the influences of collaborative partnerships between pre-service and practising teachers on attitude, confidence and self-efficacy towards the teaching of primary school science, and thus provide insights into what makes science teacher learning effective.

The study is associated with the second semester unit, EDST201 Science and Technology Education, for third year Bachelor of Education students in semester two of the university calendar. Participants will be asked to complete a confidential questionnaire at the beginning and end of the research period. From this cohort, a group of 10-15 student volunteers will be asked to participate in a part school - part university based, learning experience. These participants will be partnered with volunteer practising teachers and will spend 5 weeks working part time in schools, with some tutorial time given in lieu of this.

Teacher participants will be asked to attend a two hour workshop at the beginning of the study and then work in their classrooms with pre-service teachers for the following 5 weeks. Pre-service teachers will be expected to be in schools for approximately 2 hours per week. The researcher will request interviews with teacher and pre-service participants and with consent; these will be digitally recorded as part of the data collection process.

All data collected will be kept confidential and code names will be used in reporting on data to ensure individual participants can not be identified.

The school based experience will see pre-service teachers working collaboratively with practising teachers to plan, implement and reflect on the teaching of Science and/or Technology outcomes linked to other areas of the curriculum (literacy, numeracy, arts, etc). The university based experience will cover theories and pedagogies of teaching in Science and Technology through lectures, and round table discussions about the school experience in the tutorial sessions held every third week in order to support the teaching experience. Participants will be asked to complete a reflective booklet outlining their planning and reflection sessions in the schools.

Pre-service teachers involved in the research will have the same assessment tasks as the rest of the third year cohort enrolled in the unit. This assessment includes two tasks: a research assignment centred around an excursion venue or classroom project for the teaching of Science and Technology, and a lesson plan and reflection on lessons. School based participants may use lessons and reflections from their school experience.

There are no foreseeable risks beyond normal day-to-day living associated with your participation in this project. Where the research may cause distress, the student counsellor at Australian Catholic University will be available, as will the Head of School of Education if any other matters of concern should arise.

Teacher participants stand to benefit from this experience by extending their Science and Technology teaching experience and in doing this, work collaboratively and reflectively with pre-service teachers. Previous study has shown that this creates a more relaxed environment for teachers and pre-service teachers to work together without the pressure of having to assess pre-service teacher performance all of the time. It will also provide an opportunity to be involved in reflective practice and the strengthening of practice in integrating science outcomes across the curriculum. The findings from this research have the potential to shape teacher education in the future. It is likely that findings from this study will be published in journals and presented at conferences, although the identity of participants will be kept confidential at all times on these occasions.

Participation in this study is voluntary and you can choose not to participate or to withdraw from participation at any time during the project without having to give a reason nor justify that decision. However, it will not be possible to withdraw questionnaires once they are submitted due to the anonymous nature of these.

Confidentiality will be ensured during the conduct of the research and in any report or publication arising from it.

Any questions regarding this project should be directed to the Principal Investigator/ Supervisor or the Student Researcher

Dr. Caroline Smith
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School of Education
Australian Catholic University
St. Patrick's Campus
Locked Bag 4115*.*
Fitzroy, VIC, 3065.

Mellita Jones
Ph. (03) 5336 5372
School of Education
Australian Catholic University
Aquinas Campus
PO Box 650,
Ballarat, 3353.

A summary report of the project findings will be available online at the website of Mellita Jones for participants to access on completion of data analysis by accessing http://my.acu.edu.au/staff/organisation/staff_directory/ .

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Please note that this study has been approved by the Human Research Ethics Committee at Australian Catholic University.

In the event that you have any complaint or concern about the way you have been treated during the study, or if you have any query that the Investigator or *Supervisor and Student Researcher has (have) not been able to satisfy, you may write to the Chair of the Human Research Ethics Committee care of the nearest branch of the Research Services Unit.*

VIC: Chair, HREC
C/o Research Services
Australian Catholic University
Melbourne Campus
Locked Bag 4115
FITZROY VIC 3065
Tel: 03 9953 3158
Fax: 03 9953 3315

Any complaint or concern will be treated in confidence and fully investigated. The participant will be informed of the outcome.
If you agree to participate in this project, you should sign both copies of the Consent Form, retain one copy for your records and return the other copy to the Principal Investigator/Supervisor or *Student Researcher.*

………………………………………. ……………………………………….
Principal Investigator/Supervisor Student Researcher

INFORMATION LETTER TO PRE-SERVICE TEACHER PARTICIPANTS

TITLE OF PROJECT: THE INFLUENCE OF COLLABORATIVE PARTNERSHIPS IN SCIENCE TEACHER EDUCATION AND PROFESSIONAL DEVELOPMENT ON THE ATTITUDES, CONFIDENCE AND SELF-EFFICACY OF PRE-SERVICE AND PRACTISING TEACHERS TOWARDS THE TEACHING OF PRIMARY SCHOOL SCIENCE.

NAME OF PRINCIPAL SUPERVISOR: CAROLINE SMITH

NAME OF STUDENT RESEARCHER : MELLITA JONES

PROGRAMME IN WHICH ENROLLED: PhD

Dear Participant,
You are invited to participate in a project which is being undertaken as part of a PhD study for Mellita Jones. The purpose of the project is to investigate the influences of collaborative partnerships between pre-service and practising teachers on attitude, confidence and self-efficacy towards the teaching of primary school science, and thus provide insights into what makes science teacher learning effective.

The study is associated with the second semester unit, EDST201 Science and Technology Education, for third year Bachelor of Education students in semester two of the university calendar. Participants will be asked to complete a confidential questionnaire at the beginning and end of the research period. From this cohort, a group of 10-15 student volunteers will be asked to participate in a part school - part university based, learning experience. These participants will be partnered with volunteer practising teachers and will spend 5 weeks working part time in schools, with some tutorial time given in lieu of this.

Teacher participants will be asked to attend a two hour workshop at the beginning of the study and then work in their classrooms with pre-service teachers for the following 5 weeks. Pre-service teachers will be expected to be in schools for approximately 2 hours per week. The researcher will request interviews with teacher and pre-service participants and with consent; these will be digitally recorded as part of the data collection process.

The school based experience will see pre-service teachers working collaboratively with practising teachers to plan, implement and reflect on the teaching of Science and/or Technology outcomes linked to other areas of the curriculum (literacy, numeracy, arts, etc). The university based experience will cover theories and pedagogies of teaching in Science and Technology through lectures, and round table discussions about the school experience in the tutorial sessions held every third week. Participants will also need to complete a reflective booklet outlining their planning and reflecting sessions in the schools.

The assessment for the unit will be the same for university based participants, non-participants and the school based group. School based participants may use their school experience to inform the completion of these tasks. Full details of these tasks and their criteria will be available through the unit outline as normal.

There are no foreseeable risks beyond normal day-to-day living associated with your participation in this project. The time commitment required from participants has been minimised by marrying involvement in the research with the assessment and attendance for the EDST201 unit. Where the research may cause distress, the student counsellor will be available. If you become concerned at any time with academic matters associated with completing the unit, the Head of School will be available for consultation.

Participants stand to benefit from this experience by extending their professional experience in schools. This experience may be enhanced by the collaborative nature of their partnership with teachers. Previous study has shown that this creates a more relaxed environment for you to practice your planning and teaching skills in a realistic setting without the pressure of 'failing rounds'. The findings from this research also have the potential to shape teacher education in the future. It is likely that findings from this study will be published in journals and presented at conferences, although the identity of participants will be kept anonymous at all times on these occasions.

Participation in this study is voluntary and you can choose not to participate or to withdraw from participation at any time during the project without having to give a reason nor justify that decision. This will in no way impact on your ability to successfully complete this unit.

It will not be possible to withdraw questionnaires once they are submitted due to the anonymous nature of these.

Confidentiality will be ensured during the conduct of the research and in any report or publication arising from it.

Any questions regarding this project should be directed to the Principal Investigator/ Supervisor or the Student Researcher

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A summary report of the project findings will be available online at the website of Mellita Jones for participants to access on the completion of data analysis.

Please note that this study has been approved by the Human Research Ethics Committee at Australian Catholic University.

In the event that you have any complaint or concern about the way you have been treated during the study, or if you have any query that the Investigator or *Supervisor and Student*

Researcher has (have) not been able to satisfy, you may write to the Chair of the Human Research Ethics Committee care of the nearest branch of the Research Services Unit.

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Fax: 03 9953 3315

Any complaint or concern will be treated in confidence and fully investigated. The participant will be informed of the outcome.
If you agree to participate in this project, you should sign both copies of the Consent Form, retain one copy for your records and return the other copy to the Principal Investigator/Supervisor or *Student Researcher.*

……………………………………….	……………………………………
Principal Investigator/Supervisor	Student Researcher

CONSENT FORM

Copy for Participant

TITLE OF PROJECT: THE INFLUENCE OF COLLABORATIVE PARTNERSHIPS IN SCIENCE TEACHER EDUCATION AND PROFESSIONAL DEVELOPMENT ON THE ATTITUDES, CONFIDENCE AND SELF-EFFICACY OF PRE-SERVICE AND PRACTISING TEACHERS TOWARDS THE TEACHING OF PRIMARY SCHOOL SCIENCE.

NAME OF PRINCIPAL SUPERVISOR: CAROLINE SMITH

NAME OF STUDENT RESEARCHER: MELLITA JONES

I .... *(the participant)* have read (*or, where appropriate, have had read to me)* and understood the information provided in the Letter to Participants. Any questions I have asked have been answered to my satisfaction. I agree to participate in this 9 week study, working in collaborative partnerships with pre-service teachers, planning, implementing and reflecting on lessons that link Science and/or Technology outcomes with other areas of the curriculum. I understand that there may be questionnaires, reflective writing tasks and digital recording of discussions and interviews as a part of this involvement and that I can withdraw my consent at any time without comment. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way.

NAME OF PARTICIPANT: ....
(block letters)

SIGNATURE .... DATE ....

SIGNATURE OF PRINCIPAL INVESTIGATOR/ SUPERVISOR: ....
DATE:………………………..

SIGNATURE OF STUDENT RESEARCHER:...
DATE:.....................………

Appendix 2: Letter to Principals

Dear Principal,

The enclosed document outlines a research project that I am undertaking as a part of my PhD doctoral study at Australian Catholic University. The research is centred on primary Science education and examines a model of teacher professional development that intertwines with teacher education. The impetus for this research lies in my own passion for Science as well as my role as a Science teacher educator at Australian Catholic University, Aquinas campus.

In this research, I am investigating the use of collaborative partnerships between practising and preservice teachers as they plan, implement and reflect on integrated Science lessons. I am interested in evaluating the collaborative partnership as a model of professional development and teacher education, particularly looking at its impact on confidence, attitudes and pedagogical knowledge of Science. I will be drawing on Mark Hackling and Vaughn Prain's resource Primary Connections, recently developed through the Australian Academy of Science, which links Science and Literacy outcomes. This resource draws on the 5Es of constructivism (Engage, Explore, Explain, Elaborate, Evaluate) which has similarities to Murdoch's stages of inquiry: 'Tuning In, Finding Out, Sorting Out, Going Further, Reflecting and Acting'.

I am hoping that you may have staff who are interested in participating in this project. Teachers' involvement essentially requires attendance at two afternoon workshops, completion of an initial and final questionnaire, the possibility of 1-2 interviews and the partnering with preservice teachers over a seven week period (Term 3) to plan, implement and reflect on integrated Science lessons, using a 5Es approach. See attached pages for further information.

Preservice teachers are involved through a Third Year, Bachelor of Education, Science and Technology Education unit at Australian Catholic University, Ballarat campus. They will have assessment requirements associated with their involvement and will be given 10 hours of unit contact time in lieu of their school based experience.

I would like to stress that teachers will not be acting as supervisors of preservice teachers, but rather, a collaborative partnership will be emphasised. Details of expectations of both practising and preservice teachers who are involved are attached.

Professional Development certificates issued by Australian Catholic University in conjunction with the Ballarat Catholic Education Office will be awarded to participants, recognising 6 hours of Professional Development in Science.

I hope you are able to be involved in this opportunity. If you have staff who are interested, could you please let me know by Wednesday, August 8, 2007. If you would like any further information, please do not hesitate to contact me at Australian Catholic University on 5336 5372 or mobile: 0417 415654 or by email: mellita.jones@acu.edu.au .

Looking forward to working with you,

Yours faithfully,

Mellita Jones
Science and Mathematics Education
Australian Catholic University.

Collaborative Partnerships between Preservice and Practising Teachers in Science Education

PhD Research by Mellita M. Jones
Science and Mathematics Education
Australian Catholic University

<u>Proposal RE Science Education Research Project</u>

Overview:

- 10-12 Teachers from Ballarat Primary schools, partnered with 10-12 preservice teachers from Australian Catholic University, Ballarat campus (3rd Year BEd) working part-time in schools;
- Partners to collaboratively plan, implement and reflect on integrated Science lessons using a 5Es (Engage, Explore, Explain, Elaborate, Evaluate) constructivism approach;
- Primary Connections resource linking Science and Literacy Outcomes will be introduced as a model;
- Changes in confidence and knowledge about Science teaching to be explored as a result of these collaborative partnerships. Collaborative Partnership model to be evaluated.

Expectations of Participating Teachers:

- Attend 2 afternoon workshops
    1. <u>Thursday August 16, 4.00pm – 6.00pm</u>:
       PD in 5Es constructivism model and reflective practise
    2. <u>Thursday, October 18, 4.00pm – 6.00pm</u>
       Reflective Evaluation of Model and Science Learning
- Complete an initial and final questionnaire measuring self-efficacy beliefs about teaching Science
- Work collaboratively with students to plan, implement and reflect on a minimum of 5 integrated Science lessons spanning a 5 week period (Week beginning Aug 20, for the reminder of Term 3)
  nb. A template for planning/reflection will be provided. Reflection can be through discourse. Preservice teacher will have to provide a summary of the reflective discourse to university lecturer.

A professional development certificate recognising 6 hours of Science professional development will be awarded to participants.

In addition to this, I will be looking for 5 teachers from the cohort who would be willing to be part of some case-study research, with their preservice teacher partners. This will involve 1 to 2 semi-structured interviews with the researcher during the 8 week period.

Expectations of Participating Preservice Teachers:

- Attend all lectures and some tutorials in EDST201 Science and Technology Education; the unit the research is attached to.
- Attend the workshop sessions with participating teachers (Aug 16 and Oct 18)
  This is in lieu of their tutorials for these weeks.
- Plan, implement and reflect on a minimum of 5 integrated Science lessons with their teacher partners over a 7 week period (Week beginning Aug 20 – Week beginning Oct 15)
  (5 Weeks of tutorials are given as time in lieu of this)
- Report a summary of reflective discourse they enter with their teacher partners online each week.
- Complete and submit a lesson plan for one of the lessons implemented in schools with their teacher partner.

In addition to this, I will be looking for 5 teacher-preservice teacher partners from the cohort who would be willing to be part of some case-study research. This will involve 1 to 2 semi-structured interviews with the researcher during the 8 week period.

Nb. Preservice teachers would be in schools on a part time basis as they have other university commitments. The times in schools would be negotiated within individual partnerships.

Summary Timeline

School Term 3:
Week 4; Aug 16: 1st Afternoon Workshop; ACU, Aquinas; 4pm – 6.00pm
Week 5-10: Partnerships working in schools on integrated Science lessons.

School Holidays

School Term 4:
Week 1: Preservice teachers available if there is work to finish off in schools.
Week 2; Oct 18: Final afternoon workshop; ACU; 4.00pm – 6.00pm.

Appendix 3: Questionnaires

Science Research Project

Exploring Collaborative Partnerships as a Model for Science Teacher Professional Development and Science Teacher Education

Mellita M. Jones
Australian Catholic University

Semester 2
2007

Preservice Teacher Questionnaire

PRESERVICE TEACHER QUESTIONNAIRE

Attitudes and Confidence with Science

BACKGROUND DEMOGRAPHICS

Gender: M F (circle appropriate)

Age: ______

What course are you studying? B.Ed: ☐ B.Ed (GE): ☐

Are you studying : Part Time ☐ Full Time ☐

When did you enter your teaching course: Straight after Year 12 ☐ After a gap year ☐ As a Mature Age student? ☐

If you have entered the course as a mature age student, what did you do prior to studying teaching?

What year level did you study Science to in Secondary School?

Have you ever studied Science as an Undergraduate or Post Graduate Student? Indicate level.

How would you rate your confidence in teaching each of the following areas of Science?

Biological Science

Very High Average Very Low

Chemical Science

Very High Average Very Low

Earth & Space Science

Very High Average Very Low

Physical Science

Very High Average Very Low

How many Science lessons have you taught on professional experience? ____________

PRESERVICE TEACHER ATTITUDES TOWARD SCIENCE AND SCIENCE TEACHING

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.

SA	= Strongly Agree
A	= Agree
UN	= Uncertain
D	= Disagree
SD	= Strongly Disagree

1.	When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	**SA**	**A**	**UN**	**D**	**SD**
2.	I will continually find better ways to teach science.	**SA**	**A**	**UN**	**D**	**SD**
3.	Even if I try very hard, I will not teach science as well as I will most subjects.	**SA**	**A**	**UN**	**D**	**SD**
4.	When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach.	**SA**	**A**	**UN**	**D**	**SD**
5.	I know the steps to teach science concepts effectively.	**SA**	**A**	**UN**	**D**	**SD**
6.	I will not be very effective in monitoring science experiments.	**SA**	**A**	**UN**	**D**	**SD**
7.	If students are underachieving in science, it is most likely due to ineffective science teaching.	**SA**	**A**	**UN**	**D**	**SD**
8.	I will generally teach science ineffectively.	**SA**	**A**	**UN**	**D**	**SD**
9.	The inadequacy of a student's science background can be overcome by good teaching.	**SA**	**A**	**UN**	**D**	**SD**
10.	The low science achievement of some students cannot generally be blamed on their teachers.	**SA**	**A**	**UN**	**D**	**SD**
11.	When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher.	**SA**	**A**	**UN**	**D**	**SD**
12.	I understand science concepts well enough to be effective in teaching primary science.	**SA**	**A**	**UN**	**D**	**SD**
13.	Increased effort in science teaching produces little change in some students' science achievement.	**SA**	**A**	**UN**	**D**	**SD**
14.	The teacher is generally responsible for the achievement of students in science.	**SA**	**A**	**UN**	**D**	**SD**
15.	Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	**SA**	**A**	**UN**	**D**	**SD**
16.	If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.	**SA**	**A**	**UN**	**D**	**SD**
17.	I will find it difficult to explain to students why science experiments work.	**SA**	**A**	**UN**	**D**	**SD**
18.	I will typically be able to answer students' science questions.	**SA**	**A**	**UN**	**D**	**SD**
19.	I wonder if I will have the necessary skills to teach science.	**SA**	**A**	**UN**	**D**	**SD**
20.	Given a choice, I will not invite the principal to evaluate my science teaching.	**SA**	**A**	**UN**	**D**	**SD**
21.	When a student has difficulty understanding a science concept, I will usually be at a loss as to how to help the student understand it better.	**SA**	**A**	**UN**	**D**	**SD**
22.	When teaching science, I will usually welcome student questions.	**SA**	**A**	**UN**	**D**	**SD**
23.	I do not know what to do to turn students on to science.	**SA**	**A**	**UN**	**D**	**SD**

What are you hoping to achieve/obtain through your involvement in this project?

Science Research Project
Final Questionnaire

Exploring Collaborative Partnerships as a Model for Science Teacher Professional Development and Science Teacher Education

This is essentially the same questionnaire you completed at the beginning of the project. It is being used again to measure any changes that the partnership experience may have had on your attitudes and beliefs towards Science and its Teaching.

Mellita M. Jones
Australian Catholic University

Semester 2
2007

Preservice Teacher Questionnaire

PRESERVICE TEACHER QUESTIONNAIRE

Attitudes and Confidence with Science

BACKGROUND DEMOGRAPHICS

Gender: M F (circle appropriate)
Age: ______

When did you enter your teaching course: Straight after Year 12 ☐ After a gap year ☐ As a Mature Age student? ☐

How would you describe the level of collaboration in the partnership with the teacher you worked with for the following areas:

Planning:	☐High Collaboration	☐ Medium Collaboration	☐ Minimal Collaboration	☐ No Collaboration
Implementing:	☐ Team Teaching	☐ Some Team Teaching	☐ No Team Teaching	☐ Other _________
Reflecting:	☐Collaborative reflection on both our teaching/planning	☐ Collaborative reflection, mostly on my teaching/planning	☐ Teacher gave feedback, but reflection was on my own	☐ Other _________

How would you rate your confidence in teaching each of the following areas of Science after the project?

Biological Science

Very High — Average — Very Low

Chemical Science

Very High — Average — Very Low

Earth & Space Science

Very High — Average — Very Low

Physical Science

Very High — Average — Very Low

Has this unit had any impact on your level of confidence in how to teach Science?

Very High Impact — Average Impact — Very Low Impact

Has this unit had any impact on your level of knowledge about Science?

Very High Impact — Average Impact — Very Low Impact

How would you rate your understanding of 5Es and how to implement them in Science teaching?

Very High — Average — Very Low

How many Science lessons have did you teach in the Science Research Project experience? __

What did you achieve/obtain through your involvement in this project?

What would be needed to help you achieve more for your development as a Science teach in a project like this?

Has your involvement in this project influenced the frequency with which you intend to teach Science once in schools? If so, how?

List what you see as the barriers to your teaching Science?

PRESERVICE TEACHER ATTITUDES TOWARD SCIENCE AND SCIENCE TEACHING

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.

SA	= Strongly Agree
A	= Agree
UN	= Uncertain
D	= Disagree
SD	= Strongly Disagree

1.	When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	**SA**	**A**	**UN**	**D**	**SD**
2.	I will continually find better ways to teach science.	**SA**	**A**	**UN**	**D**	**SD**
3.	Even if I try very hard, I will not teach science as well as I will most subjects.	**SA**	**A**	**UN**	**D**	**SD**
4.	When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach.	**SA**	**A**	**UN**	**D**	**SD**
5.	I know the steps to teach science concepts effectively.	**SA**	**A**	**UN**	**D**	**SD**
6.	I will not be very effective in monitoring science experiments.	**SA**	**A**	**UN**	**D**	**SD**
7.	If students are underachieving in science, it is most likely due to ineffective science teaching.	**SA**	**A**	**UN**	**D**	**SD**
8.	I will generally teach science ineffectively.	**SA**	**A**	**UN**	**D**	**SD**
9.	The inadequacy of a student's science background can be overcome by good teaching.	**SA**	**A**	**UN**	**D**	**SD**
10.	The low science achievement of some students cannot generally be blamed on their teachers.	**SA**	**A**	**UN**	**D**	**SD**
11.	When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher.	**SA**	**A**	**UN**	**D**	**SD**
12.	I understand science concepts well enough to be effective in teaching primary science.	**SA**	**A**	**UN**	**D**	**SD**
13.	Increased effort in science teaching produces little change in some students' science achievement.	**SA**	**A**	**UN**	**D**	**SD**
14.	The teacher is generally responsible for the achievement of students in science.	**SA**	**A**	**UN**	**D**	**SD**
15.	Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	**SA**	**A**	**UN**	**D**	**SD**
16.	If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.	**SA**	**A**	**UN**	**D**	**SD**
17.	I will find it difficult to explain to students why science experiments work.	**SA**	**A**	**UN**	**D**	**SD**
18.	I will typically be able to answer students' science questions.	**SA**	**A**	**UN**	**D**	**SD**
19.	I wonder if I will have the necessary skills to teach science.	**SA**	**A**	**UN**	**D**	**SD**
20.	Given a choice, I will not invite the principal to evaluate my science teaching.	**SA**	**A**	**UN**	**D**	**SD**
21.	When a student has difficulty understanding a science concept, I will usually be at a loss as to how to help the student understand it better.	**SA**	**A**	**UN**	**D**	**SD**
22.	When teaching science, I will usually welcome student questions.	**SA**	**A**	**UN**	**D**	**SD**
23.	I do not know what to do to turn students on to science.	**SA**	**A**	**UN**	**D**	**SD**

Science Research Project

Exploring Collaborative Partnerships as a Model for Science Teacher Professional Development and Science Teacher Education

Mellita M. Jones
Australian Catholic University

Semester 2
2007

Teacher Questionnaire

TEACHER ATTITUDES TOWARD SCIENCE AND SCIENCE TEACHING

BACKGROUND DEMOGRAPHICS

Gender: M F (circle appropriate) Age: ______

For how many years have you been teaching? _________

What year level did you study Science to in Secondary School? __________

What is your highest level of qualification? ____

Have you ever studied Science as an Undergraduate or Post Graduate Student? YES NO
If yes, indicate level:

Certificate ☐ Diploma ☐ Bachelor ☐ Masters ☐ Doctorate ☐

Have you engaged in Professional Development in Science? YES NO

If yes, can you indicate the nature of the PD you have mainly engaged in:

☐ Series of workshops across one month or longer ☐ Workshop (Full day) ☐ Workshop (1/2 day) ☐ Workshop (2 hours or less)

☐ Other (please describe):

How many hours per week (on average) would you typically teach Science to the one class? _________

Is there a Science Coordinator at your school? YES NO

Is there access to funds or a specific budget for Science equipment in your school?

☐ Access to some funds if required ☐ Specific Science Budget ☐ No access to funds for Science equipment.

Is Science a part of your school reports to parents? YES NO

Have you ever applied the 5Es framework in teaching Science? YES NO

How would you rate your confidence in teaching each of the following areas of Science?

Biological Science Very High Average Very Low

Chemical Science Very High Average Very Low

Earth & Space Science Very High Average Very Low

Physical Science Very High Average Very Low

TEACHER ATTITUDES TOWARD SCIENCE AND SCIENCE TEACHING

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.

SA	= Strongly Agree
A	= Agree
UN	= Uncertain
D	= Disagree
SD	= Strongly Disagree

1.	When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	**SA**	**A**	**UN**	**D**	**SD**
2.	I am continually finding better ways to teach science.	**SA**	**A**	**UN**	**D**	**SD**
3.	Even when I try very hard, I don't teach science as well as I do most subjects.	**SA**	**A**	**UN**	**D**	**SD**
4.	When the science grades of students improve, it is most due to their teacher having found a more effective teaching approach.	**SA**	**A**	**UN**	**D**	**SD**
5.	I know the steps necessary to teach science concepts effectively.	**SA**	**A**	**UN**	**D**	**SD**
6.	I am not very effective in monitoring science experiments.	**SA**	**A**	**UN**	**D**	**SD**
7.	If students are underachieving in science, it is most likely due to ineffective science teaching.	**SA**	**A**	**UN**	**D**	**SD**
8.	I generally teach science ineffectively.	**SA**	**A**	**UN**	**D**	**SD**
9.	The inadequacy of a student's science background can be overcome by good teaching.	**SA**	**A**	**UN**	**D**	**SD**
10.	The low science achievement of some students cannot generally be blamed on their teachers.	**SA**	**A**	**UN**	**D**	**SD**
11.	When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher.	**SA**	**A**	**UN**	**D**	**SD**
12.	I understand science concepts well enough to be effective in teaching primary science.	**SA**	**A**	**UN**	**D**	**SD**
13.	Increased effort in science teaching produces little change in some students' science achievement.	**SA**	**A**	**UN**	**D**	**SD**
14.	The teacher is generally responsible for the achievement of students in science.	**SA**	**A**	**UN**	**D**	**SD**
15.	Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	**SA**	**A**	**UN**	**D**	**SD**
16.	If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.	**SA**	**A**	**UN**	**D**	**SD**
17.	I find it difficult to explain to students why science experiments work.	**SA**	**A**	**UN**	**D**	**SD**
18.	I am typically able to answer students' science questions.	**SA**	**A**	**UN**	**D**	**SD**
19.	I wonder if I have the necessary skills to teach science.	**SA**	**A**	**UN**	**D**	**SD**
20.	Given a choice, I would not invite the principal to evaluate my science teaching.	**SA**	**A**	**UN**	**D**	**SD**
21.	When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better.	**SA**	**A**	**UN**	**D**	**SD**
22.	When teaching science, I usually welcome student questions.	**SA**	**A**	**UN**	**D**	**SD**
23.	I don't know what to do to turn students on to science.	**SA**	**A**	**UN**	**D**	**SD**
24.	Effectiveness in science teaching has little influence on the achievement of students with low motivation.	**SA**	**A**	**UN**	**D**	**SD**
25.	Even teachers with good science teaching abilities cannot help some kids learn science.	**SA**	**A**	**UN**	**D**	**SD**

What are you hoping to achieve/obtain through your involvement in this project?

Science Research Project
Final Questionnaire

Exploring Collaborative Partnerships as a Model for Science Teacher Professional Development and Science Teacher Education

This is essentially the same questionnaire you completed at the beginning of the project. It is being used again to measure any changes that the partnership experience may have had on you're attitudes and beliefs towards Science and its Teaching.

Mellita M. Jones
Australian Catholic University

Semester 2
2007

<u>Teacher Questionnaire</u>

BACKGROUND DEMOGRAPHICS

Gender: M F (circle appropriate) Age: ______

For how many years have you been teaching? __________

How would you describe the level of collaboration in the partnership with the teacher you worked with for the following areas:

Planning:	☐ High Collaboration	☐ Medium Collaboration	☐ Minimal Collaboration	☐ No Collaboration
Implementing:	☐ Team Teaching	☐ Some Team Teaching	☐ No Team Teaching	☐ Other _________
Reflecting:	☐ Collaborative reflection on both our teaching/planning	☐ Collaborative reflection, mostly on my teaching/planning	☐ Teacher gave feedback, but reflection was on my own	☐ Other _________

How would you rate your confidence in teaching each of the following areas of Science?

Biological Science — Very High — Average — Very Low

Chemical Science — Very High — Average — Very Low

Earth & Space Science — Very High — Average — Very Low

Physical Science — Very High — Average — Very Low

Has this project experience had any benefits for your professional development in Science?

High Benefits — Some Benefits — No Benefits

Would you like to be involved in a partnership like this, with a Science focus, again?

☐ **Yes** ☐ **No**

Would you recommend a partnership like this to other teachers?

☐ **Yes** ☐ **No**

What did you achieve/obtain through your involvement in this project?

What would be needed to help you achieve more for your own professional development in a project like this?

Has your involvement in this project influenced the frequency with which you intend to teach Science from now on? If so, how?

List what you see as the barriers to increasing the priority of Science in your teaching?

TEACHER ATTITUDES TOWARD SCIENCE AND SCIENCE TEACHING

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.

SA = Strongly Agree
A = Agree
UN = Uncertain
D = Disagree
SD = Strongly Disagree

1.	When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	**SA**	**A**	**UN**	**D**	**SD**
2.	I am continually finding better ways to teach science.	**SA**	**A**	**UN**	**D**	**SD**
3.	Even when I try very hard, I don't teach science as well as I do most subjects.	**SA**	**A**	**UN**	**D**	**SD**
4.	When the science grades of students improve, it is most due to their teacher having found a more effective teaching approach.	**SA**	**A**	**UN**	**D**	**SD**
5.	I know the steps necessary to teach science concepts effectively.	**SA**	**A**	**UN**	**D**	**SD**
6.	I am not very effective in monitoring science experiments.	**SA**	**A**	**UN**	**D**	**SD**
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8.	I generally teach science ineffectively.	**SA**	**A**	**UN**	**D**	**SD**
9.	The inadequacy of a student's science background can be overcome by good teaching.	**SA**	**A**	**UN**	**D**	**SD**
10.	The low science achievement of some students cannot generally be blamed on their teachers.	**SA**	**A**	**UN**	**D**	**SD**
11.	When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher.	**SA**	**A**	**UN**	**D**	**SD**
12.	I understand science concepts well enough to be effective in teaching primary science.	**SA**	**A**	**UN**	**D**	**SD**
13.	Increased effort in science teaching produces little change in some students' science achievement.	**SA**	**A**	**UN**	**D**	**SD**
14.	The teacher is generally responsible for the achievement of students in science.	**SA**	**A**	**UN**	**D**	**SD**
15.	Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	**SA**	**A**	**UN**	**D**	**SD**
16.	If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.	**SA**	**A**	**UN**	**D**	**SD**
17.	I find it difficult to explain to students why science experiments work.	**SA**	**A**	**UN**	**D**	**SD**
18.	I am typically able to answer students' science questions.	**SA**	**A**	**UN**	**D**	**SD**
19.	I wonder if I have the necessary skills to teach science.	**SA**	**A**	**UN**	**D**	**SD**
20.	Given a choice, I would not invite the principal to evaluate my science teaching.	**SA**	**A**	**UN**	**D**	**SD**
21.	When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better.	**SA**	**A**	**UN**	**D**	**SD**
22.	When teaching science, I usually welcome student questions.	**SA**	**A**	**UN**	**D**	**SD**
23.	I don't know what to do to turn students on to science.	**SA**	**A**	**UN**	**D**	**SD**
24.	Effectiveness in science teaching has little influence on the achievement of students with low motivation.	**SA**	**A**	**UN**	**D**	**SD**
25.	Even teachers with good science teaching abilities cannot help some kids learn science.	**SA**	**A**	**UN**	**D**	**SD**

Appendix 4: Planning and Reflection Book

Collaborative Partnerships Implementing Science Education

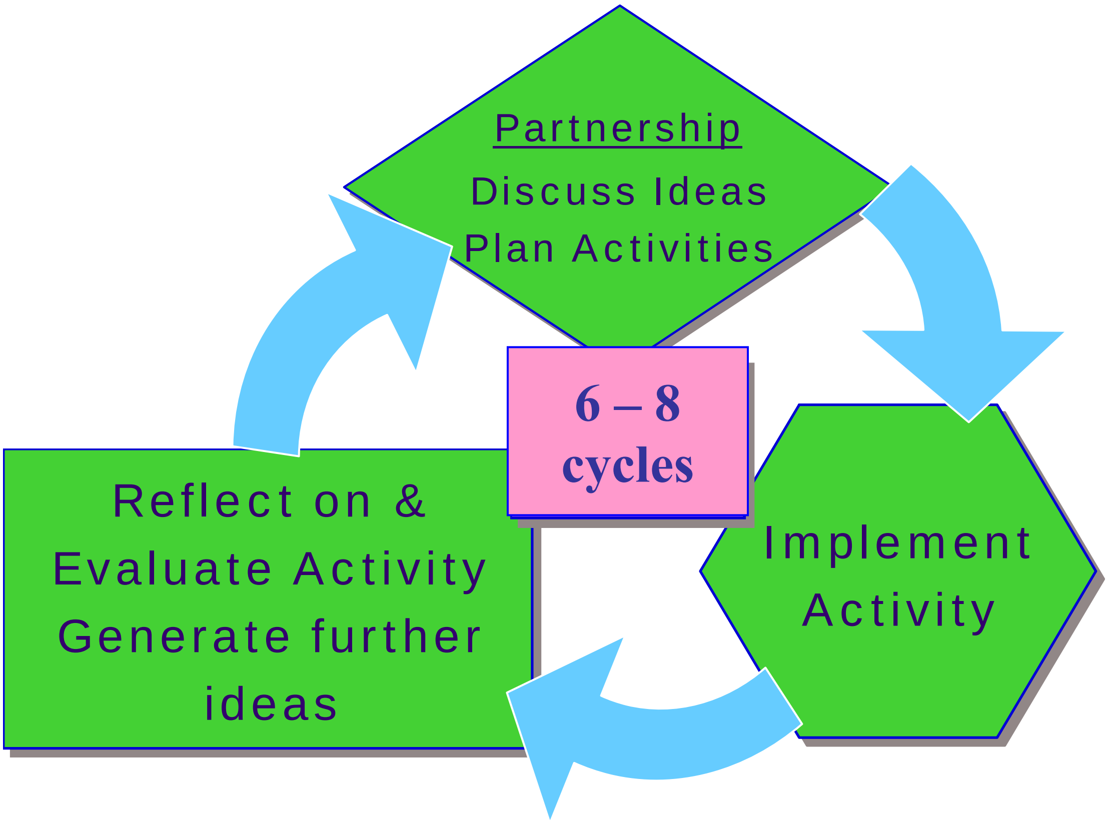
Planning and Reflection Booklet

To guide the planning and reflection on integrated Science Lessons.

Participant 1 and Participant 2

Example Primary School

Cycle of Planning, Implementing and Reflecting



Preservice teachers are responsible for summarising the planning and reflective discourse, conducted by partnerships, on a weekly basis on ACUOnline. This forms part of their assessment in the unit EDST201.

Queries/Comments to:
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Planner

	Day/Date	Venue	Time
Activity One Planning Meeting			
Implementation			
Reflection Meeting			
Activity Two Planning Meeting			
Implementation			
Reflection Meeting			
Activity Three Planning Meeting			
Implementation			
Reflection Meeting			
Activity Four Planning Meeting			
Implementation			
Reflection Meeting			
Activity Five Planning Meeting			
Implementation			
Reflection Meeting			
Activity Six Planning Meeting			
Implementation			
Reflection Meeting			
Activity Seven Planning Meeting			
Implementation			
Reflection Meeting			
Activity Eight Planning Meeting			
Implementation			
Reflection Meeting			

Notes Page:

Activity One Plan:

Activity Description (Include aspects of 5Es to be focussed on):

Areas of Integration and how integration is achieved:

Intended Duration (No. of Lessons; Length of each Lesson):

Teacher Role (In preparation/Implementation):	**Preservice Teacher Role** (In preparation/Implementation):

Resources required for activity:

How would you each rate your confidence about the Science involved in this lesson?

High **Medium-High** **Medium** **Medium-Low** **Low**

Activity One Reflection:

Was the intended stage(s) of the 5Es model successful? How?

Signs of successful learning from students:

Critical moment or incident in the lesson that could be a focus for improvement:

How might this be improved?

What changes have there been in your confidence, content knowledge or ideas about teaching Scinece as a result of this lesson?

Where on the continuum below would you rate these changes? (Teachers use X, Preservice teachers use ●)

Significant Improvement — No Change — Significant Reduction

Activity Two Plan:

Activity Description (Include aspects of 5Es to be focussed on):

Areas of Integration and how integration is achieved:

Intended Duration (No. of Lessons; Length of each Lesson):

Teacher Role (In preparation/Implementation):	**Preservice Teacher Role** (In preparation/Implementation):

Resources required for activity:

How would you each rate your confidence about the Science involved in this lesson?

High **Medium-High** **Medium** **Medium-Low** **Low**

What factors from previous activities have influenced planning in this activity?

Activity Two Reflection:

Was the intended stage(s) of the 5Es model successful? How?

Signs of successful learning from students:

Critical moment or incident in the lesson that could be a focus for improvement:

How might this be improved?

What changes have there been in your confidence, content knowledge or ideas about teaching Scinece as a result of this lesson?

Where on the continuum below would you rate these changes? (Teachers use X, Preservice teachers use ●)

Significant Improvement					No Change					Significant Reduction

Activity Three Plan:

Activity Description (Include aspects of 5Es to be focussed on):

Areas of Integration and how integration is achieved:

Intended Duration (No. of Lessons; Length of each Lesson):

Teacher Role (In preparation/Implementation):	**Preservice Teacher Role** (In preparation/Implementation):

Resources required for activity:

How would you each rate your confidence about the Science involved in this lesson?

High **Medium-High** **Medium** **Medium-Low** **Low**

What factors from previous activities have influenced planning in this activity?

Activity Three Reflection:

Was the intended stage(s) of the 5Es model successful? How?

Signs of successful learning from students:

Critical moment or incident in the lesson that could be a focus for improvement:

How might this be improved?

What changes have there been in your confidence, content knowledge or ideas about teaching Scinece as a result of this lesson?

Where on the continuum below would you rate these changes? (Teachers use X, Preservice teachers use ●)

Significant Improvement					No Change					Significant Reduction

Activity Four Plan:

Activity Description (Include aspects of 5Es to be focussed on):

Areas of Integration and how integration is achieved:

Intended Duration (No. of Lessons; Length of each Lesson):

Teacher Role (In preparation/Implementation):	**Preservice Teacher Role** (In preparation/Implementation):

Resources required for activity:

How would you each rate your confidence about the Science involved in this lesson?

High **Medium-High** **Medium** **Medium-Low** **Low**

What factors from previous activities have influenced planning in this activity?

Activity Four Reflection:

Was the intended stage(s) of the 5Es model successful? How?

Signs of successful learning from students:

Critical moment or incident in the lesson that could be a focus for improvement:

How might this be improved?

What changes have there been in your confidence, content knowledge or ideas about teaching Scinece as a result of this lesson?

Where on the continuum below would you rate these changes? (Teachers use X, Preservice teachers use ●)

Significant Improvement	No Change	Significant Reduction

Activity Five Plan:

Activity Description (Include aspects of 5Es to be focussed on):

Areas of Integration and how integration is achieved:

Intended Duration (No. of Lessons; Length of each Lesson):

Teacher Role (In preparation/Implementation):	**Preservice Teacher Role (In preparation/Implementation):**

Resources required for activity:

How would you each rate your confidence about the Science involved in this lesson?

High **Medium-High** **Medium** **Medium-Low** **Low**

What factors from previous activities have influenced planning in this activity?

Activity Five Reflection:

Was the intended stage(s) of the 5Es model successful? How?

Signs of successful learning from students:

Critical moment or incident in the lesson that could be a focus for improvement:

How might this be improved?

What changes have there been in your confidence, content knowledge or ideas about teaching Scinece as a result of this lesson?

Where on the continuum below would you rate these changes? (Teachers use X, Preservice teachers use ●)

Significant Improvement					No Change					Significant Reduction

Activity Six Plan:

Activity Description (Include aspects of 5Es to be focussed on):

Areas of Integration and how integration is achieved:

Intended Duration (No. of Lessons; Length of each Lesson):

Teacher Role (In preparation/Implementation):	**Preservice Teacher Role (In preparation/Implementation):**

Resources required for activity:

How would you each rate your confidence about the Science involved in this lesson?

High **Medium-High** **Medium** **Medium-Low** **Low**

What factors from previous activities have influenced planning in this activity?

Activity Six Reflection:

Was the intended stage(s) of the 5Es model successful? How?

Signs of successful learning from students:

Critical moment or incident in the lesson that could be a focus for improvement:

How might this be improved?

What changes have there been in your confidence, content knowledge or ideas about teaching Scinece as a result of this lesson?

Where on the continuum below would you rate these changes? (Teachers use X, Preservice teachers use ●)

Significant Improvement					No Change					Significant Reduction

Activity Seven Plan:

Activity Description (Include aspects of 5Es to be focussed on):

Areas of Integration and how integration is achieved:

Intended Duration (No. of Lessons; Length of each Lesson):

Teacher Role (In preparation/Implementation):	**Preservice Teacher Role** (In preparation/Implementation):

Resources required for activity:

How would you each rate your confidence about the Science involved in this lesson?

High **Medium-High** **Medium** **Medium-Low** **Low**

What factors from previous activities have influenced planning in this activity?

Activity Seven Reflection:

Was the intended stage(s) of the 5Es model successful? How?

Signs of successful learning from students:

Critical moment or incident in the lesson that could be a focus for improvement:

How might this be improved?

What changes have there been in your confidence, content knowledge or ideas about teaching Scinece as a result of this lesson?

Where on the continuum below would you rate these changes? (Teachers use X, Preservice teachers use ●)

Significant Improvement — No Change — Significant Reduction

Activity Eight Plan:

Activity Description (Include aspects of 5Es to be focussed on):

Areas of Integration and how integration is achieved:

Intended Duration (No. of Lessons; Length of each Lesson):

Teacher Role (In preparation/Implementation):	Preservice Teacher Role (In preparation/Implementation):

Resources required for activity:

How would you each rate your confidence about the Science involved in this lesson?

High **Medium-High** **Medium** **Medium-Low** **Low**

What factors from previous activities have influenced planning in this activity?

Activity Eight Reflection:

Was the intended stage(s) of the 5Es model successful? How?

Signs of successful learning from students:

Critical moment or incident in the lesson that could be a focus for improvement:

How might this be improved?

What changes have there been in your confidence, content knowledge or ideas about teaching Scinece as a result of this lesson?

Where on the continuum below would you rate these changes? (Teachers use X, Preservice teachers use ●)

Significant Improvement					No Change					Significant Reduction

Appendix 5: Interview Questions for Practising teachers

Appendix 5: Practising teacher Interview Questions

1. How did you approach the partnership?

2. What have been some of the highlights of the partnership? Can you say why?

3. What hasn’t worked as well as you would have liked? Can you say why?

4. Describe a typical planning session (look for evidence of collaboration and use of 5Es. Ask if/how these have factored if it doesn't come out).

5. What needs to happen for planning sessions to be improved?

6. Describe a typical post-lesson reflection (again look for evidence of collaboration as well as identification of an incident/key moment for improvement).

7. What would you need for reflection sessions to be improved?

8. Has this experience had any impact on your learning about Science? If so, how?

9. Has the 5Es framework had any impact on your approach to Science because of your involvement? If so, how? Which E’s in particular?

10. Could you describe any changes in your knowledge about Science or its teaching from this experience?

11. How are you feeling now about the partnership?

In our final workshop, scheduled for the 18th October, we will look at overall benefits/problems working in this manner and hopefully get you to share some of the things you have been doing. So before I go...

12. Is there anything else you would like to add or comment on?

Appendix 6: Round Table Discussion Frameworks

Round Table Discussion 1 - Week 6

1. Round the table: no more than 2 min each
- what school are you at?
- what are your impressions about the experience so far?

Structure for addressing Items 2 and 3 below:

a) Person 1 contributes their experience, focusing on the given question.
b) Others interject with similar experiences that had similar/different outcomes.
c) We try to identify causes of particular outcomes and think of ideas to better ensure desirable outcomes.
d) We move around the table to person 2 and repeat the process until everyone has had a turn.

2. **From one of the lessons you have been involved in, what was a critical incident/moment that you would like to improve on?**
    - Set the context of he lesson (what was intended)
    - Describe the incident/moment (what happened)
    - What factors may have contributed to the incident/moment (why did it happen)
    - What could we do differently next time?

3. **How do you feel the experience to date has help you build knowledge/understanding about Science or how to teach Science?**

4. **From one of the lessons you have been involved in, what is your biggest feeling of success to date?**
    - What made it successful? (luck, planning, prior experience, pre-empting, other?)

Round Table Discussion 2 - Week 10

1. How did you approach the partnership?
2. What have been some of the highlights of the partnership? Can you say why?
3. What hasn't worked as well as you would have liked? Can you say why?
4. Describe a typical planning session
5. What needs to happen for planning sessions to be improved?
6. Describe a typical post-lesson reflection
7. What would you need for reflection sessions to be improved?
8. What have you learnt through this experience?
   What have you learnt about Science?
9. How was the 5Es framework incorporated in your experience?
10. Could you describe any changes in your knowledge about Science or its teaching from this experience?
11. How are you feeling now about the partnership?
12. Would you be involved in something like this again? Would you recommend it to others?
13. How would you compare this experience with teaching rounds for your learning?
14. Is there anything else you would like to add or comment on?

Appendix 7: 5Es framework

Table A.8.1: The 5Es Framework

PHASE	DEFINITION
ENGAGE	Engage student and elicit prior knowledge. *Diagnostic assessment.*
EXPLORE	Provide hands-on experiences of the phenomenon. *Formative assessment*
EXPLAIN	Develop science explanations for observations and represent developing conceptual understandings. Consider current scientific explanations. *Formative assessment.*
ELABORATE	Extend understandings to a new context or make connections to additional concepts through student-planned investigations. *Summative assessment of the investigating outcomes.*
EVALUATE	Students represent their understanding and reflect on their learning journey and teachers collect evidence about the achievement of outcomes. *Summative assessment of conceptual outcomes.*

Australian Academy of Science, 2009, p. 9