Science and Mathematics Education Centre

NEW TRICKS FOR OLD HANDS: HOW EXPERIENCED PRIMARY TEACHERS INCORPORATE NEW SCIENCE CURRICULA INTO THEIR PRACTICE

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ABSTRACT

Primary teachers are constantly required to make changes in their teaching practice. This thesis reports on a year in the professional life of two experienced primary school teachers as they engage in implementing a new science program called *Primary Investigations* (Australian Academy of Science, 1994). The study examined the issues that arose as the two adapted the strategies and philosophies of the new program into their pre-existing pedagogical frameworks. The study used qualitative methods of data collection and analysis. Over ten months of participant observation several stories or narrative vignettes were created to highlight the major issues faced by the two teachers. These stories were then analysed to identify several propositions about curriculum implementation and primary science.

The narrative vignettes provide descriptive accounts around several implementation issues. The two teachers experienced some problems with the supply of equipment to support their teaching and lacked the subject knowledge to identify when the equipment was inadequate. The teachers had high expectations of the teachers' resource book but a lack of science content knowledge hindered their ability to use the document with confidence. While the teachers believed that science is important for children they lacked the confidence and questioning skill to engage the students in 'science talk'. The teachers were able to transfer pedagogical knowledge from other disciplines to overcome some of the dilemmas they faced in science lessons. Both teachers displayed a strong 'ethic of care' for the children in their class that covered gaining knowledge, behaviour towards others and safety during science lessons. There was evidence that the past experience of both teachers in their childhood and educational years had been influential in their beliefs about their interest and ability to teach science. The two teachers' personal and professional lives interacted in complex ways as they adjusted to the demands of the school year and the impact of implementing the new science program. Finally the two teachers lacked certainty in science teaching – they experienced epistemological confusion in their understanding of the nature of science. These issues lead to several implications for primary teachers of science, teacher educators, school leaders and curriculum developers.

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When I first contemplated undertaking the doctoral program it seemed like a good alternative to watching television. During my early studies the mental stimulation of engaging in discourse with my peers enticed me to continue my dalliances. Little did I realise the number of learning curves to negotiate and the patience required by my supervisor Dr. John Wallace. I owe John a debt of gratitude for being a critical friend who supported and nurtured my emerging skills and self-belief, helping me to appreciate that the process of writing a doctoral thesis is as much about personal growth as it is about changing the world. Thank you for sharing and caring John.

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Finally I wish to dedicate this thesis to my father, Bill Liddicoat, who taught for over 50 years. Starting life in a one-teacher school he learnt the value of self-reliance and getting children to support each other in their learning. Wherever he taught he introduced gardens, built tennis courts and became a part of the community. He was a mentor for many young teachers sent to the Goldfields to teach and he became my mentor when I began teaching. With a generous heart, a wealth of stories and experiences to share about every aspect of the culture of teaching, he contributed greatly to many lives.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This study examines the way that two primary teachers of science introduced a new science program, based on constructivist underpinnings, into their teaching. It looks at the various issues of implementation as these two experienced teachers adapted the strategies and philosophies of the new program into their pre-existing pedagogical frameworks. The study is guided by the following broad research question: How do experienced teachers of primary science incorporate a new, constructivist based, science program into their teaching? Data for the study, collected over ten months of participant observation, comprise field notes, classroom transcripts, transcripts of interviews with the teachers and students, and curriculum documents. Using the technique of narrative analysis (Polkinghorne, 1995), the data are presented in the study as a collection of stories highlighting the major issues faced by the two teachers. The stories are analysed using analysis of narrative (Polkinghorne, 1995) to identify several propositions about curriculum implementation and primary science.

1.2 AIMS OF THE RESEARCH

The aim of the study is to contribute to the knowledge base about how experienced primary teachers undertake curriculum change. The study is guided by a broad question — How do experienced primary teachers incorporate a new science program into their teaching? — allowing the emergence of issues and themes from the data collection and analysis. The use of a hermeneutic dialectic process during the data collection (Guba & Lincoln, 1989) ensured that the themes are grounded in what the participant teachers

accept as reflecting their beliefs about the dilemmas and changes they experienced as they implemented the new science program.

It is hoped that the stories will help other teachers and trainers of teachers to experience vicariously some of the day to day concerns facing primary science teachers and help them reflect upon their teaching practice. The emergent themes will provide material for teacher educators to develop understandings about issues of implementation and experienced primary teachers.

1.3 MY STORY OF CHANGE

While this study presents the story of two primary teachers engaged in teaching a new science program, in many respects, this is also my story. As a participant observer, I was privileged to enter the classrooms of these two teachers on a weekly basis over the period of one year. This experience afforded me the opportunity to reflect on my own growth as a teacher of science and a researcher. The metaphor that best describes this process is one of a 'monkey ball' used by sailors to throw a light line to shore followed by the heavy rope to tie off the ship. The three participants in this research story (the two teachers and myself) are undeniably connected through our shared experiences of change. The image of the 'monkey ball' represents my experiences in changing my own science teaching.

Several years ago, I became involved in teaching the new science program described in this study, *Primary Investigations* (Australian Academy of Science, 1994). As the science coordinator in my school, I encouraged my colleagues to trial the new science program. This involvement led to becoming a *Primary Investigations* trainer and facilitator for groups of teachers from other schools. The dual roles of science teacher and science teacher-leader added another layer of change to my understanding about science, teaching and teachers. This 'monkey ball' of experiences connected me to the two primary teachers in this study, Lesley and Lynley. Through our shared experience, this study has 'docked' the ship containing new understandings about teachers and curriculum change.

Each of us brought to the teaching of science a perspective that was uniquely our own. Our stories are set within frameworks of events that informed our particular choices in life and learning. It therefore seems appropriate to outline my own experiences as a student and teacher in the Western Australian education system.

I was raised and educated in a large mining town during the 60's and early 70's. This meant living through some significant changes in science education. Primary schools at the time were still engaged in predominantly nature-based science education, but the secondary schools were implementing a new science curriculum, called Science A (qualitative general science which everyone did) and Science B (quantitative physics and chemistry for the more able students). My earliest recollections of science were during my fourth year at primary school. In Year Four we moved from the junior school to the 'big' school, separated by a grassed area and invisible lines in the playground. In Year Four I was 'grown up', and learnt to write with pen and ink. The Year Four teacher was my first male teacher and his love of nature and science manifested itself through many wonderful exhibits in our classroom. We were all very impressed when he dug up an anthill and created an ant farm in the classroom. He also constructed a thin glass box into which he layered different types of soil and placed earthworms inside so that we could see how the soil was mixed up as the earthworm travelled around. He also encouraged us to bring in materials for the nature table. During Year Five we had a female teacher who dressed like a model, we thought. We grew broad beans and placed them in different parts of the room to test the impact of light and water. Science was sometimes fascinating and firmly linked to nature studies. This view of science was reinforced by family outings in the local bush areas when we were encouraged to collect rocks and small animals and, as our father was a teacher, he supplied the proper names for everything.

Coming from a large family meant that by the time I was to enter high school, four of the seven siblings who had gone before me were unable to live up to my mother's expectations. Having excelled at school herself, she found it difficult to appreciate that for a variety of reasons we found education a struggle. In the first year of high school students were allocated to classes depending upon the reports and recommendations from primary school. Although my results were not outstanding, I was placed in the top class, termed a professional class. This, in effect, meant that we were not destined for

commercial studies. This placement also meant that our class was expected to study general science (Science A) and chemistry and physics (Science B). While general science seemed straightforward, the more complex chemistry and physics, with its strong mathematical elements proved much too difficult. We were also not helped by having the teacher inform the class, at the beginning of the course, that a third of us would fail. Being one of five girls in the class also limited my opportunities to learn as I struggled to compete with the boys for the teacher's time. The work was very difficult but, at one point, I managed to get the idea of how to balance chemical equations and it was such a relief. However when the time came to complete the Year Ten external examination (Junior Certificate), science and mathematics proved my downfall. Undeterred, my mother suggested that I study chemistry in my senior high school years and I recall asking the chemistry teacher to write a note to discourage her.

In my senior high school years, a new biology course (*Web of Life* Biology) was being implemented throughout the school system and, after years of struggling with science, this bought a sense of order and enjoyment for me. The topics were laid out in a large book that we kept and could browse through. The variety of hands-on experiments made me feel like a scientist involved in important activities. Everyone was expected to do their own experiments in small groups, which meant the girls were able to work together. Dissecting rats, looking at intestines, growing plants, understanding gene patterns and testing blood types made science possible to decipher and fun.

My father was a schoolteacher in both the primary and secondary system. He was a well-respected member of the community, known for his fairness and love of sports. Around the meal table, he often recounted stories about incidents from his day at school. Many stories were about the funny things that happened in his class but others were about problems he overcame, giving an insight into the way in which he resolved issues. For much of his teaching career he worked with students who had come through the system still unable to read and write effectively. In their final year at high school he made sure they gained some level of literacy and participated in interesting extra curricular activities. He used his influence in the community to find them employment. Sometimes, we had film nights when the projector was bought home to show us documentaries being viewed at school. Another treat for us was to be included in night visits to the high school when the sprinklers were shifted in our father's extensive rose

garden. He used to joke about using weeding as punishment for students who misbehaved. On hot summer nights we accompanied him to the high school and revelled in being able to walk the exciting and spooky wooden veranda. We would also accompany him into his empty classroom and office, when he was acting deputy principal, and be shown his latest project or timetable efforts. These occasions, for me at least, brought home in a quiet way the smells and mystery of schools with blackboards, chalk and papers. My father's style of teaching seemed to be one of inclusion in all aspects of community life, and caring for those in his class and school community. I believe that he made a real difference in people's lives. His influence on me was significant. Not only did he subconsciously influence my beliefs about teaching, but he also became my hero and mentor as I embarked upon my own teaching career.

To be a teacher like my father was a life-long goal. Poor academic results in my final external examination (Leaving Certificate) saw me first enrol in nursing. However, I was soon offered a position at the same teachers' college that my father attended over 40 years previously. This was a real highlight. I changed from nursing to a three-year primary teaching diploma course. Science at teachers' college focussed on the *Teaching Science Through Discovery* (Carin & Sund, 1970) approach that had been developed in America. The approach resembled the work we had done in high school biology and it seemed to make a lot of sense to teach in this way. We were encouraged to develop sets of cards that could be used by small groups of children at stations around a room. Experiments were set up to be observed and the results and diagrams were written up in an orderly, prescribed way. It was hands-on and the procedures were expected to train students to be young scientists. We were still encouraged to provide a nature table for the children to explore. Here was the science I remembered from primary and secondary years that was achievable, fun and orderly. Another significant aspect of my primary training involved learning about psychology and sociology. Both of these subjects revealed that learning was complex and often affected by the children's development outside of the classroom. Although I experienced some difficulty spelling the words related to these two subjects, I was fascinated by the links to children's experiences and found many echoes in my personal development as a learner. The intrigue of it all still grips me.

Not surprisingly when I finally graduated and was given my own class of Year 4/5s, science was not as simple as it had seemed at college. Many hours were spent making trays of equipment and typing instructions for experiments. Materials were difficult to find in the school and the children had no idea how to work in small groups. The problems of managing groups and equipment meant that teaching science was quite a challenge.

It was not long after this that I left teaching to have my family. However, after six years at home, I had the opportunity to upgrade my skills and become a home economics teacher. I was one of a small group of mature-age teachers who went through a demanding course that included food nutritional science. We all found this aspect of the course a real struggle but, with the enthusiasm of the science lecturer and some determination, we all managed to gain credible passes. As positions in the city for home economics teachers were difficult to find, I re-entered primary teaching. I found myself volunteering to be the science coordinator as each teacher was expected to manage a particular subject in the school. When *Primary Investigations* was offered to schools to trial, I persuaded the other teachers in my school to become involved. Knowing that my science knowledge level was limited, I also enrolled in postgraduate studies in science education. One thing led to another and I was soon invited to join a team of train-the-trainers facilitators to help other schools to implement the new *Primary Investigations* program. My friendship with Lesley and Lynley - the two teachers described in this study - developed during this time and when I was looking for sites to collect data for my doctorate, they willingly agreed to become involved in exchange for my help and advice.

Collectively, these experiences of growing up, going to school, teaching and helping others to teach have shaped my ideas about science and teaching science, particularly at the primary level. I have come to understand my own strengths and shortcomings and hopefully, as a result, I have a deeper appreciation of the experiences of primary teachers. It is this connoisseurship (Eisner, 1994) that I bring to this study of the science teaching at the primary level.

1.4 PRIMARY SCIENCE IN WESTERN AUSTRALIA

This study takes place during the introduction of *Primary Investigations* (Australian Academy of Science, 1994), into Western Australian (WA) schools. I feel that it is important to situate this development within the broader context of primary school science in WA over the past 40 years or so. In the period leading up to the 1960's the influence of the Gould League society within the Education Department of WA set the science agenda firmly in the nature study field. Many schools conducted Gould League Clubs and focussed on studying plants and animals, particularly birds. The 1960's saw the introduction of an innovative primary science textbook called *Teaching Science Through Discovery* (Carin & Sund, 1970) from the United States. This textbook was developed to equip teachers with science skills and procedures aimed at producing children that could imitate scientists and their methods. The approach aimed to provide children with the skills necessary for completing the 'real' science work expected in secondary schools. Carin and Sund (1970) made a special note in their revised edition in support of the process bias of their material, that it would "stress the importance of the child's discovery of science concepts and principles through being involved in the use of science processes" (p. XX).

In the 1970's there was an emergence of an indigenous state curriculum moving away from the reliance on imported material. By the middle of the 1970's the Education Department of WA (1974) had developed a primary school program called *I Do Science,* structured around four major science topics of Matter, Energy, Plants and Animals. The teachers were expected to work through each topic area during the year. Some districts developed materials for teachers, organised into topic boxes, in an attempt to provide materials needed to implement the program. In many schools there was still the tendency to concentrate on the more familiar topics of plants and animals. By the 1980's, the Education Department began to relinquish centralised control over curriculum materials and teachers were encouraged to use alternative sources of material to develop their own science programs. The *I Do Science* curriculum materials were still in use in some primary schools in the 1990's, supplemented by materials from various other curricula. However, it was generally regarded that primary science in WA and in other states was being taught in a piecemeal way and was in need of serious reform (Fensham, 1988).

1.5 THE NEW PROGRAM, PRIMARY INVESTIGATIONS

In the late 1980s, the Federal Department of Education, Employment and Training (DEET) commissioned research to determine the state of science teaching in Australia. The research found that primary science education was in a state of 'crisis' in Australian schools (DEET, 1989). Several other studies at the same time attributed this crisis to poor science content knowledge among primary teachers (Appleton, 1991, DEET, 1989, Symington, 1980, Yates & Goodrum, 1990). Wallace and Louden (1992), for example suggested that, "few teachers have a strong basis of science content knowledge or pedagogical content knowledge" (p. 512). Paradoxically, although teachers had a poor background in science, primary teachers consistently ranked science as being one of the most important school subjects (Jeans & Farnsworth, 1992).

Against this background, the Australian Academy of Science, decided to support the development of a new national primary science, technology and environmental program. The Academy initiated action in May of 1991 by inviting primary school teachers across Australia to participate in focus group discussions about the issues surrounding the teaching of science. The results of these discussions were reported in a booklet, *First Steps in Science and Technology* (Australian Foundation for Science, 1991). The report indicated a trend towards national curriculum development that led the Academy, in 1992, to consult with curriculum advisors and tertiary educators to evaluate some of the existing programs used in Australia and overseas. This work was led by Denis Goodrum, who examined the suitability of adapting the Biological Science Curriculum Study *Science for Life and Living* program (BSCS, 1989) from the USA for use in Australian schools. Goodrum also consulted science curriculum advisors in New South Wales, Victoria, Queensland and Western Australian and the coordinator of the Curriculum Corporation's Science Curriculum and Teaching Program. In his report Goodrum suggested that:

> We are beginning to realise the importance of teaching about science, technology and the environment in primary schools, as this is the time when attitudes are formed and rational problem-solving skills are developed. Literacy and numeracy dominate the primary school curriculum. There has been a lack of commitment to science and

> technology at this level by education systems specially and society generally. (Australian Academy of Science, 1992, p. 1)

After an extensive discussion and consultation period, the Academy team concluded that there were strong similarities between *Science for Life and Living* and the proposed national science and technology curriculum. It was proposed that the Australian adaptation would incorporate material on the Australian environment and additional open-ended investigations, and be underpinned by constructivist ideas about teaching and learning. The new development had a national perspective with support by key players in science education in Australia including the CSIRO, and state and commonwealth governments.

Invitations were sent out to all Australian schools at the end of 1992 to participate in trialing the new program, which would be called *Primary Investigations*. The aim of the trial was to supply equipment, teachers' notes and professional development to primary teachers. It would "accommodate teachers who are reluctant about teaching in these areas, while offering more experienced teachers opportunities for innovation and extension." (Invitation, 1992, see appendix F). In WA, six schools were chosen out of a final total of 38 schools Australia-wide. Teachers were expected to participate in two days of professional development before commencing the program. They were also asked to supply feedback about lesson timing, sequence of the activities and additional information about their impressions of the success of the lessons and suitability of the written material. This information was seen as crucial to the final writing of the new science program. The Academy project team, led by Goodrum conducted seven, two-day workshops, between late January to late February in all states, effectively working with over 700 teachers and school support staff. Across Australia, 80 classes from Year One to Year Seven, comprising about 12 000 students, were engaged in trialing the new science program. *Primary Investigations* was the largest trialing and development of a national primary science curriculum package conducted in Australia.

During 1994 the Academy project team began the task of re-writing the material using the suggestions given by teachers and matching of the program with the draft national statements and profiles in science, technology, and society and environment (Education Department of Western Australia, 1992). The Academy also began training trainers to

help schools implement *Primary Investigations* in 1995. Over the years 1995-97, full-scale introduction of the program took place across the country. The program was most successful in WA, with indications that at the end of 1997 that over 80 per cent of WA schools had taken up the program over the three-year period (STAWA Survey, 1997, see Appendix G).

1.6 LITERATURE

The 1989 DEET study identified primary science teaching in Australia as being in a state of 'crisis'. This state of science teaching in Australia was earlier identified in the 1970s by Symington (1974) in a paper titled *Why so little primary science*? Seddon's (1981) research also highlighted concerns about the lack of quality of science lessons, and the overuse of teacher-directed sessions and television programs. In 1982, White also expressed concerns about what he saw, as a decrease in primary science teaching in many schools. In New Zealand, Biddulph, Osborne and Freyberg (1983) reported that primary teachers developed ways to ignore science and what science was taught was typically teacher-directed. Scott (1989) went further, adding that the lack of quality teaching was due to science lessons being conducted at the end of the day, put off if time ran out, given to the relief teacher to teach or amalgamated with other subjects as research topics. Goodrum, Cousins and Kinnear (1992) found that teachers were more familiar with lecture, demonstrations or research styles of science teaching.

The persistent issue of poor quality primary science teaching has also been well documented in studies carried out by Appleton (1991), Symington (1980), and Yates and Goodrum (1990). Many teachers in primary schools are seen as experienced practitioners who hold a set of beliefs and experiences about science teaching and learning (Baird, 1988). This expert teachers' knowledge is seen by Carter and Doyle (1989) as being 'event-structured'. The majority of primary teachers have only learnt biology and human biology as students (Ball & Goodson, 1985; Greenwood, 1996). Their lack of formal studies in the area of physics and chemistry add to teachers' beliefs that they are not qualified to teach the 'harder' science. For many teachers their own experiences when learning science are embedded in what Sutton (1993) describes as descriptive, objective truths that were to be learned, rather than questions about the world. These attitudes to science, according to Shrigley, Koballa and Simpson (1988)

"are organised around beliefs; beliefs are their cognitive backdrop. Attitudes and beliefs are learned, both are bi-directional (like-dislike) and both have a tendency toward action" (p. 669). Experienced teachers' beliefs, values and habits of working are based upon their experiences (Fishbein & Ajzen, 1975; Hargreaves, 1994).

The majority of experienced primary teachers have an extensive range of pedagogical knowledge but their lack of content knowledge and pedagogical content knowledge in science inhibits their attempts to teach science (Appleton, 1991; De Boo, 1989; Symington, 1980; Yates & Goodrum, 1990). While many primary teachers acknowledge the importance of science (Scott, 1989; White, 1982), the pressure of the school day and the need to manage an array of equipment for lessons adds to the difficulty of teaching science (Jeans & Farnsworth, 1992). Primary teachers are subjected to what Huberman (1983) calls the 'classroom press' because they can be expected to teach up to six subjects a day.

Primary teaching is not performed in isolation but occurs within a social setting, community, that has many participants (Hargreaves, 1994; Tobin & Tippins, 1993). There is a perception in the broader school community that primary schools are seen as providers of literacy and numeracy (Goodrum 1993) with science left to secondary and tertiary institutions. As the DEET (1989) report pointed out science was either not taught at all in primary schools or it was taught so poorly that the children arrived in secondary schools with entrenched misconceptions about science concepts. Although teachers work within these social communities, they become isolated within their classrooms (Baird, 1988; Hargreaves, 1995; Wallace & Louden, 1992) with limited opportunities to engage in discussions and reflection about educational changes.

Experienced teachers have an established pedagogy of teaching refined over many years. While they may have mastered many of the complexities of the teaching day, most still struggle with teaching science. The difficulties of managing equipment (Jeans & Farnsworth, 1992), the development of science discourse (Edwards & Mercer, 1990; Gallas, 1995; Sutton, 1993), the uncertainty about the nature of science and science education (Abell, 2000), the emphasis on providing a caring classroom environment (Gilligan, 1982; Noddings, 1988; Sockett, 1989) and the social milieu within which

primary teaching takes place, all seem to conspire to make science teaching difficult in primary settings.

In this study these issues are employed as themes or 'touchstones' around which the data are organised (in the form of narrative vignettes). The themes were selected with reference to data, the participants and the literature. Each of the data chapters was deliberately developed to stand alone and appropriate literature is introduced at the beginning of each of these chapters. In this way the theme is discussed, with reference to the prevailing literature, alongside the data.

1.7 METHODOLOGY AND METHODS

The following is a brief outline of the methodology used for this study. A more detailed description and rationale will be provided in Chapter 2. The study will focus upon the implementation of *Primary Investigations* by two experienced primary teachers over the course of one school year. The study is intended to capture the story of this process employing qualitative and interpretive case study methods, and incorporating a constructivist perspective (Guba & Lincoln, 1989). In keeping with the concept of fourth generation evaluation, the principles of the hermeneutic dialectic circle are used to guide the methodology (Guba and Lincoln, 1989). The hermeneutic process ensures the emergence of grounded theories by allowing me to work in a close personal manner with the major stakeholders of the study. This methodology also encompasses interpretive research methodology that, according to Erickson (1986), focuses on "the immediate and local meaning of actions, as defined from the actors' points of view" (p.119).

The method of data collection corresponds to a qualitative, case study approach as outlined by Merriam (1988) and Wolcott (1988). Wolcott (1988) suggests that the ethnographic mainstay is "participant observer" and as such "he or she would never for a minute rely solely on a single observations, a single instrument, a single approach" (p. 192). Merriam (1988) states that a case study will be descriptive and inductive, while focusing on a particular aspect of a phenomenon.

The study will be conducted in two primary classrooms, a Year Two and a Year Five class, in two suburban government primary schools in the state of Western Australia. Data will be collected over a ten-month period. Each of the classes will be observed each week and regular interviews conducted with the teachers. The use of multiple data sources will, according to Cohen and Manion (1991), "attempt to map out, or explain more fully, the richness and complexity of human behaviour by studying it from more than one standpoint" (p. 269). The data will include interviews, observations, journals, field notes, audio tapings, questionnaires and curriculum documents.

Data will be analysed in an ongoing manner alongside the data collection, to arrive at themes, vignettes and propositions that are the result of data being consolidated, reduced and interpreted (Merriam, 1988). According to Guba and Lincoln (1989) "the sample becomes more directed, the data analysis more structured, the construction more definitive" (p. 180). The ongoing analysis is arrived at through consensus with the participants in the study, references to literature and the researchers development of hunches and ideas. Guba and Lincoln (1989) suggest the analysis is "characterised by a thick description that not only clarifies the all-important context but that makes it possible for the reader vicariously to experience it" (p. 181).

Analysis will comprise of several stages. The first stage is what Polkinghorne (1995) calls narrative analysis. Using this technique, the data will be used to construct several narrative vignettes of science teaching featuring the teacher and students. Erickson (1986) suggests, "the narrative vignette has functions that are rhetorical, analytic, and evidentiary" (p.150). The vignettes, organised around five central themes, will be used to depict the different ways that the teachers engaged with the new science program. The themes, selected after close scrutiny of the data, are used as issue touchstones to assist with the conceptualisation and organization of the vignettes. Alongside the vignettes, the literature on each of the themes will be introduced to provide additional and concurrent contextual information about each theme.

The next phase of analysis is based upon a teachers' knowledge framework developed by Adams and Krockover (1997). The vignettes are analysed according to five knowledge areas; pedagogical content knowledge; subject matter knowledge; general pedagogical knowledge; knowledge of self and knowledge of the milieu of teaching. The

final stage of analysis employs Polkinghorne's (1995) analysis of narrative. This will involve a cross-case analysis of the vignettes to identify several overarching propositions. A discussion of these propositions will be conducted in the penultimate chapter of the thesis. The final chapter will be comprised of a conclusion and a discussion of the implications of the research.

1.8 QUALITY CRITERIA

The criteria used to determine the quality of this study are based upon those developed by Guba and Lincoln (1989). These authors refer to what they call the parallel criteria that are "intended to parallel the rigor criteria that have been used within the conventional paradigm for many years" (p.233) but had not been constructed to reflect the quality of grounded theory. The parallel criteria include credibility, transferability, dependability and confirmability. There are also the authenticity criteria that include fairness, ontological authenticity and educative authenticity. Both sets of criteria will be treated in detail in the methodology chapter.

1.8.1 Parallel Criteria

Guba and Lincoln (1989) suggest several methods of ensuring the credibility of the study — prolonged engagement, persistent observation, peer debriefing, negative case analysis and member checking. In this study prolonged engagement was achieved by spending ten months in the classrooms of the two teachers. Persistent observation was conducted through intensive study of the two sites using multiple and complementary methods. Peer debriefing was achieved through doctoral colloquia, discussions with the other fellow researchers and with my supervisor. Negative case analysis involved my use of hindsight, reflection on literature and refining the data to clarify that the theme and propositions arrived at were appropriate. I also conducted regular member checks with the two participants so that they could provide their perspective on the research question, the data collection and the emerging themes and propositions.

Transferability was achieved in this study by providing a 'rich description' of the place, people and culture in the form of narrative vignettes. It is hoped that this technique will

allow the reader a vicarious experience of the setting and to decide for him/her self whether the setting and interpretations have wider applicability.

Dependability was achieved in this study by providing an audit trail that documents the logic of process and method decisions. The detail of this trail is to be found largely in the methodology and methods chapter (Chapter 3).

The confirmability criteria are concerned with establishing that the data, interpretations and evaluations of the research are grounded in the situation and participants. Again, evidence for this is to be found in Chapter Three, but also in the richness and verisimilitude of the vignettes provided in the data chapters.

1.8.2 Authenticity Criteria

Fairness was achieved in this study by developing ethical relations with all the participants and making explicit the audit trail of their beliefs and values. Negotiations with the participants were based on principles of openness and trust. Member checks were also used throughout the process of construction of data and emergent themes.

Ontological authenticity was achieved through the development of participant constructions during the process of the research. My aim here was to improve their understandings of the major issues and themes emerging and improve their understandings of their culture. Educative authenticity will be determined by the extent to which the work is useful to others. While this is difficult to ascertain in advance, I have tried to enhance the usefulness of the study by making the writing of the research story as accessible as possible and suggesting implications for teachers and science educators.

1.9 OUTLINE OF THE THESIS

This study will investigate the manner in which two experienced primary teachers' implement a new science program into their teaching practice. The study will be guided by the following broad research question: How do experienced teachers of primary science incorporate a new, constructivist based, science program into their teaching? In

this introductory chapter I outline the aims of the study, background information about my experience with change in my teaching career, a brief summary of the literature and outline of the methods to be used in the study. The methodology and methods are outlined in more detail in the second chapter. The subsequent five chapters present a series of narrative analyses or vignettes of science teaching, organized around five themes that emerged from observations, discussions and the literature. The traditional literature review does not appear as a separate chapter but is offered at the beginning of these five chapters. The aim here is to keep the literature close to the themes as they are represented by the vignettes. At the end of these five chapters, there is a preliminary analysis based on a teachers' knowledge framework. Chapter 8 presents eight overarching propositions arising from an analysis of the narrative vignettes. The final chapter will deal with the conclusion and a discussion of the implications of the research.

CHAPTER 2

METHODOLOGY AND METHODS

2.1 AIM AND RESEARCH QUESTION

The methodology selected for the study reflects the nature of this investigation into how two experienced teachers implemented a new science program into their teaching practice. The following broad research question is intended to guide the initial reading of the literature, the data collection, reflections on my own practice, and lead to further areas of focus. "How do experienced primary teachers incorporate a new science program into their teaching?"

Further specific questions will emerge as the study proceeds. My reading of the literature, for example, suggests that some fruitful areas of focus may include the strategies used by these experienced teachers, the importance of content knowledge and how teachers use structured curriculum materials.

2.2 STUDY DESIGN

The study is a qualitative and interpretive case study, incorporating a constructivist perspective (Guba & Lincoln, 1989). In keeping with the concept of fourth generation evaluation outlined by Guba and Lincoln (1989) the principles of the hermeneutic dialectic circle provided the method for this study. The hermeneutic process ensures the emergence of grounded theories (Glaser & Strauss, 1967; Strauss & Corbin, 1990) by allowing me to work in a close personal manner with the major stakeholders of the study. This methodology also encompasses interpretive research methodology that, according to Erickson (1986), focuses on "the immediate and local meaning of actions, as defined from the actors' points of view" (p.119). The features of an interpretive

approach are summarised by Cohen and Manion (1989) as individual small-scale research centred on human actions. The research acknowledges my subjectivity as I interpret the specific actions of participants and search for meanings. Looking at the micro-concepts from an individual perspective allows for personal constructions and negotiations to be included. Eisner (1991) adds that "such knowledge is made possible by the enlightened eye – the scene is seen – and the ability to craft text so that what the observer has experienced can be shared by those who were not there" (p. 30).

2.2.1 Qualitative Research

Qualitative research allows the researcher to bring to light the 'rich' meaning of what is explored, to recreate a vicarious experience for the reader to read and reflect upon (Eisner, 1997; Peshkin, 2000). Hitchcock and Hughes (1989) see this as "detailed appreciation of both the immediate interactional circumstances of events in the social world and the historical and cultural context out of which they grow" (p. 25). Qualitative research enables the collection of stories about educational change, giving a realistic depiction of the interplay of social, political and cultural issues that make up the fibre of human interaction (Cage, 1989; Gubrium & Holstein, 1997; Miles & Huberman, 1984; Tobin & Tippins, 1993). The value of using qualitative research according to Merriam (1988) is that, "researchers are interested in insight, discovery and interpretation rather than hypothesis testing" (p. 10). Hitchcock and Hughes (1989), Shulman (1988) and Eisner (1979) agree that these qualities are all too frequently ignored in other forms of research. Eisner (1994) suggests that we "research reflective efforts to study the world and to create ways to share what we have learned about it" (p. 8). In understanding the connection between research and practice, Kennedy (1997) acknowledges the disillusionment of audiences with the ability of research to "reflect more adequately the ambivalent and ambiguous character of education" (p. 10).

Qualitative research encompasses any research that produces an outcome that does not rely upon statistical techniques and evaluations (Patton, 1990; Strauss & Corbin, 1990). Eisner (1991) suggests that there are six features that make a study qualitative. These are that the study is "field focused" taking account of animate and inanimate objects, is non-manipulative and "naturalistic"; that the "self is an instrument" making sense of the situation; that the study is interpretive in character, aiming to uncover the social,

political and cultural reasons for behaviour; that the study uses "expressive language and presence of voice in text to promote empathy and display their signature"; that there is "attention to particulars" making the best case possibly through sensitivity to the "aesthetic features" and lastly the employment of "multiple forms of evidence to persuade by reason".

Qualitative research utilises a prescriptive set of techniques and evaluation that Guba and Lincoln (1989) suggest has been developed to match techniques and evaluation criteria found in quantitative research methods. Therefore, while this research sits within the paradigm of qualitative research, the epistemological beliefs of constructivism align the study with the fourth generation evaluation, an interpretive methodology incorporating a constructivist perspective (Guba & Lincoln, 1989). These authors suggest that this involves "interpreting the meaning of… demographic and descriptive data in terms of cultural norms and mores, community values, deep-seated attitudes and notions, and the like" (p. 119).

The study of education is particularly suited to qualitative research because education involves a community of people who engage in the process of education and share a particular culture. The culture is made up of shared beliefs and attitudes that can be identified as belonging to a particular system (Fishbein & Ajzen, 1975; Hargreaves, 1994). Qualitative research is also able to capture the intricacies of the relationships within these cultures in the school setting (Lythcott & Duschl, 1990). The task of the researcher according to Burns (1990) is to "capture what people say and do as a product of how they interpret the complexity of their world, to understand events from the viewpoints of the participants; it is the lifeworld of the participants that constitutes their investigative field" (p. 9). In studying such a culture, Wolcott (1988) defines this qualitative research as ethnographic because it portrays " literally, a picture of the 'way of life' of some identifiable group of people" (p.188). An ethnographer looks for the complexity and context of the study (Cohen & Manion, 1989; Hitchcock & Hughes, 1989; Wolcott, 1994). Being part of the school culture I bring to this research my own store of experiences and perceptions when observing, discussing and reflecting upon "the way of life" (Eisner, 1991).

2.2.2 Hermeneutic Dialectic Process

The hermeneutic dialectic process, according to Guba & Lincoln (1989) is "hermeneutic because it is interpretive in character, and dialectic because it represents a higher – level synthesis" (p. 149). The purpose of this process is to 'form a connection' between the researcher and the participants' constructions, allowing for mutual exploration and clarification of the viewpoints and emergent themes (Richardson, 1994). In this way the researcher and participants are 'educated' and 'empowered' through the process of negotiating and refining the constructions of the themes of the study.

The hermeneutic dialectic process operates through a set of assumptions about the position the researcher and participants hold with regards to their abilities to negotiate effectively during the study. These six conditions, given by Guba and Lincoln (1989) are listed below:

1. A commitment from all parties to work from a position of integrity.
2. Minimal competence on the part of all parties to communicate.
3. A willingness on the part of all parties to share power.
4. A willingness on the part of all parties to change if they find the negotiations persuasive.
5. A willingness on the part of all parties to reconsider their value positions as appropriate.
6. A willingness on the part of all parties to make the commitments of time and energy that may be required in the process (p. 149-150).

The hermeneutic dialectic process, explained in detail in *Naturalistic Inquiry* (Lincoln & Guba, 1985) begins with the researcher talking to a participant about the issues related to what is being investigated. This information is used to inform the next set of observations and interviews to clarify concerns and issues. This cyclic process is continued with all participants until identifiable themes have emerged that may then be subject to input from other information generated through a similar process with different participants or sources of information. This process can also inform how

subsequent observations and lines of investigation are pursued. Each new construction is negotiated and refined to establish the major themes. Guba and Lincoln (1989) also highlight that "the inquirer's own etic (outsider) construction may be introduced for critique" (p. 154). Through the process of dealing with participants when discussing ideas and issues in forming their constructions the researcher has a sophisticated knowledge of the emergent themes. While this does not confer more power to the researcher it is seen to advance the ability of the researcher in the negotiation process. The hermeneutic dialectic progress includes the 'tacit knowledge' (Polanyi, 1966) of the researcher, knowledge that is known but not necessarily definable about the research. Richardson (1994) states that "research on the practice of teaching has recently shifted from a focus on effective behaviours toward the hermeneutic purpose of understanding how teachers make sense of teaching and learning" (p. 5).

2.2.3 Case Study Research

Case study research is recognized as an appropriate research design for the study of education (Cortazzi, 1993). The case study helps to provide a detailed picture of the complexities of the classroom interactions between teacher and students (Merriam, 1988). Doyle (1990) suggests that "teachers' knowledge is 'event structured' therefore teachers' knowledge is fundamentally particularistic and situational. Their knowledge is, in other words, case knowledge" (p. 356). Conducting this research as an ethnographic case study acknowledges that this method provides the best means of documenting the socio-cultural analysis of specific issues and dilemmas that arise for the two experienced teachers as they implement a new science curriculum.

This ethnographic case study is further defined by an interpretive perspective allowing for 'rich, thick description' to develop grounded theory (Guba & Lincoln, 1989). Interpretive research facilitates a deeper level of abstraction linked to a more theoretical base in developing conceptual interpretations of dilemmas and issues about people or programs being investigated. Merriam (1988) states that a case study will be descriptive and inductive, while focusing on a particular aspect of a phenomenon. Shulman (1992) points out that case studies are specific to the setting and locally situated revealing the human condition particular to the case largely explained through the use of a narrative.

Stake (1988) characterised a case study as a bounded system where "the search is for an understanding of the particular case, in its idiosyncrasy, in its complexity" (p.256).

2.2.4 Narrative Inquiry

In this study narrative vignettes or stories made sense because of the complexity of the teachers' 'lifeworlds'. Having personally been raised on 'stories' of teaching and teachers around the dinner table and being a part of the 'war stories' tradition of teaching, the technique of narrative inquiry (Carter, 1993; Connelly & Clandinin, 1988; Elbaz, 1990; Gudmundsdottir, 1991) seemed most appropriate to this study. Carter (1993) suggests that narrative can be viewed as a means for teachers to organise their knowledge and contains three definite characteristics, "(a) a situation involving some predicament, conflict or struggle; (b) an animate protagonist who engages in the situation for a purpose; and (c) a sequence with implied causality (i.e., a plot) during which the predicament is resolved in some fashion" (p. 6). Olsen (1990) suggests that narrative "provides a format into which experienced events can be cast in the attempt to make them comprehensible, memorable, and shareable" (p. 100-101). Casey (1995) sees several reasons for using narrative research, including enabling teachers to give voice to their experiences. Elbaz (1990) gives six reasons why stories should be used in educational research. These include: the reliance on tacit knowledge to be made clear, the story is imbedded in meaningful context, the story has a structure that relies on traditional literature, contains a moral or dilemma to be learnt, provides an avenue to comment on social issues, and it makes clear the connections between thought and action of the storyteller. Narrative inquiry is seen as a way of providing a method to gather and analyse teachers' narratives (Cortazzi, 1993). Connelly and Clandinin (1988) define narrative as "the making of meaning through personal experience by way of a process of reflection in which storytelling is a key element and in which metaphors and folk knowledge take their place" (p. 16).

Connelly and Clandinin (1990) suggest, "narrative is a way of characterising the phenomena of human experience and its study is appropriate to many social science fields" (p. 2). In this study, it was important to tell the stories of the two teachers. Moreover, I needed to acknowledge that my position as participant observer would affect the teachers' performance. When reviewing the tapes of the lesson, the journal

entries and the taped interviews with the teachers after the lesson I tried to capture what was divulged during each lesson in the form of a narrative vignette. In creating the vignettes about the teachers' attempts to implement the new science program I have also tried to acknowledge my own perspectives on teaching and learning. My own perspectives determined what I was capable of seeing, recording and reflecting upon and also what I chose to leave in the story (Smith, 1981). I have tried as much as possible to stay close to the dialogue and including as much of the teachers voice as possible. I hope that the stories stand alone in their complexities for readers to interpret according to their perspective at the time of reading. Cortazzi (1993) suggests that "naturally-occurring narratives necessarily contain sufficient context for listeners' correct interpretation" (p. 20). Shulman (1988) suggests that narrative case studies are "no different from any other literary creation. The author's intentions and the reader's constructions are rarely identical" (p. 6).

An important element of the narrative vignettes is that each story is reflected within the other teacher's practice. As the vignettes were written and discussed by the teachers and myself, the themes that emerged echoed in both classrooms. This resonance of themes between the different year levels and teachers provided another level of analysis of the data adding another aspect to the 'triangulation' of data. Erickson (1986) suggests, "the narrative vignette has functions that are rhetorical, analytic, and evidentiary" (p. 150). Shulman (1992) suggests that because "narratives are specific, local, personal and conceptualised…[one does] not speak of validity of a narrative, but of its verisimilitude…does it ring true?" (p. 22). In keeping with the hermeneutic dialectic process, the vignettes were used as interview triggers to gain an understanding of the way in which the teachers engaged with the new science curriculum. The analyses were shared with each of the participants as member checks to improve the authenticity of the data. Connelly and Clandinin (1986) state that "using narrative method for the study of the classroom 'teachers' stories are retold in the narrative accounts in such a way that the observed and reflected upon events are embedded in narrative unities within the person's life both personal and professional. It is this historical dimension that permits us to recast the narrative in terms of unities of personal and professional experience" (p. 307).

2.2.5 Subject Of The Study

The study was conducted in two primary classrooms, one Year Two the other Year Five, in the state of Western Australia. Data were collected over a ten-month period. Each of the classes was observed once a week for a one-hour science lesson and regular interviews conducted with the teachers and students (see Appendix H for a chronology of lessons observed). The lessons observed follow the teachers' attempts to implement the new science program called *Primary Investigations* (Australian Academy of Science, 1994) and using unstructured participant observations I tried to discern on-going behaviours as they occurred and make appropriate notes. As a participant observer my role was to work with the students during the lessons and to offer support to the teachers both during the lesson and after the lesson when together we reflected on the issues arising from the lesson. The teachers were selected because they elected to incorporate the new science curriculum into their teaching and have varied experience in teaching science in primary schools. Both teachers were informed of the purpose and conduct of the study and agreed to take part. The parents of both groups of students were informed of the study and written permission was sought. The students were also encouraged to express themselves about issues related to their science learning. All interviews and information from the teachers were held in strict confidence and anonymity will be maintained.

2.3 DATA GATHERING TECHNIQUES

The method of data collection corresponds to a qualitative case study approach as outlined by Merriam (1988) and Wolcott (1988). Merriam (1988) suggests that a case study will be descriptive and inductive, while focusing on a particular aspect of a phenomenon. The use of multiple data sources will, according to Cohen and Manion (1991), "attempt to map out, or explain more fully, the richness and complexity of human behaviour by studying it from more than one standpoint" (p. 269). The use of multiple data sources also means reliance upon a limiting single observation or approach is avoided. The collection of information using a multiple data approach provides 'triangulation' (Denzin, 1970; Mathison, 1988, Wolcott, 1988), seen as the real strength of ethnographic research. As this study investigated change in two teachers, it was

important to immerse myself in the weekly science lessons. The study employs multiple means of data collection including participant observation, interviews, journals, field notes, audio tapings, student records and questionnaires.

2.3.1 Participant Observation

Wolcott (1988) suggests that the ethnographic mainstay is 'participant observer' and as such "he or she would never for a minute rely solely on a single observations, a single instrument, a single approach" (p. 192). In this study the observational technique involved observing and recording anecdotal notes in a journal during each science lesson. Audio tape recordings were used during the one-hour science lesson to record the comments, responses, strategies utilised and interplays between the teacher and students and student to student. The use of videotaping was considered and rejected because I felt that it would make the teachers and students too self-conscious. This is based upon my own personal experience of participating in a colleagues masters study. The use of videotaping also would have placed a burden on me because it requires an additional level of technical expertise. I did audiotape each lesson and the interviews with the teacher.

As a participant observer I was aware that my presence would create a difference. In an effort to minimising this impact I attempted to blend with the children as much as possible. When working in my own classroom I was often overlooked by visiting teachers if I was seated at a desk helping a child. For most of the observations I tended to sit with groups of children or place myself at the back of the room in the corner. By lowering my visibility it was hoped that the teachers would not 'see' me. The tape recorder had the capacity to pick up all voices in the classroom within a reasonable range so the technology assisted me. The recorder was portable and was easily carried when moving from groups of children to class discussions at the front of the room. The children, after a couple of lessons, acclimatised to the recorder and engaged in discussions freely when I joined their groups. During whole class discussion I either sat on the floor with the children or off to one side at the back of the group, copying the posture of the teachers during these sessions. This allowed time for me to observe the interplay between groups of children and the teacher and the strategies the teacher used during these sessions. The final discussion sessions at the end of each lesson also

presented opportunities to observe and note the strategies used by both teachers to bring closure to the learning. Both teachers used this session to 'wrap up' their lessons. From these observations I was able to note points of interest to discuss with the teachers in the interview that typically followed each lesson.

As the participant observer, aware that the teachers would appreciate a spare pair of hands, it was easy for me to become part of the lessons. With my previous experience implementing the new science program and years as a primary teacher, it was not difficult to work alongside teachers who shared a familiar culture. There was also a danger in this familiarity because it was easy to fall into the teaching role, when my primary role was that of observer and researcher. The role of observer was new and fraught with difficulty because I found myself in a position of observing and making comment upon experienced teacher colleagues, who also became friends (Abell, 2000). At times it felt like a betrayal of trust when I focused on the teaching dilemmas they faced. It would have been very easy to avoid these incidents, but I learnt that the dilemmas faced by these teachers explained why experienced teachers find it difficult to change their teaching practice. My observations also provided the foundation for the next round of observations and discussions, helping me move from a personal to an analytical perspective. Guba and Lincoln (1989) acknowledge the part that the "the inquirer's own etic (outsider) construction may be introduced for critique" (p. 154). Polanyi (1966) adds that the 'tacit knowledge' of the researcher must also be considered part of the study because it informs the decisions taken, the lenses through which the researcher operates.

2.3.2 Interviews

The use of interviews is another source of data suggested as part of qualitative interpretive research and is in keeping with the hermeneutic dialectic process suggested by Guba and Lincoln (1989). As recommended by Merriam (1988), in this study the interviews were open-ended wherever possible, with "neither the exact working nor the order of the questions determined ahead of time" (p.74). The informal interviews and the science lessons were audio taped (Appendix C & D), transcribed and analysed to identify the emergent themes and this, in turn, provided directions for subsequent observation and formal interviews. The audiotapes provide comprehensive records of

student and teacher behaviour that were preserved for subsequent analysis (Cohen & Manion, 1991).

Informal interviews were conducted at the conclusion of the lessons to provide the teachers with a forum to reflect upon the lesson and discuss issues they thought had arisen from the lesson. Initially the idea was for the teachers to maintain a reflective journal about their teaching but it quickly became clear that this was unworkable. The teachers found that the time and effort required to find materials, read and understand the requirements of the new science curriculum was greater than they had anticipated. The informal interview sessions became an oral journal for the teachers with some direct questions from me to prompt them about incidents that I had observed during the lesson. These audiotapes were transcribed and offered to the teachers for review (Appendix C).

The formal interview sessions were conducted after the teachers had read the narrative vignettes written about the themes that emerged from the observations and informal interviews. The teachers were able to discuss and negotiate what part of the narrative vignette should be included and asked specific questions about the theme to further refine the analysis of the data. The formal interviews were then transcribed and analysed, clarifying the teachers' positions on the themes. After the narrative vignettes and analysis were written the teachers were invited to read and further reflect and comment upon the story and analysis.

2.3.3 Other Techniques

The data include field notes (Appendix E) written as anecdotal records during the science lesson. Field notes were used to record on-going interactions within the classroom between teacher and students, students and students and interplay of other personnel within the school who interacted with the teacher during the lessons. The field notes were used to record information about the setting of the classroom, placement of materials, movement of the children around the room and other outside influences that impacted on the flow of the lesson. The field notes for each lesson were expanded with my reflections of the lesson at the end of the day and after the informal interview session with the teachers. The journal therefore contains the field notes and

my reflections upon the lesson and discussions with the teachers about the way the lesson unfolded. The journal also contains references to informal conversations with other teachers, including the principals and parents involved in the science program, the teacher and the children.

The teachers were also given a questionnaire (Appendix B) about their experiences and beliefs about learning and teaching science. The questionnaire was designed to prompt the teachers to reflect on their teaching experiences, preferred methods of teaching, and significant influences that helped to shape their beliefs in science as a subject and their capacity to teach science. The information was also used to prompt the teachers during the interviews. Students' worksheets were also copied as needed and relevant pages from the *Primary Investigations* materials were used as background material for the stories and analyses.

2.4 DATA ANALYSIS

Data were analysed in an ongoing manner, suggested by Merriam (1988), while engaged in data collection to arrive at themes, vignettes and propositions that were the result of data being consolidated, reduced and interpreted. According to Guba and Lincoln (1989) "the sample becomes more directed, the data analysis more structured, the construction more definitive" (p. 180). The ongoing analysis was arrived at through consensus with the participants in the study, references to literature and my development of hunches and ideas. Guba and Lincoln (1989) suggest the analysis is "characterised by a thick description that not only clarifies the all-important context but that makes it possible for the reader vicariously to experience it" (p. 181).

Analysis comprised of several stages. The first stage is what Polkinghorne (1995) calls narrative analysis. Using this technique, the data were used to construct several narrative vignettes of science teaching featuring the teacher and students. The vignettes, organised around five central themes, were used to depict the different ways that the teachers engaged with the new science program. The themes, selected after close scrutiny of the data, were used as issue touchstones to assist with the conceptualisation and organization of the vignettes. Alongside the vignettes, the literature on each of the

themes was introduced to provide additional and concurrent contextual information about each theme.

The next phase of analysis is based upon a teachers' knowledge framework developed by Adams and Krockover (1997). The vignettes were analysed according to five knowledge areas; pedagogical content knowledge; subject matter knowledge; general pedagogical knowledge; knowledge of self and knowledge of the milieu of teaching. The final stage of analysis employed Polkinghorne's (1995) analysis of narrative. This involved a cross-case analysis of the vignettes to identify several overarching propositions. A discussion of these propositions will be conducted in the penultimate chapter of the thesis. The final chapter comprises of a conclusion and a discussion of the implications of the research.

2.5 SELECTION OF SCHOOL AND GAINING ENTRY

My role as a *Primary Investigations* trainer working with primary schools gave me access to a number of schools. Initially I intended to work with a single Year Two teacher because of my past experience with teaching science at this level. Undertaking such an intensive long-term study was to be a challenge for me because my previous studies had relied upon more quantitative data collection. I reasoned that working with a familiar year level dealing with a program that I had come to understand over the last three years would enable me to focus upon the interactions of the teacher and children during the science lesson.

The first school I approached, the Year Two teacher was not comfortable having someone watching especially as I had been the trainer working with her school and she felt intimidated by my perceived expertise. I approached another Year Two teacher, Lesley, introduced through a former colleague. Lesley had not taught science for five years, but was now required to include it in her teaching. She willingly agreed to the new science program because she had never enjoyed teaching science previously and she was aware of her lack of experience and expertise in science teaching. Lesley seemed comfortable with the opportunity to have me available to help her with the science program. Lesley had also been a trainer, supporting teachers in the implementation of

'*First Steps'*, an innovative primary language program. I felt that we had a strong bond of mutual respect based upon our shared experiences.

The second teacher, Lynley, was the science coordinator at her school and had been instrumental in encouraging the school to adopt the new science program. We met up during my visit to the school as a *Primary Investigations* trainer. Lynley was anxious to provide the resources for the school in the way of programs, equipment and support for the teachers. Lynley also supported her principal's plan for the school to be a leader in science education for the district. Including Lynley's Year Five class in the study gave me an opportunity to compare a junior grade and middle grade. In this way, I thought that the study would benefit from studying the experiences and practices of two different teachers.

Having established a rapport with the two teachers, the principals were approached by letter and in person to seek their agreement for me to conduct the study. Once this was secured the parents were sent a letter to explain the intention of the research, steps that would be taken to ensure anonymity and the time of a meeting to allow them the opportunity to question me about any aspects that were of concern for them.

2.6 ETHICAL CONSIDERATIONS

This study involved both the teachers and children in their classes. Letters of introduction were sent to the teachers and principals of the two schools, to establish agreement to become part of the study. Letters were then sent to the parents of both classes to inform them of the purpose of the study and to ask their permission for their child to be involved in the study. Permission was sought to observe and tape-record the science lessons and to conduct interviews when necessary. Attending parent meetings at the beginning of the study allowed parents to gather information about the study and gave me an opportunity to answer questions about the purpose of the study and address issues and concerns.

The nature of the study design demanded mutual respect, good relationships and the establishment of a cooperative environment. Initial interviews with teachers clearly outlined the extent to which my role as participant observer would impact upon their

lessons. The teachers were made aware of my credentials as a practicing classroom teacher who had previously implemented the new science program. The study was to be mutually beneficial to all participants. I agreed to assist in the classroom wherever possible and they agreed to help me with my research. There were opportunities for the teachers to reflect on their professional development through their teaching practice and implementation of the new curriculum program. At all times during the study I was careful to accommodate changes to timetables and possible absenteeism of teachers.

Anonymity was preserved for all participants via the use of pseudonyms. The information and data generated during the study was subject to the agreement and approval of the teachers. Confidentiality for teachers and children was respected at all times to preserve their dignity, privacy and integrity (Guba & Lincoln, 1989).

2.7 QUALITY CRITERIA

The criteria used to determine the quality of this study are based upon those developed by Guba and Lincoln (1989). These authors refer to what they call the parallel criteria that are "intended to parallel the rigor criteria that have been used within the conventional paradigm for many years" (p. 233) but had not been constructed to reflect the quality of grounded theory. These criteria include internal validity, external validity, reliability, and objectivity. These parallel (trustworthiness) criteria include credibility; transferability; dependability and confirmability. The authors also introduced what they call the authenticity criteria — reflecting the constructivist paradigm — which include fairness, and ontological and educative authenticity.

2.7.1 Parallel Criteria (Trustworthiness)

2.7.1.1 Credibility

Guba and Lincoln (1989) suggest several methods of ensuring the credibility of the study — prolonged engagement, persistent observation, peer debriefing, negative case analysis and member checking. In this study prolonged engagement was achieved by spending 10 months in the classrooms of the two teachers. Persistent observation was conducted through intensive study of the two sites using multiple and complementary

methods. Peer debriefing was achieved through doctoral colloquia, discussions with the other fellow researchers and with my supervisor. Negative case analysis involved my use of hindsight, reflection on literature and refining the data to clarify that the theme and propositions arrived were appropriate. I also conducted regular member checks with the two participants so that they could provide their perspective on the research question, the data collection and the emerging themes and propositions.

2.7.1.1.1 Prolonged Engagement

In this study prolonged engagement was achieved by spending 10 months in the classrooms of the two teachers. The study was conducted over a full teaching year with weekly visits to the classroom during the science lessons. In the limited times before the science lessons, I assisted the teachers in their final preparation and discussed any issues they had with the lesson plan. On occasions I was able to keep the class occupied while these final preparations were being made. Having the opportunity to engage with the class in this way meant that the children also saw me as another teacher and afforded me their trust and acceptance of my place in their classroom. Securing this familiarity with both the teacher and the children allowed the lessons to proceed in a relative normal way.

Operating from within the same culture as the two teachers in this study, it was not difficult to immerse myself into the routines and teaching styles they presented in their science lessons. Having experienced the format of the science lessons, understood the expected roles and behaviour of the small group work and being familiar with the science concepts, meant that I was speaking the same language as the teachers. This understanding ensured that the children were not confused about different adults having different expectations of classroom behaviour during the science lessons. The lessons were a re-run of the path I had taken in understanding the new science program. Familiarity with problems arising throughout the implementation of the science program enabled me to understand what the teachers were experiencing and cast me in the role of advisor.

Prolonged engagement also allowed ample opportunity to build a trust with the teachers and explore other issues relating to their teaching while not be directly responsible for the science lessons. In striving to investigate the issues at the heart of the teachers'

reasons and capacity to change there needed to be discussion and sharing of more intimate knowledge about their background experiences and life outside of their teaching role. It was my privilege to develop a sound working relationship that afforded me the opportunity to discuss such issues with the teachers over the year.

2.7.1.1.2 Persistent Observation

Persistent observation was conducted through intensive study of the two sites using multiple and complementary methods. The prolonged engagement in the science lessons on a regular weekly basis allowed me to clarify the major emerging themes. My observation was then focused upon these themes and with time and repetition the themes were consolidated. According to Guba and Lincoln (1989) "the sample becomes more directed, the data analysis more structured, the construction more definitive" (p. 180).

2.7.1.1.3 Peer Debriefing

Peer debriefing was achieved through doctoral colloquia held on a weekly basis at the University as well as many other informal conversations with postgraduate colleagues. I also had discussions with my supervisor at regular intervals. He provided guidance helped me clarify my thoughts and directions.

2.7.1.1.4 Negative Case Analysis

Negative case analysis involved my looking for examples that did not fit with the emerging themes. I reflected on whether the themes were appropriate and the stories an adequate representation of those themes. Often this reflection took place in the context of discussions with the teachers, colleagues and my supervisor. By constantly revisiting my data, the literature and my analysis, I was able to reassure myself that the story told had been subject to proper scrutiny.

2.7.1.1.5 Member Check

At the conclusion of each lesson I debriefed and discussed with the teachers incidents that occurred during the science lesson. During these sessions we also discussed wider ranging issues, including the type and amount of school support and items of a personal

nature. The debriefing sessions were audio taped and presented to the teachers, along with the transcript of the lessons, for acknowledgement and approval of the content. Items that the teachers did not wish to become part of the data were left out.

This raw data became the basis of the narratives illustrating the major themes identified through the processes of prolonged engagement and persistent observation. As each major theme was identified, the teachers were asked to reflect upon the stories written about that and the preliminary analyses. Formal interviews were then conducted to examine any changes arising from this process and to provide further clarification of the issues for the teachers. This process continued throughout the entire study, further refining and enriching the data and analysis.

2.7.1.2 Transferability

Transferability is seen as the ability to be able to generalise about the study to the wider community in which it is set. This study is based upon the construction of a grounded theory and relies upon the building of a 'rich description' of events, people, places and the culture of the school. It is hoped that this technique will allow the reader a vicarious experience of the setting and to decide for him/her self whether the setting and interpretations have wider applicability. The building of such a description must also recognise and acknowledge the 'lens' through which the researcher is operating. There also need to be a description of the setting and the participants as well as the events so that those who wish to copy this study will be able to identify the major players and replicate the framework of the study. In this study, the narrative vignettes have been used to provide such 'thick description'. In doing so, I have stayed as close as possible to the original transcripts to preserve the authenticity of the narrative vignettes.

2.7.1.3 Dependability

Dependability was achieved in this study by providing an audit trail that documents the logic of process and method decisions. Each step of this process has been carefully considered and documented to enable others to replicate the structure of the study. It goes without saying that the content of such a study would differ each time it was conducted because of the nature of the researcher, the teachers involved and the

program being implemented. In Appendices C& D there are examples from the transcripts of lessons and interviews demonstrating the high correlation between what is offered as raw data and the finished stories.

2.7.1.4 Confirmability

The confirmability criteria are concerned with establishing that the data, interpretations and evaluations of the research are grounded in the situation and participants. Again evidence for this is to be found in the richness and verisimilitude of the vignettes provided in the data chapters. Through the extended procedure of the hermeneutic dialectic process the vignettes were identified, written and reflected upon myself, the participants, peers and my supervisor. Evidence for this is found in Appendix D where transcriptions of lessons used to create the vignettes testify that authentic voices were utilised in the narrative vignettes. The audit trail from original transcripts to finished story is clear.

The data chapters containing the narrative vignettes were then embedded within the literature related to that particular theme, aligning the current literature to the story and the theme. The literature therefore reflects the argument or line of discussion that assisted in making clear the emergent theory. This procedure is in line with the ideas of Lincoln and Guba (1985) who point out that "if the literature is to be critiqued via the case, should not the case writer know in what sense, so as to be sure to include materials that would make such a critique possible?" (p.369).

2.7.2 AUTHENTICITY CRITERIA

Guba and Lincoln (1989) have devised "what we have now called 'authentic criteria,' which spring directly from constructivism's own basic assumptions" (p. 245). These criteria include fairness, ontological authenticity and educative authenticity.

2.7.2.1 Fairness

Guba and Lincoln (1989) suggest there are two techniques that should be employed to provide 'fairness' in the research. The first is to allow all stakeholders the opportunity to

read and reflect upon the construction of the research. In this research the major stakeholders were the two teachers. The stories were checked by each teacher for their clarification of the themes that emerged and also allowed them the opportunity to comment upon the construction of the narrative vignettes. In this process the level of debate and negotiations about the constructions was a sensitive issue. While in the role of researcher I had only just emerged from the classroom myself and did not consider myself to be an experienced researcher-negotiator. Indeed I was in awe and deeply grateful to the teachers for allowing me to observe them while they grappled with the new science program. To have someone observe your teaching is never an easy task and while I tried not to be too visible, just a non-judgemental observer, it became obvious that the teachers expected feedback about their performance. I found this difficult to do, but tried to base all of my dealings on principles of openness and trust.

The second fairness technique suggested by Guba and Lincoln (1989) "is the open negotiation of recommendations and the agenda for subsequent action" (p. 246). In an attempt to keep the research agenda transparent and to honour the generosity of the two teachers each piece of work constructed was given to the teachers to review and reflect upon. Interviews were scheduled to allow an opportunity to discuss issues arising from the stories and subsequently from the analysis of the stories. The two teachers had never previously been involved in research of this nature and were unfamiliar with the process. What they were familiar with was the sharing of stories and the discussion of incidents occurring during lessons. For the two teachers the act of opening up their lessons for discussion was a familiar strategy, as was the expectations of input from significant others about their teaching.

2.7.2.2 Ontological Authenticity

Ontological authenticity was achieved through the development of participant constructions during the process of the research. My aim here was to improve their appreciation of the major issues and themes emerging and improve their understandings of their culture. This study provided the two teachers with an opportunity to assess their experience of dealing with change in a focused manner. Throughout the study the teachers often referred to the expansion of their science content and pedagogical

content knowledge, and a better understanding of the underpinning ideas behind the new science program.

2.7.2.3 Educative Authenticity

Educative authenticity will be determined by the extent to which the work is useful to others. While this is difficult to ascertain in advance, I have tried to enhance the usefulness of the study by making the writing of the research story as accessible as possible and providing implications for science educators. Guba and Lincoln (1989) suggest a major technique to achieve this is "the testimony of selected participants in the process will attest to the fact that they have comprehended and understood the constructions of others different from themselves" (p. 249). In this study there is evidence that the participants understood the relevance of the themes and analyses to their work.

CHAPTER 3

MANAGING EQUIPMENT

Primary teachers have struggled with science teaching for many years and the associated persistent issues and have been well documented by authors such as Appleton (1991), Symington (1980), Yates and Goodrum (1990) and others. And yet, the majority of primary teachers are experienced teachers who enjoy a wide range of pedagogical knowledge. It is a lack of content knowledge and pedagogical content knowledge in science that inhibits their attempts to teach science with ease (Appleton, 1991; Baker, 1994; Carre & Bennett, 1993; De Boo, 1989; Symington, 1980; Yates & Goodrum, 1990). Commenting upon the level of science being taught in primary schools 20 years ago Seddon (1981) said that, "if any general picture of primary science can be synthesised it is that, on average, children have some experience of science in their primary schools. But frequently this experience is teacher directed or second hand, such as from watching television" (p. 41).

Little appears to have changed in the intervening years. For many experienced primary teachers, science teaching has been grounded in the culture of the 'nature table' and the majority studied biology and human biology as students (Ball & Goodson, 1985; Greenwood, 1996; Grossman, Wilson & Shulman, 1989; Skamp, 1991). Whereas pre-service teachers express a preference for first-hand practical lessons using equipment, experienced teachers seem to shy away from such strategies (Appleton, 1984). Three possible reasons have been suggested for this difference:

1. Teachers who are recent graduates are different from most experienced teachers in that they tend to use hands-on strategies.
2. Many students change their opinions about preferred strategies during their teacher training.

3. Constraints within the school influence many teachers, even recent graduates, to change their preferred strategies – perhaps from what they would like to be able to do, to what they feel can actually be achieved (Appleton, 1984, p. 157).

Teachers find the application of theory into practice is more complex because of the constraints placed upon them at the school level with regard to the supply of materials, timetable commitments, support for new ideas, availability of space in their own classroom or a separate room to conduct experiments and the ability to transfer concepts into achievable lessons (Brickhouse & Bodner, 1992; Everston, 1989; Johnston, 1988; Schmidt & Knowles, 1995; Veenman, 1984).

For primary teachers the difficulty in obtaining and organising equipment is often given as one of the major reasons for their reluctance to teach science (Jeans & Farnsworth, 1992). Materials, resources, tools and equipment are an integral element of many subjects in primary education. Concrete hands-on experiences often require equipment for the children to manipulate, enabling them to construct their own understanding of concepts. In the early years there is a strong emphasis on supplying equipment in mathematics, for example, to assist children in developing a conceptual understanding of mathematical patterns and relationships. The issue of equipment in science lessons is very real and relies upon resources being given to supply appropriate equipment for a range of science experiments. Jeans and Farnsworth (1992) found that "the equipment available is a matter of the funding priority [and] teachers would teach more science if there was more equipment available" (p. 216). The collection and housing of such a range inevitably falls to one teacher within the school who is already engaged in a full load of classroom teaching. With a limited budget, time for preparation and space to house the collection the task is fraught with difficulty. Primary teachers are under pressure to manage resources for several subjects - sometimes up to six each day - creating what Huberman (1983) calls the 'classroom press'.

The lack of content knowledge about science not only contributes to the teachers' lack of belief in their ability to teach science concept, it also inhibits their knowledge about the intent and purpose of equipment. The need for special equipment is what makes science appear to be 'hard science' and when items of equipment do not respond or perform as expected teachers are not sure what to do next and see equipment as a source of concern. Jeans and Farnsworth (1992) found a high correlation between

teachers' confidence and competence in science teaching. According to these authors, three factors contributed to a lack of confidence and competency. Teachers cited the lack of science knowledge, inadequate materials and the organization required for materials as the most significant. The time required to gather consumable materials and the funding required, inhibits the ability of teachers to provide for science activities that require consumable materials. Goodrum, Cousins and Kinnear (1992) found that reluctant primary science teachers listed material collection as an initial concern in their study but, after the year of the study, they become more confident and competent because of "a structured programme with supporting materials" (p. 165).

Abell and Roth (1992) identified lack of science equipment as a constraint in delivery of science lessons and, when this was compounded by a lack of content knowledge, the teacher had to rely upon the textbook and associated lecture and paper and pencil methods. The authors found that "the abstract nature of the … content and {the teachers} lack of knowledge, combined with limited teaching resources did influence … classroom practice" (p. 591). Greenwood (1996) also found a correlation between pre-service teachers lack of content knowledge and their ability to understand concepts in science. This influences teachers' abilities to understand the use of equipment and their capacity to provide appropriate questions to facilitate children's understandings of the concepts being explored.

The teachers in this study have different backgrounds in teaching, and different learning experiences in science. Lynley studied biology at a high school level and during her teachers training course was keenly involved in the nature studies programs. As the science coordinator in her school Lynley supplied most of the equipment for the other teachers when they implemented the *Primary Investigations* program. Lynley had previously participated in organising kits in science for teachers at a whole district level, assisting the district supervisor. Lynley was aware that her colleagues found science difficult to teach and had suggested that the school become involved in the new science program.

Lesley completed her secondary education studying biology and human biology in high school because she was considering a career in nursing. Throughout Lesley's pre-service training her interests lay in language arts rather than science. This interest in language

continued into her teaching career with Lesley becoming a coordinator for *First Step*, a language program developed by the Education Department of Western Australia. Lesley was not adverse to teaching science and had always linked science with her language topic when programming. Lesley admitted that, although her previous science lessons were fun and meaningful, they did not develop scientific concepts. She avoided teaching science for the previous five years because the school science coordinator taught science throughout the school. Prior to the study, Lesley agreed to adopt the new science program to help her overcome her shortcomings. Lesley had also made it clear that she would only participate if the science coordinator made sure the equipment was prepared for her. Lesley was also able to enlist the help of her teacher's aide in the preparation of equipment for each lesson.

3.1 VIGNETTES ABOUT MANAGING EQUIPMENT

This section contains two teaching vignettes or stories selected to illustrate the importance of the supply of appropriate equipment in developing science concepts. The first vignette describes Lynley's Year Five children investigating air pressure by building a bottle diver. The children were investigating how changes impact upon a closed system. The second story is about using magnets to sort objects in Lesley's Year Two class. The children had previously sorted objects into categories and in the lesson they were using a magnet to reclassify a known set of objects. Both teachers' used the *Primary Investigations* strategy of assigning specific roles to students working in groups – roles such as manager, speaker and director. Each student also had *Primary Investigations* workbooks containing basic instructions for each activity, diagrams and questions. In both vignettes the equipment presented problems for the teachers and the children, influencing the success of the lessons.

3.1.1 Bottle Divers

Lynley had been working with the Year Five children for four weeks on the new science curriculum. In today's lesson she was using bottle divers to illustrate the concept of a system. The children were to identify and analyse the interactions within the bottle diver system. A bottle diver is constructed by suspending an eyedropper in water, in a sealed two litre pep bottle. When the sides of the bottle are squeezed the eyedropper descends

due to a change in pressure. Lynley still had to organise the last few items for the lesson and make an operational bottle diver to demonstrate to the class. Lynley examined the eyedroppers in the school supply and realised that many were old and the perished rubber tops were difficult to remove. She soon identified this as a problem because the children might need to insert a piece of wire to weight the eyedropper, so that it descended during the experiment.

"I used an eyedropper from home last night and it didn't cross my mind that the rubber stoppers would be perished on these at school," said Lynley. "It just shows you how little some of the equipment is used around here."

"How will the children manage if they need wire?" I asked.

"Well, I didn't have to put wire in mine last night, so I'll tell them to try the system without the wire and if they find they need the wire they will have to come to me to remove the rubber. They are really old aren't they?" said Lynley.

Exchanging the eyedroppers was impossible so it was hoped they would do the job well enough for today. Finding the best eyedropper for the demonstration Lynley showed me how, by squeezing the sides of the bottle, the eyedropper descended to the bottom of the bottle. Nothing happened no matter how hard the bottle was squeezed. The lid was checked for leaks, the water level checked to see if less water would do the job and finally the eyedropper was weighted with a piece of wire as the teachers' resource book had suggested. After each alteration the diver still resisted the pressure on the side of the bottle. We watched the clock tick around to the lesson time and felt the panic rising.

"When I did this last night it worked the first time," Lynley said. "I should have left it together for the demonstration."

"If it worked once it must work again," I replied. "Let's go through the steps in the book one at a time and check we have done everything properly."

We read through the instructions yet again, checked our equipment, left out the piece of wire, changed the eyedropper, lowered the water level and got desperate. Not being

defeatist by nature we struggled to make sense of it and, in doing so, Lynley turned to the last piece of information available to us. The diagrams! There had to be a clue to the system through the diagrams. Like a jigsaw puzzle we checked each picture and then Lynley saw it.

"There it is!" she cried. "The water level shows the eyedropper sitting just under the water level, the black line, and not above it."

We squeezed the bottle to pop the eyedropper out the top, made a mess, filled the eyedropper with a little more water and made sure it sat just below the water level. Eureka! It worked this time.

The class assembled and Lynley explained the lesson to the children, seated on the floor at the front of the classroom. She also discussed the systems they had been working with in previous lessons.

"Alright," said Lynley. "So again today were going to be looking at a system. A special system and were going to try and relate this system to things that we use in our world today. Technologically, other things have been based on the principle that we are working with today. So we are going to be looking at a system. We are just going to look at this..."

"The thing in the bottle!" sang out Len.

"Good Len," Lynley acknowledge. "A very simple system. I want you to watch it carefully. What can you see in the system? What is involved in the system? What have I in my hand?" The children, when selected by the teacher, went on to describe the items making up the bottle diver. Satisfied the children were aware of the parts of the system Lynley went on to demonstrate how it worked. "Alright," said Lynley. "I want you to watch the eyedropper in the bottle, just watch it." (She squeezed the bottle and the class went, "Oh!") "Alright...let's have another look."

The class was suitably impressed and focused on making the magical bottle diver. Lynley went through the team skills, especially the rule of moving into their groups quickly and

quietly. The children were made aware of the need to work quietly so as not to disturb other teachers when they were outside on the cement veranda. Lynley reminded them to take turns and listen to the group director who would read the instructions. After reading the information the group manager was to get the equipment necessary to the activity. Once they had accomplished this task Lynley again called them to attention to discuss the need for care when operating the eyedroppers.

"Now some of these," Lynley began. "Boys are you listening? Rodney you don't know if you need it yet dear. Your eyedropper may not need a small nail but today you have a piece of wire. To take the rubber off the glass stem it should come apart. Now if you have difficulty in taking the top off yours would you please give it to the group speaker to bring to me so that I can help you. I don't want you to tear the rubber top if it can be avoided."

The groups were given a small glass jar instead of a jug, as listed in the book, so Lynley asked them to be especially careful and use a carpet square to stop slipping with spillage on the concrete. As the class moved out to the verandah two groups asked about the eyedropper.

"How about you try it first," Lynley suggested. "Read the instructions and try it because it will work without the nail sometimes, other times you need to put the nail in. See if it will work without the nail first and if it won't come back I will help you for sure. Who is the reader?"

The class settled onto the veranda space with all their equipment. Each group seemed to be preoccupied with the problems of the eyedropper and it was difficult for Lynley to encourage them to read their instructions for the activity. A group of girls worked out that the glass jar made it easier for them to trial the eyedropper's ability to float under the surface of the water. Janet was still determined to put the nail into the eyedropper because this is how it was shown in the diagram. Kieran focused the group by reading the instructions from the book and eventually they created the system.

The girls were very excited about getting the bottle diver to work but Lynley had to prompt them about reading the information and following the steps set out in the book.

Lynley also prompted the group about air pressure by asking through questions about what was happening to the water in the eyedropper. The group looked closely at the way the water levels behaved in both the bottle and the eyedropper. They discovered that the water level in the eyedropper rose when pressure was exerted on the side of the bottle. They suggested that the extra water added the necessary weight to make the eyedropper descend to the bottom of the pep bottle.

At the conclusion of the lesson Lynley spoke to the children about the need to read their instructions carefully. Many groups had not followed the steps in their student books properly. When she asked how many had used the nail to make the eyedropper sink it turned out that none had needed it after all. Not all groups had been able to manage the activity in the time but all of them had been able to observe a working model in a nearby group.

* * *

Lynley allowed time to organise the equipment because she was familiar with what supplies were available. When vital pieces of equipment were not functional or unavailable this presented problems at the last minute. Lynley was able to proceed because she improvised using the equipment provided. She took up valuable lesson time explaining the lack of good eyedroppers, the use of wire instead of the nail and a glass jar instead of a jug. Once the children began their experiment many focused on pulling apart the eyedropper. The children became concerned about the need to use the wire (nail) because it had been mentioned and it was shown in the diagram. This aspect of prescriptive curriculum did not allow the children to manipulate the materials to achieve their objective. The children were unfamiliar with the need to read through the steps of the activity, like a recipe, to investigate a phenomenon. The use of technical information was new as was the notion that a group member would be responsible for making sure the group stayed on task and followed the instructions.

* * *

3.1.2 Magic Sorters

The Year Two class had only been working with the new science program for two weeks. The children were becoming familiar with the concept of sorting objects according to criteria given by the teacher or self generated. For this lesson the teacher was to give the children a small round ceramic magnet, as used on refrigerators, so that they could group objects according to whether they stuck or didn't stick to the magnet. While the children were out at recess I watched Lesley sort through the equipment and noticed that the magnets were long bar magnets and some were very old. When I commented on this Lesley remembered that the science coordinator had experienced trouble locating the magnets. The fact that they were not round ceramic magnets did not concern Lesley because she assumed that Jessica, the science coordinator, knew what she was doing.

"This was all Jessica could find in the school," Lesley said. "My Monday is very busy and I had to run all over school for these anyway. Jessica agreed to help us out with the material otherwise I would find it too hard."

We tested the magnets and discovered some were indeed weak but there was no time or indeed alternative sources within the school to exchange them. The science coordinator was the deputy principal who had a strong background in language and library studies but not science. The rest of the materials were arranged in an ice cream container. The children returned after the siren and sat on the mat with expectant, eager faces. They really are very young at the beginning of the year.

Lesley began the lesson by discussing the work the children had done the previous week. She explained that the children would again be sorting but instead of shapes it would be a set of different objects. The children would be working in small groups so Lesley went over the rules of how to work as a team. Team work meant to cooperate, no loud noises, stay with your partner, take turns at talking and doing, move into your teams quickly and quietly, don't change your role badges and lastly don't go near other groups and be noisy. Lesley explained that today's task would be to sort the objects in the ice cream container. She stressed that the partners had to share the task and come up with one way of sorting.

"What you can do, is one of your partners can make the first bit and the other partner can make the different bits," offered Trevor.

"You do whatever you feel is the right way for your group to work and solve the problem of sorting them into two different groups," Lesley responded. "That means that one lot of objects has to have something the same about them, something similar or some way they can all go together and the other groups will have some other way of them all going together."

The children moved off and after an initial discussion about who would do what part they were able to sort the objects by a variety of criteria. When enough time had been given Lesley called them back to the blue mat and asked the children to give their reasons for sorting the objects. Lesley liked to praise the children who were working well as a way of encouraging those who were not on task.

"Look at Angela and Crystal," Lesley said. "I must make a comment about how beautifully those two work together. They obviously remembered all their jobs they had to do, the manager job and the speaker job and they work together very well. Would you like to share with the group how you sorted your things Crystal?"

"Well," Crystal replied. "We sorted ours from the ones that we can recycle and the ones that we can't."

"I thought that was a very interesting one," said Lesley. "I don't think I would have thought of that interesting one. Thank you Crystal."

Lesley made sure all the groups shared their different ways of sorting, congratulated them on the different ways they had sorted the material and went on to described the next part of the lesson. "Wow!" said Lesley, "We have got some really interesting ways haven't we. I'm going to come around to your groups now and give you a very special little thing your going to use to help you sort all those objects in maybe a different way."

"It's only one thing?" called out Ralph.

"Yes." Lesley replied. "It's one thing but it is going to help you sort all your other little things into two groups. You might find yet another way of sorting out the things you have got in your ice cream container. Sort of like a magic wand I suppose but its a little bit smaller. It is going to help you sort out the objects into two groups but I'm not going to tell you anything more other than that."

The children moved into their group to wait for the 'magic wand'. Kevin immediately recognised the magnet because he said it was metal and heavy. Lesley noticed that the magnet was not working too well but did not have another to offer him. She suggested that he ask another group to share its magnet when it had finished. Lesley spoke to another group who had not discovered it was a magnet. Darcy had worked out that it was hard and Nancy said it was metal. Lesley 'accidentally' dropped a paper clip onto the magnet that stuck and the children thought it might be a magnet.

"Ah!" Darcy sang out.

"Oh! What did I do?" Lesley asked.

"It's a magnet," replied Darcy incredulously.

"It's a magnet because they just do this," said Nancy. "They don't pick it up and fall down again - it just picks it up because magnets can pick things up, if it picks this one up. Oh! It can't pick this one up, but its metal."

Obviously the magnet was not strong but Darcy was able to manipulate it so that it gave a result. The children organised their items into hard and soft but when reminded that they needed to use a magic sorter, they changed the criterion to magnetic and non-magnetic. The bell rang and the children were instructed to stop and listen. Lesley had a sheet to help them record the information about which items had stuck to the magnet and which had not. They were asked to do this neatly. The children quickly settled to sharing the task of putting a circle around the 'yes' or 'no' beneath the pictures of the items supplied.

Lesley found that two boys working together were having difficulties with sharing the work. Mark had become tired of waiting for Andy to finish sharpening his pencil and had completed the groupings using a weak magnet. When he copied his results onto the sheet provided, the information was incorrect. Lesley suggestion that Andy needed to share in the work so that he should check the answers Mark had given. Both boys thought this was okay but Andy quickly found that the objects he thought should have stuck didn't. Lesley asked the girls in a nearby group to let Andy use their magnet.

"Look this one sticks now," said Andy.

"It's different," Mark said. "I'll have to cross out that one."

"Just put a cross through it and write the new answer," said Lesley.

Lesley rang the bell and asked the children to pack up their equipment and bring it with them when they sat on the blue mat. She then asked the children to share their ideas about what they had discovered when they used the magnet.

"We tried to sort our objects into lots and lots of interesting groups," Lesley began. "Next we used our magic wand. Now what was the magic wand? What was special about the magic wand I gave you, Kevin!"

"It was a magnet." Kevin replied.

"How did that change the way you were sorting your groups out, Anne?" asked Lesley.

"Well, because it sticks to metal things and you change your idea," said Anne.

"Anne, would you like to share what your group had in one group?" asked Lesley.

"We had the metal bottle lid and the safety pin and paper clip in one group and the twirly thing," she replied.

"When I looked at that I thought it's got plastic so it would go in the 'no' group," said Lesley.

The majority of groups were able to arrive at the conclusion that some items would stick to the magnets and others would not. The session was over before Lesley had an opportunity to cover all the group's findings, as she always liked to.

* * *

Lesley was happy to teach the new science program providing the science coordinator and the teacher's aide organised the equipment for her. On Monday she had a full teaching day with yard duty at lunchtime. As this was the beginning of the new program Lesley was still struggling with the need to prepare the equipment for each lesson. At the back of the teachers' resource book the items needed were listed for each lesson. The science coordinator collected some equipment and the teacher's aide added the rest. The list asked for magnets and the science coordinator had a box of magnets to share throughout the school. The type of magnet was specific in the teachers' lessons plan but the aide had not been given this to read. The idea of using the round ceramic magnets was meant to disguise the magnet properties of the 'magic wand'. Having little opportunity to exchange magnets Lesley proceeded with the lesson but found the children experienced frustrations when their magnets did not perform properly. Lesley was unaware that magnets lose their magnetism over time and was not overly concerned with the outcome of the lessons because she felt the children had been able to work well in their groups well enough.

* * *

The two stories illustrate how two experienced teachers implemented a new science program and in particular the way in which the supply and management of equipment influenced their lessons. The two teachers have varied experiences in learning and teaching science that was reflected in the way they resolved the issue of equipment in their lessons. Their knowledge about teaching was reflected in their understanding of pedagogical content knowledge, subject matter knowledge, general pedagogical knowledge, knowledge of self and knowledge of the milieu of teaching (Adams &

Krockover, 1997). In this chapter the first three categories of teachers' knowledge are used as a framework to analyse the two stories.

3.2 PEDAGOGICAL CONTENT KNOWLEDGE

Pedagogical content knowledge is the way in which teachers manage to connect the children with the subject matter. It includes teachers' knowledge of the curriculum, their knowledge of instructional strategies and their appreciation of students' understandings of subject matter. The two teachers in this study were teaching science using new resources and strategies. Two issues arose in relation to their ability to supply and manage equipment essential to the lesson. The first issue concerns the way in which the teachers accommodated the lack of good quality equipment in the lessons. The second issue concerns the role of explicit teaching notes in guiding teachers' use of science equipment.

With regard to the first issue, Lynley the Year Five teacher, had the responsibility of supplying the science equipment for the whole school. Lynley allowed herself time to collect the equipment from the storeroom before her lesson. She assumed that the equipment was where she had seen it last but she had not checked the quality. Instead of gathering the correct equipment Lynley had to improvise because there was no opportunity to replace the items. Lynley modified the introduction to the lesson to warn the children that the eyedroppers were perished and that they needed to replace the nail with a piece of cut wire. The children were preoccupied with these aspects of the procedure and needed a lot of encouragement to focus on creating the bottle diver.

> "How about you try it first," Lynley suggested. "Read the instructions and try it because it will work without the nail sometimes, other times you need to put the nail in. See if it will work without the nail first and if it won't come back and I will help you for sure."

Lynley also warned the students about the safety issues of using glass jars rather than plastic jugs because they were working outside on the concrete veranda.

For the Year Two class, the lack of appropriate equipment was not immediately apparent to Lesley. In the early stages of implementing the new science program Lesley relied upon the science coordinator to supply her equipment. She made it very clear that she would only be able to manage the science if she had help. What the science coordinator did not supply for the lesson, Lesley asked her aide to prepare. When the poor condition of the magnets was pointed out to Lesley she offered this explanation:

> My vivid memories were of the frenzied last minute search for the magnets, a vital piece of equipment for the lesson. We had to collect the magnets from another class's resource box as there was only one class set of them to be shared around all classes in the school. The magnets weren't in the place they were meant to be, so I went on a 'wild goose chase' around the school looking for them. I knew I only had 5 minutes to locate them before the lesson was due to start. I was always thankful for the time prior to the lesson because there was always some last minute organisation of materials or equipment needing to be done. The idea of having all the equipment and resources for a unit of work in a box in your classroom is wonderful, until something like this happens. (Lesley, Interview)

Lesley did not alter her lesson plan or replace the magnets. Some of the children exchanged their weak magnets for stronger ones. Lesley believed that the lesson was successful if the children were able to group the objects in some way. The key point in both of these lessons is that the teachers' unfamiliarity with the equipment impeded the flow of the lesson. The replacement of equipment in Lynley's class and the poor quality of the magnets in Lesley's class meant that valuable lesson time was taken up with technical and safety issues rather than allowing the children to explore the phenomena.

The second issue concerns the role of explicit written materials when establishing new teaching strategies. *Primary Investigations* was designed to support inexperienced teachers who were unsure of their ability to teach science. The teacher resource book is set out in a prescriptive manner with objectives, lesson plans and equipment clearly listed. The professional development offered to the teachers used peer-tutoring sessions to help the teachers understand the new material. Lynley's coping strategies involved memorising the sequence of the lesson. She seldom referred to the teacher resource book during the lesson. When the bottle diver failed to work before the lesson she used the resource book to go through the steps of constructing the bottle diver to help resolve the

problem. Although she followed the steps exactly, varying the water level and weight of the eyedropper, the eyedropper failed to operate effectively. As a last resort she checked the diagrams and realised that the eyedropper in the diagram was under the line of the water. When she altered the amount of water in the eyedropper, to suspend it under the level of water and operate successfully, she was none the wiser about the concept of air pressure. The italicised notes offered in the resource book as supporting information made this suggestion.

> Students should say it is a system. It has parts such as the eye-dropper, water and bottle. The parts interact to make the eye-dropper dive. Each part separately would not make this happen. Do not expect students to be able to explain why the eye-dropper rises and falls. (Australian Academy of Science, 1994, Book 5, p. 39)

Lynley was able to successfully complete the sequence of the lesson without understanding the concept of flotation.

In a similar way Lesley had no reason to suspect that the magnets in the school storeroom would not be suitable. When the magnets were located they were very old and many had become demagnetised unable to attract the lightest piece of wire. Lesley did not have the time or the resources to swap the magnets and decided to proceed with the lesson. She followed every step set out in the teachers' resource book. During the lesson she left it open in front of her and referred to it constantly. She was able to complete the steps of the lesson despite the poor magnets and the children were able to sort the material into categories.

The key point here is that both teachers were able to complete the lesson with some level of success by following the explicit instructions in the teachers resource book. The instructions were helpful in one sense because they provided step-by-step guidance for the teachers on how to assemble the equipment for the lesson. They were unhelpful in another sense because when the characteristics of the equipment available deviated from the instructions, the teachers were left floundering. Their lack of understanding about the concepts of flotation and magnetism did not stop the lesson progress because both teachers focused on the procedure of the lessons.

When the issue of poor equipment became apparent the experienced teachers were able to employ general pedagogical knowledge about classroom management to the science lesson. The teachers had developed established strategies from other subjects for managing equipment allowing them to adapt to the situation by modifying equipment and lesson sequence. The availability of an explicit instructional teachers resource book enabled them to complete their lesson despite the lack of knowledge about the concepts being developed.

3.3 SUBJECT MATTER KNOWLEDGE

Subject matter knowledge is the knowledge teachers have about science content. There are two issues related to the management of equipment. The first issue is how the teachers' lack of subject matter knowledge made it difficult for them to understand the ramifications of using poor quality equipment. The second issue is how the lack of a sound understanding of the concepts inhibited the teachers' abilities to maximise learning for the children.

The first issue deals with the dilemma the teachers faced when their lack of understanding of the concepts made it difficult for them to appreciate the teaching and learning implications using poor quality equipment. Lynley successfully built an operational bottle driver the night before the lesson but when she reconstructed the bottle diver on the day of the lesson she did not understand why the bottle diver would not work. It was only by carefully following the diagrams in the teachers' resource book that she was able to identify the position of the eyedropper. Her knowledge of flotation did not alert her to the need to have the eyedropper floating under the surface of the water.

> "There it is!" she cried. "The water level shows the eyedropper sitting just under the water level, the black line, and not above it."

Lesley's lack of knowledge about the properties of magnetics meant she was unaware that magnets lose their magnetism over time. After the difficulty of locating the magnets Lesley was not overly concerned about the issue of weak magnets. She was happy to have finally located them before the lesson was due to commence.

> "This was all Jessica could find in the school," Lesley said. "My Monday is very busy and I had to run all over school for these anyway. Jessica agreed to help us out with the material otherwise I would find it too hard."

The teachers focused on providing equipment so that the lesson could proceed. When the quality of the equipment was questionable the teachers did not understand how this affected the learning outcomes of the lesson. Both teachers were unable to exchange the equipment but they managed to complete the steps of the lesson.

The second issue deals with the lost opportunities for the children to establish their knowledge about the concepts being developed. The provision of equipment in the lesson was designed to provide the children with concrete hands-on experiences to develop their understanding of scientific concepts. Through a lack of understanding of the significance of this connection the teachers underestimated the need for good quality equipment. In the case of Lynley's lesson the need to highlight changes in the equipment diverted the children away from the phenomena to concerns about equipment irregularities and safety.

> "Now some of these," Lynley began. "Boys are you listening? Rodney you don't know if you need it yet dear. Your eyedropper may not need a small nail but today you have a piece of wire. To take the rubber off the glass stem it should come apart. Now if you have difficulty in taking the top off yours would you please give it to the speaker to bring to me so that I can help you. I don't want you to tear the rubber top if it can be avoided."

The Year Two lesson was possibly the first formal science experience about magnetism for many of the children in Lesley's class. The teacher resource book suggested the following focus for teachers.

> Let children discover for themselves the special properties of magnets. The focus of this lesson is on using a magnet as a tool to sort objects, rather than an investigation of the various properties of magnets, but children should begin to appreciate these properties. (Australian Academy of Science, 1994, Book 2, p.16)

Lesley was unable to exchange the magnets and focused on the procedural aspects of sorting objects in the lesson. The children successfully grouped their objects using a variety of categories unrelated to magnetism. The children were very excited about getting a 'magic sorter' to help with the second stage of the lesson. This excitement was short lived when some magnets did not behave as expected. For some children their knowledge of magnetism was confused.

> "Its a magnet because they just do this," said Nancy. "They don't pick it up and fall down again it just picks it up because magnets can pick things up, if it picks this one up. Oh! It can't pick this one up, but its metal."

When the children were given the opportunity to exchange the weak magnets for a working magnet, this only added to their frustration. They had to re-visit work they had previously carried out.

> "Look this one sticks now," said Andy.
>
> "Its different," Mark said. "I'll have to cross out that one."
>
> "Just put a cross through it and write the new answer," said Lesley.

The preoccupation with poor quality equipment became an issue in both classes. The teachers overcame the problems in different ways but, in both instances, the children were unable to concentrate on the phenomena they were exploring. Opportunities to extend the children's exploration were lost in negotiating alternatives to the poor equipment.

The key point is that both teachers did not understand the concepts of flotation and magnetism. Neither Lynley nor Lesley fully appreciated the relationship between the quality of the equipment and the scientific outcomes of the lesson. Hence, opportunities to extend the children's understanding about concepts were, in a sense, wasted.

3.4 GENERAL PEDAGOGICAL KNOWLEDGE

General pedagogical knowledge is the knowledge teachers hold about their classroom management. This is achieved through knowledge of learners, curriculum and appropriate instructions. General pedagogical knowledge can be transferred from one learning area to another as teachers develop strategies to deal with situations requiring similar management solutions. The main issue arising from these two stories concerns the seamless manner with which the teachers were able to adapt the lesson plan to accommodate the poor equipment.

Lynley had the responsibility of supplying equipment for the whole school and knew there were eyedroppers and nails in the science cupboard. When finalising her equipment, before the lesson, she was dismayed to find that the equipment was deficient. Lynley did not have the time or resources to exchange the eyedroppers but she was able to adapt the cut wire for nails and the glass jars for plastic jugs. Having established that it was still possible to make the bottle diver using the equipment supplied Lynley reorganised the sequence of the lesson to include warnings about the need to be careful with the equipment. Reflecting on the lesson Lynley talked about how she was able to remember the sequence of the lesson and what happens when incidents like this arise.

> Once I've focused on exactly what it is I'm going to be doing I read through all the lesson format and picture in my mind exactly how I'm going to do it. I visualise what the groups will be doing and I consider the time aspect. With preparation I make a model if there needs to be one. Like today I made the model at home and it was so simple but when I tried it at school I hadn't understood what I'd achieved. I had jagged it, so when it didn't work that really threw me. If something jolts, such as a misunderstanding somewhere then I follow the plan that I visualise and the rest will fit into place. (Lynley, Interview)

Lynley proceeded through the lesson by adapting her teaching strategies of visualising the sequence of the lesson. Lynley read through the teachers' resource book and visualised how she saw the lesson progress. She imagined how certain children would

react and think of ways of overcoming potential problems related to the management of the lesson.

Lesley decided that the issue of poor magnets was not an insurmountable problem because the children were only using the magnet as another means of classifying their objects. She focused on the process of sorting rather than developing an understanding of magnetism. With her resource book opened in front of her Lesley followed the lesson sequence. The children were excited at being given a 'magic wand' to help them sort their objects. Some children were able to guess that the object was a magnet because it was metal. When the poor quality of the magnets concerned the students Lesley allowed them to swap magnets with another group. Most of the children were reluctant to give up their magnet because they were busy exploring other objects around them. Lesley allowed more time for the groups who waited for their alternative magnets and again when they altered their recording sheets. At the end of the lesson Lesley recalled her frustration at having run out of time for discussion.

> "Even though we have an hour for the science lesson I always seem to run out of time. I like to make sure we have time for the children to share and compare their ideas. I like the idea of being able to bring the lesson together at the end." (Lesley, Interview)

Lesley felt that the children achieved the outcomes for the lesson because she had been able to follow the steps shown in the resource guide.

Notwithstanding difficulties with equipment, and the need to adjust these lesson strategies, both teachers found ways of coping. When the quality of the equipment became an issue they were both able to accommodate the necessary changes to the lesson plan. For Lynley this meant she spent quality time explaining the need for changes to the equipment and discouraging the children from exploring the equipment fully. Lesley chose to ignore the issue of the magnets and focused on getting through the lesson. Both teachers adapted to the poor equipment by altering their management techniques accordingly.

3.5 CONCLUSIONS

This chapter examines how these two experienced teachers managed equipment when teaching science. Management of equipment was an area of concern for both teachers as they introduce the new program. The two vignettes are analysed in terms of teachers' knowledge. In terms of their pedagogical content knowledge, although both teachers lacked an understanding of the concepts of flotation and magnetism they were able to complete the lesson by focusing on the procedures of the lessons. Valuable lesson time was taken up with technical and safety issues rather than allowing the children to explore the phenomena. The teachers' resource book with explicit lesson steps, equipment and suggested questions provided a safety net for the teachers. However teachers found that while the explicit procedures helped with lesson organisation they also led to an unhelpful dependence on instructions. In terms of subject matter knowledge the teachers' lack of knowledge about why the poor equipment impacted on the children's capacity to explore and develop their understanding of the new concepts. The resulting preoccupation with equipment issues restricted the children's exploration resulting in lost learning opportunities. In terms of general pedagogical knowledge the teachers familiarised themselves with the lesson plan and prepared the equipment to the best of their ability. They were both able to accommodate the necessary changes to the lesson plan with ease when the need arose. Both teachers negotiated around the poor equipment and altered their management techniques to maintain an even lesson flow.

CHAPTER 4

LANGUAGE OF SCIENCE

This chapter is about the central role of language in science lessons. Language underpins all aspects of education. When children and teachers engage in learning, language binds it together by negotiating understandings about the meanings of words. As infants, we rely on those around us to speak words consistently, in the right context, to establish meanings for words that label a person, place, toy, food, etc. (Fleer, 1992; Piaget, 1926). The acquisition of language is a remarkable achievement requiring what Holt (1967) sees as "patient and persistent experiment; by trying many thousands of times to make sounds, syllables, and words; by comparing his own sounds to the sounds made by people around him; and by gradually bring his own sounds closer to the others; above all, by being willing to do things wrong even while trying his best to do them right" (p. 56). Language acquisition is viewed as a basic learned activity of humans, that is not clearly set out and is fraught with mishap according to Chomsky (1965). As children busily search for the patterns to establish meaning to words they display a natural curiosity not unlike scientist. Children's attempts to use words are referenced against previous experiences, refined with the help of people around them and stored in categories and networks that make sense to them. The ordering of language is referred to by Sutton (1993) as 'schematising' and 'pattern seeking' (p. 1217). According to Sutton, the process of searching for the meaning of language is seen by Schwartz (1983) as children "busily exploring, testing, searching, and ordering experiences" (p.37).

When children enter primary school, and engage in initial language development, their understanding of words is firmly attached to experiences (Gardner, 1991; Lakoff & Johnston, 1980). As the children experience a new world of words and actions they are busily attempting to bring order to these new experiences because, as Schwartz (1983) suggests, "human intelligence imposes a grammar of sorts on experience and thus brings order to disorder and creates regularity out of chaos" (p. 35). The social aspects of language are a large part of education as children learn to function within a social setting

that is distinctly different to other learning settings with regulated rules and procedures. Language therefore is a socially sensitive construction, not just labels (Michaels & O'Connor, 1990; Sutton, 1993). The acquisition of language has many interacting factors that become more sophisticated and complex as children learn to include whole sentences, different meanings for the same words, intonation to convey meaning and correct tense. The field of language is complex and developing (Karmiloff -Smith, 1979)

Lakoff and Johnston (1980) describe three forms of experience that assist in the development of language - spatial, social, and emotional – arguing that we "conceptualise the non-physical *in terms of* the physical" (p. 59). This is useful for times when words are required to describe or label concepts that do not have distinct shapes. In science and mathematics there are many concepts that can be understood and described mathematically but do not have a concrete form. The children's store of language facilitates the development of further language associated with concepts and processes but the shift from oral language to a written language is complex and difficult. This change is seen as a shift from learning the relationship between meanings and sound to learning the relationship between oral language and the alphabet (Cazden, 1972). The ability to enhance language learning should include an integrated whole, natural, functional and meaningful novel experience that allows for error and should encourage children to learn from them. In this way children will respond to opportunities to engage in discussion helping them attach language and understandings, both oral and written, making meaning of new experiences (Gallas, 1995; Schwartz, 1983; Sutton, 1993). Fleer (1992) suggests that this supportive learning or scaffolding, allows teachers to assist students as joint owners when learning context, helping the student develop their own understanding of science. Language acquisition is complex and evolves as the child develops different levels of sophistication and blends new experiences. It is suggested by Vygotsky (1962) that, "Word meanings are dynamic rather than static formations. They change as the child develops; they change also with the various ways in which thought functions" (p. 124).

When subjects such as science are taught there is an appreciation for the need to learn a particular language to express ideas and concepts (Lemke, 1990). The science language is specific and often difficult to conceptualise and poses problems for teachers and children in the learning process. Teachers and children come to their science learning

with a set of experiences that have helped develop some science knowledge and terminology. This store of experiences is then set against new experiences that White (1994) found "the learner either seals off the new knowledge from his/her extensive experience-based knowledge, or struggles to integrate them" (p. 256). People have a wide range of meanings for words used in common, such as 'animal' that is different to the classifications used in science (Bell, 1981; Freyberg, 1985; Osborne, 1985; White, 1994). When defining terms such as 'wet' or 'air pressure' for example, it is extremely difficult to attach words to the concept to discuss questions such as "Does the skin get wet?" How would you describe the feeling of air pressure on the skin, for example?

Some of the scientific language used to describe processes and abstract concepts can only be demonstrated through mathematics (Lakoff & Johnston, 1980; White, 1994). Science language, although created for a specific purpose, is seen by many to create a shroud of mystery around the learning of science concepts and procedures (Scott, 1992; Sutton, 1992). Therefore school science language is often seen as Gallas (1995) states "exclusive discourse that one must master, a dispassionate discourse that relies on special structures: on hypotheses, experimentation, the identification of variables, replication, logic, the understanding of paradigms, and above all an attitude of certainly…science is seen as a field for the talented few" (p. 7). Science language, like all languages, has developed from social activity to arrive at a consensus of understanding through a process of communication to establish meaning and is very difficult to change (Sutton, 1993). Science language also has its origins in the works of people who have added to the store of scientific knowledge. Each has provided names that now describe procedure theories, equipment and methods used for recording (e.g. pipettes from the French). This means that new words in science are often the result of what makes sense to scientist with their collective, particular experiences further shrouding the language in mystery (Carr, Hayes & Symington, 1991).

Using scientific language creates a particular problem for primary teachers who often lack subject matter knowledge and pedagogical content knowledge (Appleton, 1991; Carlsen, 1993; Carr Hayes & Symington, 1991; DEET, 1989; Symington, 1980; Yates & Goodrum, 1990). For many primary teachers, their own experiences as science students originate from what Sutton (1993) describes as descriptive, objective truths that were to be learned and not questioned. This is supported by Carr, Hayes and Symington (1991)

who found "the language of science is…commonly regarded as exact, unambiguous, and as a medium for direct communication of the 'truths' of science" (p. 79). Limited understanding of science content knowledge by teachers produces a lack of confidence to teach science and engage in what Gallas (1995) describes as "science talk". The ability to engage in talking about science requires teachers to understand the concepts they are teaching, enabling them to lead the discussions and supply questions to direct children's understandings of concepts being explored (Reddy, Jacobs, McCrohon & Herrenkohl, 1998).

Another important consideration in the discussion of language development is the role of discourse to the process. If language development relies on children engaging in experiences and negotiating understanding about meaning of words then discourse is essential (Carr, Hayes & Symington, 1991; Reardon, 1993). Science lessons follow practices used in good language lessons to support constructive conversations about science concepts (Fleer, 1992; Gallas, 1995). Lists of features developed by Edwards and Mercer (1990) for classroom discourse include children's contribution, enunciation and phrases, ignoring contributions, joint-knowledge markers, cued responses, paraphrasing, recapping and implicit knowledge. The use of small group strategies is suggested to encouraging discourse during investigations but this is not a guarantee that children are fully engaged in the lesson. The need for teachers to get through a prescribed curriculum creates a dilemma when concepts and activities require time to develop. Gallas (1995) suggests that teachers take charge of discourse because "children's remarks are filtered through the teacher's mouth, usually in the form of revoicing and questioning" (p. 10). Edwards and Mercer (1990) state "The pupils frequently remain embedded in rituals and procedures, having failed to grasp the overall purpose of what they have done, including the general concepts and principles that a particular lesson's activities was designed to inculcate" (p. 104). Classroom discourse is seen as a means of socialisation of both knowledge and behaviour, initiating the child into the realm of educational procedures and the educational community (Edwards & Mercer, 1990, Gee 1990, Gleason 1988). Gallas (1995) believes that "children come to school fully prepared to engage in scientific activity and the school, not recognising the real nature of scientific thinking and discovery, directs its efforts toward training those natural abilities out of the children" (p. 13).

In summary, the literature reinforces the notion that the acquisition of language is socially constructed and is also dependant on the modelling and support offered to the learner. Science is seen as a subject that has a discretely different language that underpins understanding of science concepts. Some people find science a difficult subject to understand because they have not acquired the language skills. Language acquisition begins with discourse as children test their understanding of the sound of the word with the action or concept it represents. Teachers control classroom discourse in the classroom and in primary science lessons much of this is directed towards maintaining control. Small group work is a strategy often promoted to facilitate oral discussion of new ideas, but many teachers prefer children to work quietly. Teachers also lack confidence with subject matter knowledge, inhibiting their ability to engage with children in 'science talk'.

4.1 VIGNETTES ABOUT THE LANGUAGE OF SCIENCE

The two vignettes presented in this chapter illustrate the importance of language in developing scientific concepts and procedures. The first vignette is about Lynley's Year Five children building a Hovercraft to reinforce the concept of air movement within a system. The children had, in earlier lessons, investigated systems through simple experiments and were becoming better at observing and discussing the interactions that occurred. The second story describes an investigation of the properties of Oobleck (a mixture of cornflour and water) in Lesley's Year Two classroom. The process of classifying items according to criteria was the focus of the Year Two program. The lesson on Oobleck aimed to familiarise the children with four of their five senses when classifying items or objects.

4.1.1 Hovercrafts and Air Pressure

The Year Five children had been introduced to the concept of flotation in an introductory lesson earlier in the year by investigating an activity of a bottle diver. Using a two litre bottle full of water they had submerged an eye dropper, weighted with water, below the level of the water. Once the bottle was sealed with a lid, the children exerted

pressure on the sides of the bottle and the eye-dropper sank towards the bottom of the bottle.

This lesson required children to construct a simple Hovercraft using cardboard and adhesive tape. In the second session they refined their ideas and used a variety of equipment to develop a group Hovercraft able to negotiate an obstacle course. The lesson began with an exploration of children's ideas about the nature of air. Lynley asked selected children to demonstrate air pressure by pushing down into a plastic bag secured with an elastic band over the mouth of a jar.

"Wow! I can't do it," Rachel cried.

"Why doesn't the air go from the plastic bag when she pushes on there, Christy?" she asked.

"It is already full of air," Christy answered.

"It is already full of air," repeated Lynley. "That is Christy's version, but who has got a different version? What was in the jar Greg?"

"Air," replied Greg.

"Alright," said Lynley. "So what can we say about the properties of air?"

"It's strong," said Roy.

"It's probably gas," added Neil.

"It is a gas, yes," began Lynley. "But what physical properties did you just notice about the air?"

"Um, is the same as a fluid like water," suggested Mike.

"Good boy, it has flexibility," said Lynley. "Anyone else, come on what else did the air do?"

"Full," said Roy. "The air takes space."

"Excellent Roy, because air takes up space," Lynley replied. "Now if we know that air takes up space (she wrote this on the board) then anything pushing down on it is not going to be able to come down to the surface. (Lynley continued to demonstrate by pushing down onto the bag in the jar.) It takes up the space so if we have got air taking up space and it came up underneath something what is it going to do? Think of what happens when air comes under things."

"It expands," said Renee.

"It floats," said Jacky.

"It floats, yes that's a good idea," said Lynley. "What does she really mean by floating?"

"Um, it rises," said Neil.

"Good boy, it..." lead Lynley.

"Pushes up," suggested Ross.

"Yes," said Lynley. "Now if we know that air takes up space then anything pushing down on it is not going to be able to come down to the surface. It takes up the space so if we have got air taking up space and it comes up underneath something what is it going to do? It's going to be able to have the pressure underneath to hold up the object and that's basically the principle we are looking at today. We are going to find out things that are held up by air or space."

To consolidate the concept of air supporting objects some children were asked to blow up balloons that were placed under an upturned desk. Children were invited to stand on the table until it held six of them to demonstrate the ability of contained air to withstand

pressure. There was a lot of giggling and squealing as each of the six climbed onto the table but the balloons didn't burst. The children went to the recess break highly excited and motivated about the science lesson.

After the break the children were to construct a model Hovercraft cutting out a photocopied design from paper. Lesley had placed all the equipment on each group's table and the children were to work through the steps given in their workbooks. Enthusiastically the children began to create their paper Hovercrafts but after ten minutes Lesley rang the bell to stop the class. She congratulated them on making their Hovercrafts and then instructed them to clear their desk to carry out step seven of the lesson, which was to blow down the centre tube to make the craft hover above the table.

"Now quickly in your groups carry out step seven." said Lynley. "Make sure the tube does not go down to the surface of the table. Judy has already asked if she can cut the bottom of the tube because it is touching the surface and stopping the Hovercraft from moving freely. Take turns blowing into the tube and see what happens. I want you to do it one at a time and discuss what happens please."

The children cleared their desks and took turns at blowing into the Hovercraft. The children also found it very hard to manoeuvre the Hovercraft. After a few minutes Lynley again rang the bell to stop the children.

"Right, very interesting watching you do this because I actually only saw two people doing it correctly," said Lynley. "I will read through the instructions and you just listen."

Lynley carefully read through the instructions emphasising each of the six steps by pointing to her model Hovercraft. Time was running out and the children still had to modify their models to improve the performance. Lynley was anxious about the children's lack of progress because she had hoped to condense the three lessons on the Hovercraft to two. The second lesson, a week later, started with a revision.

"We made a Hovercraft last week," began Lynley. "Greg would you like to stand up and explain basically what a Hovercraft is and how it operates?"

"Hmm," he began, "A Hovercraft pulls up, bends up air and pushes it down so it lifts up."

Lynley was busy at the back of the room, gathering items for the construction of the Hovercraft and the class began to whisper to each other.

"Is there anything else you could say Mike?" Lynley asked. "Neil can you just let him talk please. Linda would you like to answer that? What was one thing that made the Hovercraft work?"

"It had this skirt full of air and that made it skim along." Linda replied.

"Denis can you explain what a Hovercraft is please," asked Lynley.

"Like a big cushion," began Denis. "It takes the air up and pushes it down."

"So where you have the base," Lynley added, "we now add a skirt to trap the air that is sent downwards through that central cylinder so the actual craft comes up and hovers above the surface. When you have another look at the diagram in your book you can see that clearly. Last week we really didn't achieve that."

Lynley read the passage from the children's book about how the mining industry and others have used such craft to help transport supplies and people through difficult terrain. She went over the reason the Hovercraft was invented by identifying the need for a craft that was able to travel over both land and water. Rachel added how she remembered reading how the Hovercraft stops people feeling seasick because it hovers over the water.

"It skims," added Lynley. "It hovers across the waves instead of pitching up and down like a boat does or rocking from side to side."

"What do you think may happen if there was a big swell?" asked Mike.

"It would slide up, and flip over the waves," said Neil.

"It possibly could but what does it need to be able to hover?" asked Lynley.

"A flat surface," cried Greg. "It needs a flat surface."

"Yes a surface that will help to trap the air between it and the craft," Lynley agreed. "It needs to be able to hover above but it still needs the air trapped. Now if you have huge swells it's going to be lifted onto a swell and the air is going to escape isn't it so it's not going to be that efficient. Now whether my theory or my analysis of that is correct I don't know, but that's what I'm assuming. Mike presented me with this huge problem with this big swell and to me that is what will happen. Also I haven't read enough on this and maybe you people can read about it."

Mike often presented challenging questions that tested Lynley's knowledge of the concepts being taught. Achieving the objectives of the lessons enabled the children to investigate how the Hovercraft operated but Lynley would have liked more time to read around the topic of air pressure and the operations of a Hovercraft. Lynley found that the children needed lots of time to discuss and modify their plans to achieve a working model and no two groups produced the same model Hovercraft.

* * *

The story of Hovercrafts illustrated how it is difficult to respond, with authority, to questions raised by children about the scientific nature of air. The activity of placing the hand in the air bag, a plastic bag filled with air over the mouth of a jar secured with a strong elastic band, was well structured to gain the children's attention. Lynley used this opportunity to extend the discussion and to focus on language labels describing the phenomena. To reinforce this understanding, Lynley included the balloons under an upturned table demonstration to reinforce the idea that contained air can hold up weight. She had seen the demonstration at a local science show day and thought it was very graphic. The language generated was through hands-on experiences, in a social setting incorporating the children's prior knowledge and allowing them time to negotiate meanings for the words needed by the children to describe the nature of air. Lynley shared Mike's question of the Hovercraft and high seas with the class to test their

understanding. Once the class had attempted to answer the question Lynley gave her explanation as a way of modelling problem solving for them.

* * *

4.1.2 Is Oobleck A Solid Or A Liquid?

The Year Two class were investigating Oobleck, a substance made from mixing cornflour and water, to encourage them to observe and develop some classification criteria. The criteria were to be based on the senses of touch, smell, sight and sound. For safety reasons the sense of taste was not used as children were being discouraged from tasting unknown substances. The lesson steps, as described in the resource book, were quite explicit and relied on the teacher giving clear instructions about what the children would be doing. The criteria suggested by the children were to be entered onto a class chart under the heading for each of the senses. The headings were written as the symbols of a hand, nose, eye and ear. The chart was pinned to the whiteboard in full view of the class and Lesley later displayed it in the classroom.

"Bottoms on the carpets," began Lesley. "We are going outside to do today's activity because it could be a little bit messy. I want you and your partner to find a space to sit on the floor. One child from your group can collect the equipment and look at what's inside but watch it doesn't bite. I want you just to touch it and to think of how you could describe how it feels. It could be hairy or prickly or if it was an echidna it would feel maybe spiky so have a think about some words to describe it."

Lesley supplied each group with some Oobleck inside a plastic icecream container. The children began exploring the white substance in the container while Lesley moved around listening to their descriptions. At the end of the play session Lesley asked them to suggest words for her to write under the heading of touch on the whiteboard. Lesley called the children to attention and asked if anyone had a word to describe what it felt like. She was ready to write the words under the heading of 'feel' using a symbol of a hand.

"Who has got a word?" asked Lesley. "A word, Gina, we are stopping and listening together. You will have lots of time to experiment and feel it and do other things with it in a minute. I want some words you thought of. Sandra when you touched it, how did it feel? What did it feel like when you touched it? Casey?"

"It was hard," suggested Casey.

"It felt hard," Lesley said, while writing it on the whiteboard. "What other words Denis? How did it feel on your skin? What was the feeling that you got?"

"Cold and it dried up on my fingers," said Denis."

"Grace what did you think of?" asked Lesley.

"It went smooth," she said.

"Smooth," said Lesley. "Put your hand up if you thought of smooth as well. That's the one I thought of straight away."

"When you put your finger in it and then you take it out, it dried up a bit and felt smooth," Grace added.

"Grace made an interesting comment," said Lesley. "She said that it felt smooth when she touch it as well as after she took her fingers away from it and she rubbed her fingers together and the one that was touching, the whatever it is, felt very smooth. Another word Alice. So far we have got hard, cold, smooth."

"Like powder," Anne offered.

"Shh" warned Lesley. "When we are working as a whole class Trevor you need to listen. So it felt powdery, would that be the word to describe it then, so it was powdery. Marnie have you got another one?"

"Watery," said Marnie.

"Watery," added Lesley. "So it felt watery to you like as though it was, you were putting your finger in some water. So runny, watery, any other words Steven."

"Sticky!" said Steven.

"Sticky that's a good one," agreed Lesley. "Sticky as though you felt it was going to stick to your finger. Any other different ones? Ralph how did it feel to you?"

"It feels gooey or like sloppy," Ralph said.

"Sloppy is a good one," Lesley said. "That describes it more than saying just gooey I think. Let's go down now and look at the other columns. I'm going to give you and your partner some more time to explore whatever it is in the container and I want you to think of some words that would tell us what it looks like, what it smells like and what it sound like. Does it make any strange noises?"

With the children fully engaged in exploring the new substance Lesley and I discussed the way that Oobleck behaved. She wanted to know why it appeared runny and milky but went dry and even crumbly if worked into a ball.

"Why does it do this?" Lesley asked. "What is it?"

I had not really given the matter a lot of thought until now because the lesson was successful without a deeper understanding of the principles behind the nature of starch and water. My answer reflected ideas I had observed while watching the children.

"It seems to hold a lot of moisture." I replied. "It's like the sand particles on the beach which are small. The reason is in the book, that's where the book is good, it gives you background information. Starches don't actually dissolve in water, they need cooking to break down."

"That's why when you cook it like in sauces and things..." Lesley began.

"That actually denatures the starch and it thickens the solution," I added.

"Right, good but why," Lesley began, but was then interrupted by the children and needed to attend to the class.

The lesson ran out of time before Lesley had completed all the activities so she had to leave the comparison of Oobleck to water and plasticine for the following week. At the end of the day Lesley told me how she had been looking forward to this lesson because during a Primary Investigations professional development session the group of teachers she worked with had been fascinated by the way that Oobleck behaved.

* * *

There was no doubt that Oobleck provided a stimulating substance from which the children were able to develop a list of words associated with the feel, smell, look and sound. There was also the opportunity to introduce the children to the first level of observation skills, those associated with the senses. Lesley allowed the children to contribute words from their own vocabulary during the discussions. Although Lesley had been able to compile lists of words to describe what the children observed, she had not resolved to her own satisfaction the question of what made Oobleck behave in the way it did. Lack of science knowledge didn't detract from the lesson, but it left Lesley wondering what might be an appropriate scientific explanation for the behaviour of the substance.

* * *

These two stories describe the way in which these two experienced teachers used language in their teaching. Throughout the science program new words were introduced at regular intervals. The manner in which each teacher developed the links between concrete work and language varied according to their knowledge about teaching. In this chapter the two stories are analysed using the following categories of teacher's knowledge - pedagogical content knowledge, subject matter knowledge and general pedagogical knowledge (Adams & Krockover, 1997).

4.2 PEDAGOGICAL CONTENT KNOWLEDGE

Pedagogical content knowledge is reflected in the knowledge teachers have of the curriculum, children's understandings of subject matter and their use of instructional strategies. Both teachers in this study were dealing with new strategies for teaching science. Two issues arise in relation to the familiarity and ease with which the teachers engaged in teaching the content of science. The first issue was the way in which the teachers were noticeably comfortable and confident when building children's language from the concrete experiences to explanations. The second issue concerns the underlying dilemma when teachers to allow the children to explore without telling them the answers.

The first issue is how noticeably comfortable the teachers were when engaged in the development of words related to the phenomena they were investigating. Developing meaning for words was familiar as both teachers were also responsible for teaching formal language to their classes. The technique of brainstorming to elicit words about an object or phenomena could be the same for beginning lessons on any subject - language, social science, health, mathematics or art, for example. Writing new words on the board provided a link between oral and written words. The words were then used as a reference throughout the lesson and, in the case of the Year Five class, later placed on the spelling list for the week. Both teachers provided tactile experiences for their students as a basis for the development of new language, helping the children build their language-specific knowledge. The lessons also reinforced the basic scientific skill of observing, allowing the children opportunities to refine their subject-specific language, producing labels for the children are able to attach to scientific investigation and phenomena.

Both teachers also used the strategies of repetition and expansion to construct words and ideas. In this way they encouraged and negotiated appropriate words for their experiences. The use of concrete activities gave the children the opportunity to explore the phenomena fully in spatial, social and emotional ways. Repetition and expansion was based on acceptance of ideas given by children without censure. Through questioning and support the children were encouraged to consider other words and ideas. In Lynley's class, the concept problems and solutions – when the phenomena depends on

the nature of air and its properties – is a difficult notion with which to engage within using multiple senses.

The teacher resource book for Year Five suggests the activity of pushing the bag into the jar as a way to:

> Help students to understand that the air in the bag takes up space and stops the bag from being pushed into the jar. (Australian Academy of Science, Book 5, 1994)

The initial class discussion showed how the hands-on activities generated discussion rich in subject specific words. During this session Lynley used repetition and expansion, not only to encourage descriptive words but also to explore the concept of the nature of air. The words were then written on the board and used at a later date during other language sessions. The work during her University course helped her reflect upon how important language is when describing phenomena.

> "It floats," said Jacky.
>
> "It floats, yes that's a good idea," said Lynley. "What does she really mean by floating?"
>
> "Um, it rises," said Neil.
>
> "Good boy, it..." lead Lynley.
>
> "Pushes up," suggested Ross.
>
> "Yes," said Lynley. "Now if we know that air takes up space then anything pushing down on it is not going to be able to come down to the surface. It takes up the space so if we have got air taking up space and it comes up underneath something what is it going to do? It's going to be able to have the pressure underneath to hold up the object and that's basically the principle we are looking at today. We are going to find out things that are held up by air or space."

For Lesley's Year Two class, the lesson was based on creating a list of words to describe the substance Oobleck. The teachers' resource book provides commentaries in italics, giving additional language specific information about the lesson.

> If children describe the Oobleck as 'strange' or 'yucky', encourage them to use words that describe its texture and consistency. Explain that words that describe such things as colour, shape or behaviour describe the 'properties' of Oobleck. (The behaviour of Oobleck is 'what it does' - runs, flows, drips and so on) Encourage the children to use the word 'property' in context so that they begin to develop an understanding of the term. (Australian Academy of Science, Book 2, 1994 p. 46-47)

This 'whole language' approach was similar to the way in which Lesley had previously taught science. She used science topics that followed the language theme she was developing for the term. Lesley was able to built on the children's language across a wide range of subjects using this cross-curricula strategy. In this lesson, Lesley's reference to the Oobleck being like an echidna linked this experience to work the class was doing in language about Australian animals. Repetition and expansion was also a feature of Lesley's work with the children. She answered child's single word suggestions by placing the word in a sentence. In this way she encouraged others to contribute additional descriptive words to build up the picture of how the Oobleck felt.

> "Watery," said Marnie.
>
> "Watery," added Lesley. "So it felt watery to you like as though it was, you were putting your finger in some water. So runny, watery, any other words Steven."
>
> "Sticky!" said Steven.
>
> "Sticky that's a good one," agreed Lesley. "Sticky as though you felt it was going to stick to your finger. Any other different ones? Ralph how did it feel to you?"

The second pedagogical content knowledge issue relates to how the teachers managed the dilemma of allowing children to explore, versus telling them the answers. Both teachers, particularly Lynley, struggled with this. She believed that science is delivered, like truths, usually in lecture format. She needed to assure herself that the children would 'get' the right answer. Consolidation of information was by class discussion at the

end of the lesson. Lynley felt she needed to stop the class, reiterate what they should have achieved and discovered so they got the right information from the lesson. It was too important to leave it to chance. When Lynley began the second session she made it clear to the students what she wanted them to achieve.

> "So where you have the base," Lynley added. "We now add a skirt to trap the air that is sent downwards through that central cylinder you had so the actual craft comes up and hovers above the surface. When you have another look at the diagram in your book you can see that clearly. Last week we really didn't achieve that.

In contrast Lesley used discussion session as a summing up of the discoveries allowing time for the children to share their findings. She also used these sessions to give instructions about what the children needed to accomplish in their groups.

> "Let's go down now and look at the other columns," Lesley said. "I'm going to give you and your partner some more time to explore whatever it is in the container and I want you to think of some words that would tell us what it looks like, what it smells like and what it sound like. Does it make any strange noises?"

Both teachers used discussion to allow the children an opportunity to share their information about what they had experienced during the activity. Lynley always added her summary of the knowledge that she thought the children should have achieved in the session by using the lecturing format.

4.3 SUBJECT MATTER KNOWLEDGE

Subject matter knowledge is the knowledge teachers hold of science content. Both teachers had limited exposure to the physical and chemical aspects of science, having studied biology in their final years at school. Lack of content knowledge was a concern to the both teachers. Sometimes they found themselves unable to understand the science concepts they were required to teach and consequently unable to maximise science learning for the children. The two teachers deal with the gaps in their science knowledge in different ways.

Lynley, as the Year Five science coordinator, was instrumental in bringing the new science program into the school. Lynley saw herself as a crucial source of scientific information for the children and often expressed frustration at her lack of knowledge. She had enrolled in a University course to upgrade her content knowledge. Lynley often discussed scientific concepts with her husband, Lewis, before and after lessons to see if she could have improved on any aspects of the lesson.

> Children are continually encouraged to think critically, to question and to analyse. To foster this within the child, satisfactory directions and answers from a knowledgeable source must be available. Incorrect or misleading information only serves to dampen a child's enthusiasm and expectations. When I asked Lewis about the air getting trapped in the balloons he pointed out that I hadn't taken into account the balloon itself. If the balloon is weak or if the surface we use damages it, it will not hold the air. I didn't have time to explain that to the children but I think they got the idea that contained air can hold up objects. (Lynley, Interview)

Lynley was always willing to answer questions put to her by her students. For example, Mike often asked questions about issues not essential to the success of the lesson. The questions tested her science knowledge but Lynley saw these challenges as a way of role modelling how she thought through scientific problems. She was comfortable with the idea that she was a source of information.

> Yes a surface that will help to trap the air between it and the craft. It needs to be able to hover above but it still needs the air trapped. Now if you have huge swells it's going to be lifted onto a swell and the air is going to escape isn't it so it's not going to be that efficient. Now whether my theory or my analysis of that is correct I don't know, but that's what I'm assuming. Mike presented me with this huge problem with this big swell and to me that is what will happen. Also I haven't read enough on this and maybe you people can read about it. (Lynley, Interview)

For Lesley, the lack of understanding about the nature of Oobleck was not detrimental to the lesson because of her emphasis on language. Her experience in the field of language produced a seamless lesson. Lesley was a coordinator in her school for the language program *First Steps* and was responsible for facilitating the implementation of the course. Lesley was looking forward to exploring the Oobleck with the children after her experience during the professional development day. How Oobleck worked was

only of personal interest to her and did not detract from the efficient way she generated the list of descriptive words.

The two teachers' in this study acknowledged that their subject content knowledge was inadequate. Both teachers were able to successfully negotiate the sequence of the lessons and provide opportunity for the children to investigate science concepts. The teachers were willing to improve their knowledge and attempted to answer questions raised during the lesson. Both teachers experienced awkward moments because their level of subject content knowledge makes the task of teaching science and guiding children's inquiry's challenging.

4.4 GENERAL PEDAGOGICAL KNOWLEDGE

General pedagogical knowledge is the knowledge teachers hold about their classroom management. In this chapter I focus on how the two teachers used language in the classroom and how their use of language was connected to their general pedagogical knowledge. Two strategies were apparent. Firstly discourse was used as a control mechanism to discipline children in group discussions. Both teachers controlled the conversations in whole-class situations and to a lesser extent when the children were working in groups with their peers. Secondly the teachers used lecturing as a control mechanism, ensuring the children were on task and keeping up with the sequence of the lesson.

Firstly, an example of how Lynley used discourse to control the behaviour of the class can be found in the second lesson. The class was seated at the front of the room and at the last minute Lynley was looking around the room for items for the lesson. When the children began to talk amongst themselves Lynley fired off questions to keep them quiet.

> "Is there anything else you could say Mike?" Lynley asked. "Nathan can you just let him talk please. Linda would you like to answer that? What was one thing that made the Hovercraft work?"

Lesley also used class discussions as a form of discipline to keep children focused on the lesson. Lesley, like Lynley, called upon one child to answer a question then moved to

another once she had his/her attention. In this way the discussion became a means of controlling the noise level and focusing on the task at hand.

> "Who has got a word?" asked Lesley. "A word, Gina, were stopping and listening in together. You will have lots of time to experiment and feel it and do other things with it in a minute. I want some words you thought of. Sandra when you touched it. How did it feel? What did it feel like when you touch it? Casey?"

Secondly, Lynley used a lecturing mode to stop the class on occasions to ensure that they were on task. She used the first 15 minutes of the lesson to go carefully over instructions in spite of the fact that the children had workbooks containing all the lessons steps. By 'lecturing' Lesley was able to control the noise level if the groups got too excited or were off task. Towards the end of the first lesson Lynley was conscious of running out of time because the children still had to modify their craft. Lynley stopped the class and gave explicit instructions about the six steps they should have completed. She then carefully went over the last step to ensure they fully understood what was required.

> "Right, very interesting watching you do this because I actually only saw two people doing it correctly," said Lynley. "I will read through the instructions and you just listen."

Lesley also used the lecturing mode to make sure that the children had completed their tasks. In the Year Two class the children did not have written instructions to refer to. Lesley would start the lesson with approximately 15 minutes of brainstorming and instructions about what was required during the lesson. When she recorded the children's words about the Oobleck, she used this opportunity to bring the class together. Lesley did not provide the children with a summary of their findings. She ran out of time to complete the lesson because she was unfamiliar with the content.

The two teachers were able to use familiar teaching strategies, through discourse, to control the movement and learning of their children. For Lynley the use of lecturing during the lesson was done at intervals to make sure the children were on task. Lynley also used the lecturing or transmission mode to assure herself that the children had heard the information in the right sequence. For Lesley instructions were necessary

because the children did not have a book to rely on. Lesley encouraged and developed the ideas the children presented much as she would for any language lesson. Both teachers called on children to present their ideas, even if they had not offered to do so, as a means of gaining their attention during discussion. For both teachers, management of the classroom relied on their ability to take control of the discourse.

4.5 CONCLUSIONS

This chapter examines how these two experienced teachers developed and used language when teaching science. In particular it looks at how the teachers' managed to assist children to talk about science and explore science phenomena. The vignettes focus on language development and have been analysed using three teaching knowledge categories. In terms of pedagogical content knowledge, the two teachers were most noticeably comfortable and confident when building the children's language from the concrete activities to the explanations. They used tried and true strategies of repetition and expansion to encourage the children to provide words for the phenomena under investigation. An underlying dilemma for the teachers was whether to allow the children to explore in an open-ended way or to tell them the answers.

In relation to subject matter knowledge the teachers sometimes felt uncomfortable about their inability to deliver the right answers. The Year Five teacher had recently attended a university course to improve her science content knowledge. For the Year Two teacher the lack of knowledge was not as important an issue because the lesson resembled a language lesson. In terms of general pedagogical knowledge the teachers used discourse as a means of controlling the children during lessons. Both teachers called upon children to answer questions during discussions to get their attention rather than add to their science knowledge. The Year Five teacher also used lecturing as a means of managing the children if they became too rowdy or appeared to be not working as quickly as anticipated. Lecturing was also used to ensure the children had got the right idea during the lesson and were able to make appropriate decisions at the end of the lesson. The two experienced teachers tried to facilitate children's understanding of new ideas and adapted language strategies to their science lessons.

CHAPTER 5

TEACHERS' CERTAINTY

This chapter examines primary teachers certainty (or uncertainty) about teaching science. On the one hand primary teachers believe that science lessons should be interactive, hands-on and allow for discussion of children's ideas about their world (Paris & Cunningham, 1996). On the other hand, primary teachers are often concerned that, by giving children the experiences of investigating science problems, there is no guarantee that they understand the science underlining the activity. While teachers like to stimulate discussions and follow up on interesting leads often they are also working towards the coverage of particular science concepts and skills. Oftentimes they revert to lecturing and presenting 'facts' when they need assurance that they have covered the 'right information' for a particular topic or concept. According to Abell (2002) primary teachers "envision themselves making science accessible to all children via experiences with science phenomena and science talk … However, their school science experiences have led them to also believe that it is a teacher's responsibility to make sure all children take away the products of science from the lesson. Thus they often reach closure on science activity by expecting or presenting the scientific explanation. (p. 155)"

During their own education teachers develop conflicting beliefs "about their world, some of which they use in the school classroom, others in the world outside" (Carr, 1994, p. 149). This duality is overlaid with beliefs that some science topics, such as physics and chemistry, are difficult to understand for gender reasons. Teacher's personal experience of learning science at school contributes to their lack of understanding about science concepts (Louden & Wallace, 1990; McDiarmid, Ball & Anderson, 1989; Paige, 1994; Skamp, 1992; Zeichner & Gore, 1990). If teachers are unsure of their beliefs in science as a subject, it is difficult for them to develop this in their children (Brickhouse & Bodner, 1992; Lumpe, Haney, Czerniak, 2000; Shapiro, 1994). These learned attitudes contribute to the dilemma that primary teachers face - knowing that science is important for their children but believing that they are ill equipped to help their children

understand the 'truths' of science (Abell, Bryan, & Anderson, 1998; Akerson, Flick & Lederman, 2000).

Teachers attempt to accommodate the two images of science when striving to provide effective science teaching. One horn of the certainty dilemma involves trusting that the experiences given to the children in science lessons are a powerful way of learning. The other horn of the dilemma involves providing 'right' answers to fill in the gaps in the children's knowledge. Often the dilemma is resolved by presenting science as 'facts' to be memorised and learned, often divorced of experiences. This dilemma is further complicated by the teachers' lack of knowledge about how to make the connections between the experiential (process) and the concepts (content). Teachers' lack of knowledge hinders their ability to recognise when a child's understanding needs modifications. McDiarmid, Ball and Anderson (1989) suggest that "teachers' capacity to pose questions, select task, evaluate their pupils' understanding, and make curricular choices all depend on how they themselves understand the subject matter" (p. 198). In particular physics and chemistry are seen as too difficult for most primary teachers because of a lack of confidence about content knowledge. On the other hand biology is a familiar, comfortable science that stems from memories primary teachers have of their primary science days (Paige, 1994).

Some teachers are so uncertain about teaching that they avoid teaching the subject altogether other teachers revert to a preferred transmission method of teaching when faced with uncertainty and in science this is often manifested in the lecture mode (Ball, 1997; Kahle, 1988; Licht, Stader & Swenson, 1989). Teachers adopt the lecture model because it is often how they remember their more recent science lessons in secondary and tertiary studies. Standing at the front of the room, delivering the 'truths' about science while children take notes or fill in blank sections on a prepared sheet can assure teachers that they have covered a topic properly. Carr et al. (1994), suggests that teachers favour this form of science teaching because "the view of science as a body of unambiguous right answers for transmission into learners' heads can then trap teachers into a teaching style inimical to their own and their students' learning" (p. 148). Teachers need adequate guidance if they are to increase their confidence to teach primary science otherwise they may remain held captive by what Richardson (1990)

describes as, "victims of their personal biographies, systemic political demands, and ecological conditions" (p. 16).

The two vignettes in this chapter highlight the issue of teacher certainty. For Lynley the lesson on mini bins was designed to help the children understand how soil is constructed and that the soil can be improved through recycling waste to produce compost. After a discussion about the variables at work in the mini bins the discussion included the importance of micro-organisms in the process. Lynley struggled to extend the discussion to form links between ideas and was unable to provide definitions to distinguish between fungus, bacteria and micro-organisms. Lesley elected to teach in the junior years because she knew that her lack of science knowledge would not adversely affect the children's understandings of science concepts. Having covered the steps of a lesson about landscapes, she did not anticipated that she would be asked a question about the creation theory.

5.1 VIGNETTES ABOUT TEACHERS' CERTAINTY

The two vignettes that follow highlight the issue of teacher certainty. Both teachers believe that science is important but have different levels of expertise and experience in science teaching. The first vignette is set in Lynley's Year Five class. The children discuss variables affecting soil layering in the mini compost bins they had built the previous week. The second vignette, from Lesley's Year Two class, describes a lesson where the children discuss the concepts of man-made and natural in a lesson on landscapes.

5.1.1 Mini Bins

Last week the children had prepared their mini compost bins using cardboard milk cartons. The children spent the first few minutes of the lesson entering information about how they layered the vegetable scraps, newspaper, sand and grass clippings into their milk cartons. A narrow window cut down one side and covered with clear plastic would allow them to observe how the layers changed over the next five weeks. The children placed five earthworms into their mini compost bins and they were to record changes once a week.

Lynley began the lesson talking about the soil in Australia being very old and therefore lacking in nutrients. She spoke of how farming crops takes the goodness out of the soil because we eat the grain which carries the nutrients and leave only the roughage in the stubble. Lynley discussed the manner in which wind and water eroded and leached nutrients from the soil resulting in increased salinity. Lynley then linked the use of the waste materials the children used to build their mini bins with improving the quality of our soils. Today they would be looking at the variables related to the mini bins.

"We are going to be looking at a lot of variables with the mini bins," said Lynley. "Can you see or find any variables between the mini bins there, those at the back and these on the ledge? What do you think might affect or not affect them?"

"The thickness of the layers of newspaper," Mike began. "The clippings and the sizes of the bin because we have one litre and two litre milk cartons."

"The position of the mini bins," Neil added. "These get the sun in the afternoon and the others don't get much sun."

"The mini bins near the window will get hotter," said Veronica. "Light will enter the little windows on the side of the mini bin and in the air holes."

"Worms like it dark," said Karl.

"We have many variables such as light and warmth from the sun which could affect the moisture content of the mini bins," Lynley began. "If the worms like the dark maybe they won't function as well."

"How do you know earthworms don't like light," Mike said. "They don't have eyes and they don't have a brain, they sense the vibrations."

"Good boy," said Lynley. "Do light rays vibrate?"

"They warm up," said Mike.

"It pulsates," Lynley stated.

"You wouldn't be able to tell through their skin because you are making sound waves through the air," said Mike. "Light travels as radiation."

"What happens when you are out in bright sunlight?" asked Lynley.

"You can't look out for long because it hurts yours eyes," answered Karl.

"Alright," said Lynley. "Your eyes react and maybe the earthworms have a very similar sensory organ that reacts like the pupils in our eyes by closing or dilating according to whether it is dark or light."

"But that's basically only the temperature though," added Mike.

"Good boy," Lynley answered. "It might be a temperature thing because in light they might be able to have that very fine sense of telling whether it is hot or cold. Alright, so we had better leave that there because that was an excellent perception."

The children wanted to discuss ways they could investigate reactions to light by the earthworms. Lynley agreed that they could do many experiments and even look up information in books about the earthworms. Although the discussion was interesting Lynley had to move on to the section dealing with compost heaps. "I will have to leave it there Denis, I'm sorry," said Lynley. "Let's go to our background information and we will very quickly skim these notes. We are now talking about our mini bins and the compost."

Lynley established that the materials used in the mini bins were derived from plant material, except for the sand that was the remains of rock. "Compost is the remains of plant material that has been broken down by organisms in the soil," read Lynley. "What do they mean by organisms, what are they?"

"They are protozoa, plants, bacteria and things in the soil," said Mike.

"That's correct, well done," said Lynley. "How do we know there are organisms in the soil, Veronica?"

"Bacteria and protozoa and all that live everywhere because they are in the air and even in the soil," Veronica said. "If people looked with microscope they would find it."

"Good girl," Lynley said. "We are going to do an experiment later today to see whether there are organisms in the soil or not. For now we are looking at compost materials."

Lynley spent the next 15 minutes reading the background notes from the teachers' guide about the importance of compost. The notes dealt with the ability of compost to bind soil and retain moisture and that this was important in our climate because of water restrictions during the long hot summers. Compost reduces weeds and prevents erosion of soils when used as a mulch and also reduces people's rubbish. The children were told that earthworms do not like citrus fruits or onion peel because they inhibit the activity of micro-organisms. The information became very specific so Lynley read through the information from the teachers' resource book adding pieces of information to link the reading to what the children had experienced.

> The best compost has a balance between components with a high nitrogen content (to increase the plant nutrients in the soil) and those with a high carbon content. Nitrogenous Carbon. A good general rule is to have four parts of nitrogenous material (the moist plant remains such as grass clippings and vegetable scraps) to one part of wastes high in carbon (the dry plant remains such as paper sawdust and shredded straw). At first, the micro-organisms that cause decomposition are very active and the temperature rises to about 60C. Then activity slows down and the temperature drops so that conditions are more suited to earthworms and other small animals.
> (Australian Academy of Science, Teachers' Resource Guide 5, 1994 p. 165-166)

"Did you see any signs that there may have been a higher temperature in your mini bins?" Lynley asked. "The people with their compost bin on the ledge, did you notice anything with yours? Alright we are going for a walk to look at different compost heaps and the temperatures we find in the middle of them."

At the end of the session Lynley and I discussed the difficulty of having children of varying abilities in the class. Although there was a small group of children who were very keen to discuss the issue of light and sound, earthworms' reactions and micro-organisms, the majority of the class did not understand.

"The main concepts I wanted to get across today was why we set up the mini bins," Lynley began. "What was going to happen within that compost bin and the variables they may have come across? I didn't really round it off as well as I wanted to because we just ran out of time. What I would have said to them afterwards is that the compost is returned to the soil and becomes part of the nutrients in the soil but is not actually the soil itself. Now I don't know if they are going to discover a division between compost and nutrients in the soil. The micro-organisms, are they going to float to the top or are we going to drown them out, what is going to happen?"

"I couldn't believe it when Mike wanted to go on about the sound and light rays," I laughed.

"Yes, I didn't know how to answer that one," replied Lynley. "Veronica and the others tuned into him and were ready to really get their teeth into the discussion. These kids that know all about protozoa and all these things. If we could just halve the class and put those that are really interested together it would be great. The gardener's heaps amazed me."

"I know," I said. "I had my money on the black heap."

"Yes," Lynley said. "But it was the grass clippings because they break down rapidly. It's hard to find enough time to go into everything that comes out of these lessons. Maybe we should spend more time on micro-organisms when we look at the milk experiment next week."

* * *

This lesson was a continuation of work begun the week before when the children created their mini compost bins out of a milk carton. After recording the layers created

in the compost bins the children gathered together to discuss the possible variables in the experiment. During the discussion the children suggested variables such as depth of layers, position within the room, activity of the earthworms and the presence of micro-organisms. Although a few of the students were willing to discuss the differences between protozoa and bacteria Lynley was unsure of her background information about micro-organisms. Time was also running out so she read about the background information on compost heaps from the teachers' resource book. Later Lynley acknowledged that having some children willing to discuss science at a higher level was a challenge because the rest of the class could not join in and she felt unable to comment on the direction of the discussion because her understanding of science concepts was inadequate.

* * *

5.1.2 Because God Made Us

The first two lessons in science for the year mainly involved setting up groups and establishing group rules. By the third lesson the children were beginning to listen and work in groups. This lesson dealt with organising objects depending upon the children's ideas of whether or not it would fit a criterion. The lesson required a large collection of pictures showing natural and man-made landscapes which Lesley thought would be easy to find in magazines but she found herself collecting travel brochures from the tourist bureau. She hoped that the children appreciated her effort.

The lesson started with a discussion about how the children found books in the school library according to marked shelves and they all agreed this made it easy for them to choose books to take home for reading. Lesley then followed the teachers' resource book suggestion that the children discuss how they organised their bedrooms. After considering their clothes, books and shoes it was obvious that the children knew about organising their room and most of them agreed that it was hard to keep it tidy. The main objective of the lesson was to have the children recognise and decide what made a landscape natural and what made it man-made.

"You are going to do some more sorting this afternoon but you will be sorting something quite different. You will be looking at landscapes. Does anyone know what I mean by landscapes? What are they Kevin?" Lesley asked.

"When you go out in the bush there are all the trees and snakes and that's a landscape and in the city it's all these buses," suggested Kevin.

"Good," Lesley said. "Yes, we are going to look at landscapes and that means what you can see from one spot, all the things you can see out in front of you, that's going to be the landscape. What's something that is natural in the landscape something that has always been there and it has never really been changed?"

"I know," said Jenny. "Trees are natural."

"Well done, Jenny, but Mark what is something that man has built?" Lesley questioned.

"Houses," Mark replied.

"If I walk down this street here I'm going to come to the river. What's something that's natural that I can see right there, Angela?" Lesley asked.

"Sand and water," replied Angela.

"The sand is very natural, it has always been there. Like water it is a natural part of the landscape. What is something that we could see from down there that is man-made Jenny?" Lesley asked.

"The restaurant," Jenny responded.

The children apparently understood the idea and went on to discuss the bridges and playgrounds, the roads and houses found in their environment. They discussed their home renovations and other man-made items. Groups were formed, jobs allocated and the group managers collected the equipment, a container of pictures and a sheet to glue

their final choices of landscape or man-made pictures. Before the children moved away to work Lesley went over the task once again.

"You have to sort your pictures into natural or man-made. I have used the word constructed on the board which is another word for built. Constructed means built," Lesley stressed. "We constructed some houses on Friday, it's another word for built."

The children set to work and Lesley began to move from group to group making sure they were on task. Most groups were able to quickly separate their pictures into natural and man-made landscapes and the amount of negotiating varied from group to group. Some children were happy to be told what to do and others realised that it did not matter how much they disagreed their partner was not going to listen to them.

"I can't decide if this is natural or not Miss," said Jenny.

"It looks more like a landscape to me but it has people as well," Lesley said. "You have to decide in your group because you have to be able to say why you chose it. What does your partner think?"

"Jenny makes all the decisions," said Grace.

"Alright, take them all off then," muttered Jenny. "Well this one goes here because it is a beach."

"This, this one isn't man-made because there all…" began Grace.

"Is this a man-made?" demanded Jenny.

"Hang on Jenny," Lesley cried. "One at a time. If Grace doesn't get a turn how can she learn to share?"

"There you go Jenny, your go," said Grace.

"Okay," replied Jenny. "Is a person man-made, Grace?"

"Yes," said Grace.

"Yes it is, God made them," stated Jenny.

"Well yes," Lesley said. "Why did you think men are man-made?"

"Because God made men for them to live when dinosaurs are dead," stated Jenny.

"So we are constructed are we, we are built?" Lesley asked. "How did we get built?"

"By God, because he's got special powers," said Jenny.

"Well he has," Lesley said. "People think he does."

"And this bridge is made by man," said Grace. "It's also made by God."

"And it is also made by God because he built the man," added Jenny. "But the clouds are natural."

"No, God made them," insisted Grace.

"God made them, but that's natural," replied Jenny. "This one is a city and its man made because they started to construct it and they built a city and God also helped them."

When Lesley gathered the children together to discuss their findings at the end of the lesson, she found the groups had resolved their differences in other ways. One group had decided that if an object, such a man, could move out of the picture leaving only a natural landscape then it was natural. Another group decided that whatever took up the most space in the picture, for example, a large building meant it was placed on the constructed side of the paper. When no one could agree, the picture was placed on the line in the middle of the white sheet between the two criteria.

At the end of the day Lesley spoke to Jenny's mother about how definite Jenny had been about her belief that 'God made us'. Jenny's mother laughed and said that when her husband did not want to spend a long time explaining how things were made he would say "God made it". Lately she had noticed Jenny using this standard answer when faced with decisions about things she did not know.

* * *

Initially Lesley had found the new science program to be very light on science content and felt that her time had been spent more on sorting out groups and helping the children to work together. Lesley was familiar with the technique of brainstorming about the natural and man-made elements of the pictures because she often used this in other lessons such as language. Lesley encouraged the children to work together to classify the pictures. This lead to the interesting discussion about 'God made us' where Jenny was adamant that God being a man meant that his creations are man-made. With limited time Lesley was unwilling to explore the issue in detail. She felt the main objective of the lesson, having the children complete their selections and glue the pictures, was enough. Later when Lesley asked the parent about the child's adamant response she found out that the child had learned it from her father because he would say 'God made it' when he didn't want to give a lengthy explanation to her questions.

* * *

The two stories illustrate the pitfalls of teaching science when the teacher is unprepared for the range of answers given during the discussions. The two teachers have different experiences with teaching and learning about science reflected in the way they responded to the children's discussions. The teachers were unable to respond with authority to the incidents in the stories. In analysing these vignettes I call upon three categories of teachers' knowledge - pedagogical content knowledge, subject matter knowledge and knowledge of self.

5.2 PEDAGOGICAL CONTENT KNOWLEDGE

Pedagogical content knowledge is the knowledge teachers have and use about how to connect the children with the subject matter. Three issues are examined in this analysis. The first issue deals with the ability of the teachers to proceed through the lesson without fully understanding the scientific concepts covered. The second issue deals with the reliance of the teachers upon the teacher resource book. The third issue deals with teachers' preferred pedagogy when faced with difficulties during lessons.

The first issue deals with the way in which the two teachers were able to complete the lesson while not fully understanding the scientific concepts covered in the lesson. Lynley, the Year Five teacher, had the children build a compost heap in the previous lesson using a cardboard milk carton. The discussion about the variables related to the mini bin was left for this science lesson.

> "The thickness of the layers of newspaper," Mike began. "The clippings and the sizes of the bin because we have one litre and two litre milk cartons."
>
> "The position of the mini bins," Neil added. "These get the sun in the afternoon and the others don't get much sun."
>
> "The mini bins near the window will get hotter," said Veronica. "Light will enter the little windows on the side of the mini bin and in the air holes."

An interesting discussion ensued about how earthworms sense the sunlight but Lynley redirected the children to consider the composition of the soil and the importance of compost to the soil system. When Lynley was unable to give definite answers to the issues raised she congratulated the students on their good questions and moved to the next step in the lesson.

> "I will have to leave it there Denis, I'm sorry," said Lynley. "Let's go to our background information and we will very quickly skim these notes. We are now talking about our mini bins and the compost."

Lynley was conscious of the time and the need to move on to the next step if she was to keep the children in touch with the progress of the lessons. Having children from another class in the room made it difficult for her to 'catch up' with the science content. Lynley moved the children quickly through the background information about the compost bins and took them on the walk to visit the gardener's compost heaps. Lynley postponed the discussion of earthworms and organisms because her lesson plan did not allow sufficient time.

Lesley, the Year Two teacher, used a familiar strategy of brainstorming and discussion of ideas that she borrowed from her language lessons. Lesley moved through the suggested topics of ordering books in a library, arranging bedrooms and organising the landscape. The children discussed the landscape around the school and how it contained objects that were man-made or constructed. Lesley wrote the words natural and constructed on the board as she would for a language lesson.

> "Good," Lesley said. "Yes, we are going to look at landscapes and that means what you can see from one spot, all the things you can see out in front of you, that's going to be the landscape. What's something that is natural in the landscape something that has always been there and it has never really been changed?"
>
> "I know," said Jenny. "Trees are natural."
>
> "Well done Jenny. Mark what is something that man has built?" Lesley questioned.
>
> "Houses," Mark replied.

The children moved into their groups and completed the activity of dividing their pictures into the two categories. Lesley helped the children complete the task by asking them to agree on a main classification criterion. When a dispute occurred, Lesley encouraged the children to agree or place the picture over the middle line. Lesley was happy to have the activity completed on time, discuss the results with the children and wind up the activity.

Both teachers seemed to be able to complete the lesson without fully understanding the science concepts. They maintained the structure of the lesson by moving the children

through the decision making process. In the case of the Year Five children, the answers were postponed because of a lack of time and Lynley asked the children to find the information for homework. With the Year Two class, the teacher found the lesson strategies similar to those she would use in her language lessons. She also focused on the decision making process and the task of gluing the pictures onto the sheet within the set time.

The second issue deals with the reliance of the teachers upon the teachers' resource book. Lynley normally memorised the lesson plan and did not need to refer to the resource book during the lesson. In this lesson the technical information was complex and when the discussion about the soil became difficult Lynley referred to the resource book. She read through the prepared notes to reassure herself that the children had been given the correct information.

> "Bacteria and protozoa and all that live everywhere because they are in the air and even in the soil," Veronica said. "If people looked with microscope they would find it."
>
> "Good girl," Lynley said. "We are going to do an experiment later on today to see whether there are organisms in the soil or not. For now we are looking at compost materials."

Lynley spent the next fifteen minutes reading to the class from the teachers' notes about composting. Lynley delivered the information in a lecture format. She saw this strategy as a way of tying together the information the children should have grasped about the activity. She focussed the children's attention on the temperature of the compost heaps because they would be testing the temperature of the gardener's heaps.

Lesley was unsure about teaching science and kept the book on her lap at all times, referring to the manual after each step. She found the pedagogy of the lesson to be more like a familiar language lesson. Lesley did not have a problem with the lesson, because she thought that the main objective of the lesson was to get the children to agree on a criterion for categorising the set of pictures into natural or man-made.

> "Yes, I stick very close to the lesson plan," Lesley said. "Next year I might read through and remember what we did and how it went, but this year I'm definitely following it step by step." (Lesley, Interview)

While both teachers worked through the steps suggested in the teachers' resource book, each utilised the book in a different way. Lynley normally memorised the sequence of the lesson but kept it on hand for written information when she needed to consolidate the children's understandings of the concepts. Lesley used the book as a security blanket, following each step listed like a recipe, because she had not taught science recently and was unsure of her skills.

The third issue relates to the teachers' preferred pedagogy when faced with difficulties during lessons. Lynley used lecturing as a strategy to reinforce the important information she was developing about the compost heaps. Lynley gathered the children to the front of the room when she wanted to clarify important information. In this lesson, Lynley relied upon the teachers' notes and background information to draw together the main points about the mini bins.

> "With more children in the class for the science sessions I bring them down to the front because I have so many of them with their backs to me," Lynley said. "I'm right there with them and I know who has got the idea. With some of the boys you really have to keep your eye on them."

Lynley was able to use lecturing as a way of maintaining discipline and ensuring that the children were given every opportunity to focus on the important concepts being covered in the lesson.

For Lesley the use of directed teaching was more subtle, with the children engaged in a discussion about the meaning of natural and man-made as part of a brainstorming activity at the beginning of the lesson. Although this strategy was structured and controlled by Lesley, she elicited information from the children through her questions. At the conclusion of the lesson, Lesley gathered the children at the front of the room to discuss their discoveries during the lesson. Having them return to the large blue mat signalled to the children that the end of the lesson was for sharing information.

> "Working with their groups they are so spread out, I feel as through you need to get them back together and say right what did your group do." Lesley began. "I feel that for a discussion and sharing it is a lot better to be back in one group. (Lesley, Interview)

Both teachers employed the teaching strategy of gathering children at the front of the room on the floor to focus the children on the concepts covered. Lynley used the strategy to lecture the children about the concepts. In this way she reassured herself that she had given the children all the information they needed to understand the reasons for using compost heaps and how they worked. For Lesley, the strategy was employed to share information the children had acquired during the activities. Having the children spread throughout the room made it difficult for her to consolidate the lesson. Both teachers gathered the children together at regular intervals that gave them a sense of control of the information generated during the science activity. For both teachers, the brainstorming at the beginning of the lesson and discussion sessions at the end were familiar pedagogical strategies. Both strategies, while teacher dominated, were used to motivate and consolidate information.

5.3 SUBJECT MATTER KNOWLEDGE

The two teachers were engaged in teaching science using a new program. Two issues relate to the teachers' lack of subject matter knowledge and their ability to promote learning experiences. The first issue concerns the way in which the teachers were able to respond, with authority, to discussions arising from the science activity. The second issue concerns the teachers' reliance upon the resource book to supply supporting information for concepts in the lesson.

The first issue deals with the manner in which each teacher supported the discussions that arose during the lessons. Lynley was aware of her lack of subject matter knowledge but understood and appreciated the need to allow the children an opportunity to discuss their ideas. The value of being able to discuss ideas had been reinforced during her university course. Lynley initiated the discussion by talking about the variables affecting the earthworms in the different mini bins. The effects of light and warmth were raised which lead to a discussion about how earthworms function.

"What happens when you are out in bright sunlight?" asked Lynley.

"You can't look out for long because it hurts yours eyes," answered Karl.

"Alright," said Lynley. 'Your eyes react and maybe the earthworms have a very similar sensory organ that reacts like the pupils in our eyes by closing or dilating according to whether it is dark or light."

Lynley redirected the discussion after a few minutes and using the background information supplied in the children's books she established that compost bins were made up of plant material. This lead to a lively discussion about why organisms are needed in the soil in the process of breaking down compost.

"They are protozoa, plants, bacteria and things in the soil," said Mike.

"That's correct, well done," said Lynley. " How do we know there are organisms in the soil, Veronica?"

"Bacteria and protozoa and all that live everywhere because they are in the air and even in the soil," Veronica said. "If people looked with microscope they would find it."

"Good girl," Lynley said. "We are going to do an experiment later today to see whether there are organisms in the soil or not. For now we are looking at compost materials."

After the lesson, Lynley commented that she was taken aback by the discussions and had not known how to respond to the types of organisms found in the soil.

"I wanted the children to see the difference between nutrients and soil and what might happen in the compost bins," Lynley began. "When Veronica and Karl get into a discussion with Mike it gets really interesting. Half the children can't keep up with them but I like them to talk about the concepts. Today I had to admit I did not know, which is why I told them to look up the words bacteria and fungus for homework. It gives me time to check it out." (Lynley, Interview)

Lynley encouraged the children to contribute what they understood about earthworms and micro-organisms but was unable to redirect their discussion to a satisfactory conclusion. She was unable to verify claims made by the children but instead asked them to find the information for homework.

For Lesley the discussion surrounding the choice of whether the picture was man made or natural seemed simple enough. She had spent a great deal of time discussing the differences at the beginning of the lesson and the children appeared to understand very well. As Lesley moved around she found the children had sorted most of the pictures but needed help with sharing the task. Some children tended to take over the whole activity.

> "Jenny makes all the decisions," said Grace.
>
> "Alright, take them all off then," muttered Jenny. "Well this one goes here because it is a beach."

Lesley felt that she was spending more time getting the children to work together rather than engage in 'real science'. She had thought that the lesson was more language orientated with a gluing activity attached. After the girls agreed to share the task of choosing the next picture the dilemma centred upon the criterion for placing the picture under natural or man-made. The solution was unexpected and Lesley tried to discuss the reasons for the use of the statement, 'God made us'.

> "Because God made men for them to live when dinosaurs are dead," stated Jenny.
>
> "So we are constructed are we, we are built?" Lesley asked. "How did we get built?"
>
> "By God, because he has got special powers," said Jenny.
>
> "Well he has," Lesley said. "People think he does."

Lesley, unwilling to pursue a lengthy discussion about the origins of the world, was happy to accept that the children had established in their mind a criterion to judge the picture. Reasons varied as the different groups arrived at their selection criterion. Lesley

was happy that her main objective for the lesson, sorting according to an agreed criterion, had been met and the children had completed the work of gluing the pictures under the headings on the paper.

For both Lynley and Lesley the questions raised during discussions and activities presented problems. Lynley encouraged the children to pursue their line of thinking but was unable to add to their information or extend their inquiry because she lacked the content knowledge to do so. For Lesley the issue was one of getting the pictures onto the sheet under the two headings. She was willing to accept whatever criteria the groups agreed upon.

The second issue concerns the teachers' reliance upon the resource book for background information. The resource book contains explicit lesson plans and supporting material as background information. Lynley seldom referred to the resource book when engaged in science lessons. Rather, she memorised the sequence of the lesson and the main focus questions she wanted to raise. In this lesson Lynley kept the book with her and referred to it particularly when the discussions lead away from the main concept.

> "I will have to leave it there Denis, I'm sorry," said Lynley. "Let's go to our background information and we will very quickly skim these notes. We are now talking about our mini bins and the compost."

Lynley was unsure of her subject matter knowledge and elected to read about the importance of compost from the resource book. Lynley delivered the material as a set of lecture notes because the information became very specific. Whenever possible, Lynley linked the information to what the children had experienced in building the compost bins.

> "Did you see any signs that there may have been a higher temperature in your mini bins?" Lynley asked. "The people with their compost bin on the ledge, did you notice anything with yours?"

Lynley read directly from the resource book during her lessons because the information was technical. She was anxious the children should have the 'right' information before examining compost heaps in the schoolyard.

For Lesley, the resource book was kept close at hand during every lesson. Although she was not challenged by the science content Lesley felt she needed to follow the steps of the lesson carefully. The teachers' resource book, for example, suggested discussing with the children how they organised their bedrooms. After talking about arranging their clothes, books and shoes it was obvious that the children knew about organising their room and most of them agreed that it was hard to keep a tidy bedroom.

The main objective of the lesson was to have the children recognise and decide what made a landscape natural and what made it man-made. In preparing for the lesson, Lesley read through the instructions many times. The week before she familiarised herself with the materials needed to instruct her teacher's aide about preparations. Lesley read through the lesson plan on the morning of the lesson and again during silent reading after lunch.

> The week before I'll read through the resource book and get an idea of what materials and things need to be set up and get things organised. Then usually on Monday morning I read through the whole of the lesson plan again before school and get all the materials and things set up. After lunch I have another read of the lesson again in silent reading time so that it's fresh in my mind. I also need to refer to the lesson plan during the lesson because I'm always frightened I'm going to miss the point. I find the italicised words on the side of the lesson clarify points I don't fully understand and last week it was vital because it helped me realise the focus of the lesson too. Sometimes I read the italicised words but others I don't notice because I focused on the bold type sentences. (Lesley, Interview)

For both teachers the resource book provided information about the science lesson but each relied upon this knowledge in different ways. For the Year Five teacher the reliance was on the technical information supplied, because she was unsure of her subject matter knowledge. For the Year Two teacher, the resource book was a lifeline in preparing and conducting the lesson. She was less concerned about the science content of the lesson as much as she was about missing a vital step in the procedure.

5.4 KNOWLEDGE OF SELF

Teachers' knowledge of self is based on their beliefs and values about learning and teaching. These beliefs and values have been built upon the their past experiences. There are two issues related to how the teachers' past experiences informed their science teaching. The first issue relates to their belief about their ability to understand science concepts. The second issue relates to their choice of an appropriate pedagogical strategy.

With regard to the first issue, both teachers studied senior biology during their secondary years of education that meant that they did not have a formal background in physics or chemistry. For Lynley the years spent at teachers' college reinforced the natural science areas and she had fond memories of the times spent on field trips. Lynley always loved science and did not hesitate when she was asked to take up the role of science specialist in a previous school. Lynley also felt that her contact with a district supervisor helped to develop her ability to teach science in a well-organised way.

> Oh, I've always loved science so I have always taught it but I've always done everything to fit in with my program. You know, if we were doing animals, I'd just fit in a few things as we went along. The district supervisor showed us how to put our science into the four areas of energy, matter, plants and animals. Everything revolved around that. You interrelated everything so that if you were doing plants you were still doing energy, matter and all the other things as well. By focussing through plants you went to energy and did the things that focussed on batteries and all that type of thing. (Lynley, Interview)

Lesley avoided teaching science at her previous school but when she moved to her current school she found that there was no science specialist. Previously Lesley organised her science to follow the topics in her language program, building on her language teaching strength. In this way she made strong connections with the language aspects of science. Lesley had always found the previous 'I do Science' series boring and was willing to look at other science programs. The fact that her current school was going to trial a new science program worked in her favour.

> I wanted something new and inspirational and this sounded like it was really something more interesting. Something more meaningful to the children and more child based, activity based. I had also been assured that we would get support from the science coordinator for materials. Plus I don't class myself as being scientific, you know having a lot of science knowledge, where as this just makes sense. I don't have to have a lot of science because it's all organised for me. (Lesley, Interview)

Both teachers had similar experiences with their senior science studies but developed different interests during their teaching careers. While Lynley was very comfortable in pursuing science as a subject Lesley elected to concentrate on languages. Each had different levels of expertise in teaching science

The second issue relates to the teacher's beliefs about appropriate pedagogical strategies to assist children to understand the major points in the lesson. For Lynley the use of directed teaching, in the form of lectures, was important to her. The reasons why Lynley used this strategy is that she believes the children need to be made aware of the important ideas as they work through the activities in the science lesson. Bringing the children together to wrap up the lesson is a familiar part of her pedagogy. After the lesson Lynley said that lecturing to the children was her way of making sure they had formulated the right idea about the concepts covered during the lesson.

> The main concepts I wanted to get across was basically why we set up the mini bin. What was going to happen within that compost bin and the variables they may have come across. I didn't really round it off as well as I wanted to today because we just ran out of time. (Lynley, Interview)

Lynley strived to incorporate this form of teaching at the conclusion of her lessons because she liked to tie the children's experiences in the activities with the science concepts.

Lesley also liked to employ the strategy of lecturing to bring the lesson to a conclusion. With the children spread around the room it made it difficult for her to get a sense of having covered the main ideas during the activity. In this lesson in particular the children arrived at a multiple of answers and raised some very important points about trying to identify the criteria for judging their choices of landscape and man-made.

> For the sharing and discussion it is better in a group rather than spread out. I often feel as through I don't wrap things up well enough. Often this is because we are rushing in the end and we run out of time. (Lesley, Interview)

Both teachers used the strategy of directed teaching, or lecturing to their students to ensure a sense of closure. Lynley was concerned that the children would miss the important points they should have learned. For Lesley the need to draw the children back together after being spread around the room meant that she was able to wrap up the lesson. Both teachers also used the strategy as a form of behavioural modification. Seating the children at the front of the class signalled to the children that they were being watched closely and were expected to participate in a discussion about the activity.

5.5 CONCLUSIONS

In this chapter the teacher's certainty about science and teaching science influenced the outcomes of the science lessons. The two vignettes focused on how the teachers were able to respond to discussions about science during the lessons. Three issues were examined in relation to the teachers' pedagogical content knowledge. The first issue dealt with the ability of the teachers to conduct a lesson without fully understanding the scientific concepts covered. The Year Five teacher avoided the questions raised about the science concepts during the lesson, setting them as a homework activity. The Year Two teacher treated the lesson like a familiar language lesson and focused the children's attention on getting the pictures glued into place on time. The second issue deals with the reliance of the teachers upon the teachers' resource book. Each teacher relied on the teachers' resource book in different ways. The Year Five teacher memorised the sequence of the lesson and referred only to the book for written information when she needed to consolidate the children's understandings of the concepts. The Year Two teacher used the book as a security blanket following each step listed, like a recipe, because she had not taught science recently and was unsure of her knowledge. The third issue deals with the teachers' preferred pedagogy when dealing with difficulties during lessons. The Year Five teacher lectured the children about the expected outcomes of the experiment trying to tie together the information needed to understand the science concepts. The Year Two teacher used a directed teaching strategy to give the children

time to share information they acquired during the activities and give a sense of closure to the lesson. Both teachers used this strategy at regular intervals throughout the lesson when they needed to redirect the children's attention, giving a sense of control of the information generated during the science activity.

There were two issues related to the teachers' lack of subject matter knowledge that affected their ability to promote learning experiences within the lesson. The first issue concerns the way in which the teachers were able to respond, with authority, to discussions arising from the science activity. For both teachers the questions raised during discussions and activities presented problems. The Year Five teacher learned the value of being able to discuss ideas about science and encouraged her children to ask questions despite her inability to extend these discussions because of a lacked of content knowledge. For the Year Two teacher the groups agreeing on a criterion was the issue because she did not believe there was a lot of science involved in gluing pictures onto sheets under the designated headings. The second issue concerns the teachers' reliance upon the resource book to supply clarifying information about concepts developed in the lesson. For the Year Five teacher, unsure of her subject matter knowledge, the technical information supplied in both the students' book and the teachers' resource book provided answered for most questions raised around the concept being covered. They, however, did not supply ready answers to questions raised about related topics. For the Year Two teacher, the resource book was her lifeline in both the preparation and delivery of the lesson. She was concerned about missing a vital step in the sequence of the science lesson more so than the sequence of the science content.

Finally, there were two issues related to how the teachers' knowledge of self informed their science teaching. The first issue concerns the teachers' believes about their capacity to understand science concepts. Both teachers had similar experiences with their senior science studies but developed different interests during their teaching careers. While Lynley was comfortable pursuing science as a preferred teaching subject, Leslie concentrated on languages because she knew she did not understanding science. Consequently each had developed different levels of expertise in teaching science. The second issue relates to the teachers' believes about a suitable pedagogical strategy to use in science to ensure children understood the concepts in the lesson. Both teachers used the strategy of directed teaching, or lecturing, to their children to ensure a sense of

closure to activities carried out in science. Lynley was concerned the children would fail to realise the important points of the lesson and connect them together well enough to understand the concepts covered. For Lesley the need to wrap up the lesson meant drawing the children back together because they had been spread out around the room working in small groups. Both teachers also used the strategy as a form of modifying children's behaviour. The children knew that when they were seated at the front of the classroom they were being watched closely and expected to participate in discussion.

CHAPTER 6

CARING

This chapter looks at the issue of care in the teaching of primary science. The school site represents a community of people who are drawn together for the purpose of educating new generations of young people. This community reflects the moral and ethical beliefs of the society at large. Schools consequently operate with a set of moral and ethical beliefs and therefore can't be considered an ethically neutral activity. There are two major aspects to the 'formation of self' according to Witherell (1991) - the first includes social or cultural and the second is relationship. These two aspects inform and provide boundaries on behaviour and developing the self within communities. In the school culture, decisions and behaviour are monitored according to ethical mores reflected in the wider communities. The prevalent ethical systems have been the Kantian and Utilitarianism that highlight human rationality but have ignored emotion from the process of ethical judgments. The emergence of a feminist perspective by care theorists such as Gilligan (1982), Noddings (1993), Sockett (1988) and Thomas (1990) acknowledges a greater emphasis on relating and attending to relationships as the way to develop moral life. The growth of self is achieved through our own unique narrative that according to Witherell (1991) "provided through the integration of values, purpose, and meaning," (p. 93).

The majority of primary teachers are women and many take up the role of teaching because of an 'ethic of care' which contrasts with an 'ethic of responsibility' (Hargreaves, 1994). In describing an 'ethic of care' Gilligan (1982) suggests that it is motivated by the caring and nurturing of others and being connected to them. This is seen to be more common with women but is not exclusive to them. Noddings (1993) supports this by stating that 'Shaping moral people requires the development of caring relations." (p. 50). Interpersonal reasoning is crucial in resolving ethical dilemmas and relies on a developed attitude of care between people. It is through dialogue and reasoning that we learn to acknowledge and care for each other (Brickner, 1993; Clark,

1990 & Noddings, 1991). The development of interpersonal skills is not achieved in isolation but through direct participation and practice in activities of care. The ability to develop moral reasoning is complex according to Strike (1993) and involves people interacting between 'moral data', 'moral principles' and 'background conceptions' (p. 107). The 'ethic of responsibility', on the other hand, is described as dealing with the professional obligations of planning and instruction carried out in schools.

Teaching and learning is a people activity relying on developing the skills of interrelationships with those around us. The school day is multifarious by nature with the children interacting and adjusting to each other, to different teachers and their teaching styles. Teachers and children deal with ethical dilemmas daily in their quest to understand their place within the group. Although schools expect qualities of will to intrinsically manifest themselves in children the influence of the teacher's ethical and moral beliefs and ability to assist children to 'see' situations when making judgements about issues that arise, happens throughout the school day (Sockett, 1988). Therefore it is not difficult to agree with Bricker (1993) when he points out that, "educators cannot teach forms of perception that are unfamiliar to them personally. This is why their self-awareness is so important" (p. 23). Teachers are at the centre of moral struggles and they hold a prominent position in the lives of the children during long hours of their educational life (Thomas, 1990). The creation of self-awareness is one of moral development and teachers, in striving to be professional, have to take account of the cognitive and moral development of their students (Gilligan, 1982; Noddings 1988; Sockett, 1988; Strike, 1993a). This is put concisely by Strike (1993a) when he states, "Educators must themselves learn and find ways to teach students and their communities the most difficult art of respectful discussion about important matters over which we disagree deeply. Moral dialogue requires a sensitive mix of passion and civility" (p. 185-186). Teachers are always making judgements about children's virtues, e.g. good worker, diligent, patient etc. but the deeper moral perspective of teaching is seldom recognised or addressed in a concrete manner within the curriculum and culture of the school systems (Sockett, 1988). Teachers preoccupation with virtues, suggests Sockett (1991), "places them in the position of reflective moral agent" (p. 3).

Although ethical issues are evident in the education system, the time needed to include this is often not considered affordable. Indeed Clark (1990) found that "…for teachers

generally, honesty, respect, compassion and forgiveness mean more work, not less. Morally responsible teaching requires that we go beyond (sometimes far beyond) the letter of the law of technically effective teaching" (p.255). Time given during lessons to the development of interrelation skills, develops understandings of ethical and moral beliefs between groups of people, relies on having few children in the class (Noddings, 1993). Teachers working with curriculum are seldom given or asked to provide a list of ethics and values related to the subject to be covered. Rather, it is assumed to be those set by society will be upheld by teachers. Schooling is mandatory and parents entrust their children to the education system with the knowledge that they have a limited influence on the structure and emphasis of their children's education (Thomas, 1990). Teachers have a position of influence over all aspects of their children while at school that Noddings (1988) sees as "Teachers, like mothers, want to produce acceptable persons - who will support worthy institutions, love compassionately, work productively but not obsessively, care for older and younger generations, be admired, trusted, and respected" (p. 221). For teachers their role in ensuring good quality education means they have to make sure the children's environment is conducive to learning and they are safe from negative influences physically, emotionally and spiritually (Noddings 1993). It is therefore not difficult to appreciate that teachers' relationship with children is very important. This is supported by Clark (1990) who describes teaching human relationships as "moral in character and consequence. After that between parent and child, the most profoundly moral relationship our children experience is that between the teacher and the taught" (p. 265).

6.1 VIGNETTES ABOUT CARING

The two vignettes that follow portray the way in which the two teachers in this study exhibit care in their dealings with their children. Both teachers hold strong views about their role in providing the children with the knowledge and skills to deal with their technological futures. The first vignette is about Lynley's Year Five children who were investigating mould through observation of prepared moulds on bread. The second vignette is about Lesley's Year Two class who were building beds for the three bears in the children's story of Goldilocks and the Three Bears.

6.1.1 Mouldy Oldies

In this lesson the Year Five's were observing moulds. During the recess break Lynley carefully wrapped the samples of mouldy bread in plastic and taped them securely. She also had samples of fruit, cheese and vegetables to illustrate how other foods looked when mouldy. Lynley was conscious of the fact that the spores could be dangerous if the children inhaled them. At another school her experiences with inhaling spores had alerted her to the dangers. When the children returned from their recess break there were two samples of bread, three sheets of paper and a magnifying glass on each desk. Lynley waited for them to settle into their seats.

"We are looking at Mouldy Oldies today," began Lynley. "I take myself out of that because I don't think I'm a mouldy oldie. We have two types of bread to compare and I want you to have a close look and see the difference. You can press on the bag gently but do not open it please. At another school I let the children grow moulds but when we were looking at them one of the children opened her bag and I breathed in a lot of spores. I ended up with a very sore throat for a long time and you can become very ill if you inhale the spores. Please do not open the plastic bags. Use the magnified glass to observe the mould then write what you observed."

Lynley read through the introduction in the student guide that outlined where the children could expect to find moulds. Examples given were the bottom of a refrigerator, on pieces of fruit, at the bottom of aquariums and even in their school bags. Lynley asked them to work through their student book and in their group to discuss what they found. Again Lesley stressed that they weren't to open the packets and let spores escape. The class began the task of looking at the moulds and Lynley moved among them to make sure they were reading the instructions carefully and sharing the equipment.

"Each team makes a record sheet by writing 'our mouldy bread' at the top of the piece of paper," began Brendan. "Write down your description of the mouldy, write down some of the places…"

"Hold on Brendan," interrupted Lynley. "What if you went through one step at a time. I'm sure the others in the group would find that easier to follow."

"Use the magnifying glass to look closely at the mouldy bread inside the plastic bag," Brendan started. "Do not open the plastic bag as some people are allergic to moulds. Tell your teacher if you are allergic to moulds."

The group went on to explore and discuss the colour of the mould and what they had eaten with mould on it. Robert said his father liked blue vein cheese but the children thought was disgusting because it smelt so bad. The discussion became very noisy so Lynley rang her bell and stopped them. Lynley had already stopped them twice today but she never raised her voice even when she was cross. She was low key, even and authoritative.

"Just listen, you took a long time to settle down," began Lynley. "I can't start until I have complete silence because those boys at the table need to listen. Len you have been very disruptive, I want you to stand outside for a while and think about your behaviour. I don't think having you boys together in a group is a good idea."

Lynley went over the steps the children had to follow in their books and again stressed that they were not to open the bags at all. At the end of the lesson Lynley rang the bell and asked them to discuss what they had discovered about the moulds.

"I'm very pleased to see you writing and pleased to see you drawing your diagrams," Lynley began. "Describe to me what you saw. It's shape, colour whatever. What your group decided it was, if they did make a decision and what is it really? I have had several views given to me and it's quite surprising what you think it is. You need to listen to everyone's views so no one is to speak or move and fiddle because I want you to focus on what people are saying."

"We thought the mould on the bread looked like a little tiny plant and it's eating off the food," said Jessica.

"I like that answer," said Lynley. "Good girl. Anything else Jessica?"

"Yes," she said. "We thought it was bacteria."

A lively discussion about bacteria and mould showed that the children were confused about the terms so Lynley asked them to find out for homework what each word meant. Lynley also wanted time to clarify the answer for herself. Lynley asked the children to bring along a food item next week so that each group could grow a mould.

"Just a word of warning about growing moulds at home," Lynley began. "At my last school a girl used a piece of cheese to grow her mould. Her mother allowed her to put it in the pantry on a plate. When her grandmother came to visit she thought it was a piece of blue vein cheese and ate it. Although the family had a laugh about it later they kept an eye on the grandmother for a few days to make sure she did not get ill. Please be very careful and label your food."

The children all groaned and laughed about the story but it gave them something to think about. Before Lynley finished the lesson she explained to the children that the group with the best mould specimen would get a block of chocolate to share. The children cheered loudly, Lynley laughed and dismissed the class with warnings of 'take care' and 'ride your bikes safely'. She often sent them off for the weekend by saying thank you and keep well.

At the end of the day, as Lynley tidied her room, we talked about Len and his need to be the class clown. Lynley had sent him out of the room three times during the lesson for disruptive behaviour.

"He is one of the boys from the other class," said Lynley. "Len is used to monkeying around and being an extrovert but in here he's not accepted. I stood him outside a couple of times and told him to just settle down."

"He was holding his stomach at one stage and said he had a stomach ache," I said.

"I am glad you mentioned it," Lynley said. "If I'm aware of that then next time he's unsettled I'll ask him is he feeling alright because he might react in that way when he's in pain."

We ended by talking about how the children had reacted to the competition. It had certainly raised their interest and excitement about the next lesson.

* * *

Lynley was aware of the need to stress the dangers of inhaling spores because of her experience in her last school. Not only did she wrap the samples securely and tape them down but she also reinforced the issue on many occasion. Lynley related a story to the children about a girl in her last school to illustrate the dangers to the children. During the lesson Lynley valued cooperative student behaviour as it contributed to the children's ability to complete their lesson. When Len continued to interrupt his peers and not cooperate Lynley asked him to stand outside so that he could reflect upon his behaviour. She did not raise her voice or threaten him with consequences but continued to remove him to allow him to think about what he was doing. At the end of the lesson Lynley asked the children to grow moulds at home and again warned them about the dangers. Lynley again related an interesting story about the grandmother to illustrate this point. Lynley always ended the lesson by thanking the children for their company and asking them to travel home safely. After the lesson we discussed Len's behaviour in class which was a cause of concern for Lynley. The thought that he was unwell worried her and she said that she would make a point of inquiring about this next time he misbehaved. Lynley was mindful of her children's safety and well being during this lesson.

* * *

6.1.2 Beds For Bears

This lesson was based on the story of *Goldilocks and the Three Bears*. The children, in groups of two, were asked to fill a sandwich bag with a variety of materials to make beds for the three bears in the story. The children were to investigate the properties of materials, by solving the problem of reproducing the different quality of the beds. Lesley found time spent gathering materials beforehand bothersome but had come to realise that leaving this to others did not guarantee that she was properly prepared for the lesson. At the back of the room, in bags and containers, Lesley had assembled foam,

shredded paper, straws, blocks, raffia paper, plastic bags, pop-sticks and much more. Indeed it looked more like an arts and craft lesson than a science lesson.

Before the lesson started, Lesley had to deal with two upset boys. During the recess break Trevor came into the room, tearfully explaining how Allan had accused him of doing things he did not do. Lesley calmed him down and assured him that she would have a word to Allan. When Trevor left she told me that Allan was having problems at home and she would ask the children to be kind to him. After the bell Lesley listening to a tearful Darcy who, when waiting in line, had his hair pulled by a Year One child. Lesley was horrified and with a stern face she instructed the Year Two children to remain seated while she spoke to the Year One child. The Year Two children overheard every word she said as the Year One classroom was adjacent to their room. When Lesley returned the Year Two children were reassured that she had stood up for Darcy.

Lesley began the lesson by reading the fairy story of *Goldilocks and the Three Bears*. The children happily joined in with the familiar phrases. The children loved the way Lesley used different voices for each of the bears and they laughed when Goldilocks ran away after making a mess of the house. Lesley emphasised the differences in the beds, Father Bear's bed was hard, Mother Bear's bed was soft and Baby Bear's bed was just right. Lesley explained to the children how they would use the different materials at the back of the room to help them make the beds. Each group of students had three sandwich bags to fill, representing the three different beds. Lesley emphasised how the children may need to modify their beds to build what they needed.

"You and your partner need to talk and decide together," said Lesley. "Firstly which bear do you want to start with? If it's Father Bear you will be looking for things that would be hard. You might put in layers of more than one thing. You might put some foam at the top, pop-sticks or straws in the middle and then tissues or paper on the bottom, like a sandwich."

Lesley made other suggestions, trying to reinforce the idea of layering. She talked of cutting, folding, and scrunching the material in the plastic bag. Lesley showed the students how to seal the bags and test the effects of their work by feeling with their

hands. When she was satisfied that they understood how to combine materials to make the beds she asked if they had any questions.

"You have to cooperate," Melissa stated.

"Oh! You definitely have to cooperate for this activity," Lesley answered. "You need to share ideas with your partner and not take over. You have to do one mattress at a time. You do not do one for Baby Bear and your partner does one for Mother Bear. I like you working together to make these mattresses, that's very important. The whole idea is sharing ideas with your partner and solving the problem together. Return any materials you don't use so that others can use it if they want to."

When the children were settled with their three sandwich bags, Lesley selecting the groups who we seated quietly, to collect their materials from the back of the room.

"Excuse me Ms Campbell, but Ralph said he's going to make Baby Bears' mattress on his own," said Melissa.

"I'll be telling Ralph who is the boss of the class if he is going to talk like that, where is he," growled Lesley. "I'm a little bit tired of this attitude Ralph. If we all work together and cooperate there shouldn't be a need for a boss."

After the children collected their material they set to work with a will. During the lesson Lesley kept reinforcing the importance of sharing and working cooperatively. As she moved from group to group she tested the mattresses, listened to the children's reasons for their choices and made suggestions about how to achieve the right quality for their mattresses. She praised Angela for working so well with her partner Edward. Angela had not always found it easy to share and often left the work up to her partner. With a few minutes to go she asked the children to return materials not used and tidy up ready for the class discussion. Each group created different mattresses by combining the materials to strike a balance between hard and soft. Lesley called on children who had worked well together to share their ideas with the class.

"I'm very impressed with how Andy and Darcy worked," Lesley said. "They worked very cooperatively. Would you like to come up and tell us about your mattresses?"

Andy explained what they had used to make each bed. Lesley tested and discussed the materials they had used and then asked if they had any problems.

"Yes we did," Darcy began, "with cutting the foam."

"How did you solve that problem?" asked Lesley.

"We had to tear it apart," said Darcy.

"Tear it, that's a good idea," said Lesley. "Some people were using their scissors in a safe way and other people were hacking away with their scissors. I was waiting for a little finger to drop down on the carpet. I'm pleased to see most people were using their scissors in a safe way because you have to be careful cutting through things like that. I'm glad you thought of a safer way to do it, thank you for sharing with us."

At the end of the lesson, Lesley asked the children to peg their three mattresses together and attach their names, ready for next week. After the children had left, Lesley still had to write the certificates her children would receive at the school assembly the next day. Earlier in the day she had been unable to think of someone for the certificates but the way in which Angela and Andy had cooperated had impressed her. Earlier in the year both children had found it extremely difficult to work with others and concentrate on the work they were asked to complete. She was pleased that both children were now able to share, negotiate solutions to problems and engage in the work required.

* * *

Even before the lesson began Lesley had to deal with two upset children. In the first incident she was aware that Allan was having trouble at home that was making it difficult for him to get along with his friends. She was sure that once she had explained this to the class they would treat him more kindly. In the second incident, when Darcy was upset by the Year One child, Lesley became the protector of the whole class. The

children listened with keen interest as she growled at the Year One child. As the lesson proceeded Lesley encouraged the students to be cooperative and share the making of the beds. When Melissa asked for help because Ralph would not share with her, Lesley was quick to let Ralph know that this was unacceptable. During the discussion time Lesley made a point of addressing the safety issue of using scissors. Lesley praised the work of Angela and Andy and nominated them for an award because their behaviour had improved considerably over the previous six months. They had learned to share and cooperate during the tasks set in science.

* * *

In both lessons the teachers demonstrated a caring attitude towards the children. This 'ethic of care' incorporated safety aspects when children were engaged in activities using materials that had the potential to harm. Both teachers also actively modelled and reinforced good behaviour among the children by correcting inappropriate behaviour and praising good behaviour. The teachers were willing to acknowledge that family circumstances influenced the behaviour of the children in class and tried hard to accommodate children at risk. At times when a child was upset the teachers enlisted the help of other children to support them. The lessons illustrated the many ways in which the two teachers provide an 'ethic of care' for the children. The stories will be analysed according to the teachers' pedagogical content knowledge, general pedagogical knowledge and knowledge of self.

6.2 PEDAGOGICAL CONTENT KNOWLEDGE

The major pedagogical content issue in these stories is how the teachers demonstrated their care in the science lessons through concern about safety for their students. Lynley, the Year Five teacher, had a previous experience with growing moulds when she inhaled the spores of the mould grown by a child. Prior to this lesson Lynley wrapped the two samples of mouldy bread for each group in plastic and secured them with masking tape. The thought uppermost in her mind was that the students were not exposed to the spores. When Lynley began the lesson she stressed this aspect by relating the story of the former student to the class.

> "At another school I let the children grow moulds but when we were looking at them one of the children opened her bag and I breathed in a lot of spores. I ended up with a very sore throat for a long time and you can become very ill if you inhale the spores. Please do not open the plastic bags. Use the magnifying glass to observe the mould then write what you observed."

Lynley continued to warn the students about keeping the samples secure as she moved around the groups and listening to their discussions about the mouldy bread. Lynley encouraged them to use their magnifying glass to help them get a close look at the bread. Towards the end of the lesson Lynley challenged the groups to produce the best mouldy sample for a class competition. Once the excitement over the prospect of winning the chocolate subsided Lynley again warned them of the dangers of growing moulds.

For Lesley's Year Two class the lesson had care and safety problems with the children using scissors. Lesley had not discussed, formally, the correct way in which to operate scissors in this lesson. She did raise the children's awareness of the importance of using scissors correctly when she asked a group to tell the class how they overcame a problem with cutting the sponge.

> "Tear it, that's a good idea," said Lesley. "Some people were using their scissors in a safe way and other people were hacking away with their scissors. I was waiting for a little finger to drop down on the carpet. I'm pleased to see most people were using their scissors in a safe way because you have to be careful cutting through things like that. I'm glad you thought of a safer way to do it, thank you for sharing with us."

Lesley not only praised the good work of the children who had used the scissors correctly but also acknowledged the way they had thought of an even safer way by tearing the sponge. For Lesley, it was important for children to use scissors with care and safety during their science lessons.

6.3 GENERAL PEDAGOGICAL KNOWLEDGE

There are four issues arising from these two stories concerning the manner in which the two experienced teachers used their general pedagogical strategies to facilitate care in the lesson. The first issue concerns the way in which the two teachers maintained class discipline using strategies from other learning areas. The second issue is that of monitoring appropriate group behaviour to establish the need to share and contribute. The third issue is how the teachers nurtured children at risk in their classroom. Lastly, the teachers exhibited care by using storytelling to embed the lesson in a familiar experience.

The first issue deals with the manner in which the two teachers were able to transfer discipline strategies from other subjects. Lynley had Year Five children from a composite Year 4/5 class join her for science every week. The disruption for her class was two fold. Firstly within her smaller than average room, she needed to be able to accommodate the extra furniture and children and the establish patterns of appropriate behaviour. Len, for example, was a very active, inquisitive boy who found it difficult to adjust to the interactive format of Lynley's science lessons. His normal class teacher preferred a more traditional approach to classroom management. It was not uncommon for Lynley to discipline Len but during this lesson he was more disruptive than usual. Lynley never raised her voice when she disciplined the children and used withdrawal, for short periods of times, to allow them time to reflect upon their behaviour if they repeatedly disrupted. Len was withdrawn from the lesson on several occasions because Lynley did not want him to disrupt the learning of the other students in his group.

> "He is one of the boys from the other class," said Lesley. "Len is used to monkeying around and being an extrovert, but in here he's not accepted. I stood him outside a couple of times and told him to just settle down."

In the Year Two lesson Lesley frequently used praise to discipline the children. During the end of lesson discussion time Lesley reinforced and acknowledged good behaviour by allowing the well-behaved children to present their findings first. In this way she was able to publicly reinforce the types of behaviour she found acceptable.

> "I'm very impressed with how Andy and Darcy worked," Lesley said. "They worked very cooperatively. Would you like to come up and tell us about your mattresses?"

Lesley was so impressed that she gave both Andy and Angela merit certificates which showed that she cared for the self esteem of the children by recognising their improved behaviour.

Here, the issue for both teachers is that they demonstrated care for their children by swiftly and fairly dealing with disruptive behaviour. The teachers also showed clearly the values they placed on cooperation, sharing and non-disruptive behaviour. Both teachers used many opportunities to consistently reinforce these values.

The second issue deals with how the teachers monitored appropriate group behaviour to establish the need to share and contribute. The new science program is based on cooperative small groups using a constructivist approach to developing the children's understanding of concepts through hands-on activities. The need to reinforce appropriate behaviour was necessary as the children were unfamiliar with this form of learning. Lynley constantly moved around the room listening, questioning and encouraging the children in their new roles. An issue that came up time and again in the lessons was the failure of the children to read the instructions properly. Lynley always went through the instructions carefully before the children started the activity but found that she needed to monitor the children's understanding of the instructions.

> "Each team makes a record sheet by writing 'our mouldy bread' at the top of the piece of paper," began Brendan. "Write down your description of the mouldy, write down some of the places…"

> "Hold on Brendan," interrupted Lynley. "What if you went through one step at a time. I'm sure the others in the group would find that easier to follow."

For Lesley the task of encouraging the children to relate to each other and share the responsibilities of the activities in the science lessons was important. The children had worked with the new program for six months and Ralph was still having trouble with the idea of sharing. During the lesson Lesley asked the children to share the task of making three mattresses.

> "Oh! You definitely have to cooperate for this activity," Lesley answered. "You need to share ideas with your partner and not take over. You have to do one mattress at a time. You do not do one for Baby Bear and your partner does one for Mother Bear. I like you working together to make these mattresses, that's very important. The whole idea is sharing ideas with your partner and solving the problem together. Return any materials you don't use so that others can use it if they want to."

When Melissa asked Lesley to help her because Ralph refused to cooperate Melissa was supported immediately. Lesley made a point of speaking to Ralph in front of the whole class to reinforce the need to share and to let the class know how she felt about children who were bossy.

> "Excuse me Ms Campbell, but Ralph said he's going to make Baby Bears' mattress on his own," said Melissa.

> "I'll be telling Ralph who is the boss of the class if he is going to talk like that, where is he," growled Lesley. "I'm a little bit tired of this attitude Ralph. If we all work together and cooperate there shouldn't be a need for a boss."

Both of the teachers needed to constantly reinforce group process because they were new to the children. The teachers supported the children and showed care through praise and direct intervention to help children who did not understand what was expected.

The third issue deals with how the teachers nurtured the children who were at risk in their classroom. Lynley was well aware of Len's need to be noticed and monitored his behaviour with removal from the classroom for short periods of time. When she became aware that Len was unwell she was concerned that she had misread the reason for his behaviour.

> "He was holding his stomach at one stage and said he had a stomach ache," I said.

> "I am glad you mentioned it," Lesley said. "If I'm aware of that then next time he's unsettled I'll ask him is he feeling alright because he might react in that way when he's in pain."

Lesley was seen as the protector for her children. Whenever they had problems with other students they came to her to sort them out. Before the lesson began there was an incident in the playground. Allan had upset Trevor, accusing him of doing things he didn't do. Lesley listened to Trevor and calmed him down assuring him that she would have a word with Allan. After Trevor left Lesley acknowledge that Allan was not happy at home.

> "I know Allan is having a tough time at home," Lesley began. "His mother was speaking to me only yesterday about it. I will ask the other children to be kind to him." (Lesley, Interview)

No sooner had Lesley worked her way through that crisis than Darcy came to her with his story about being bullied in the line. The whole class watched as Lesley went to his assistance by confronting the Year One child in his room. Lesley was showing the children that she would protect them inside and outside of the classroom as much as possible. Lesley reflected:

> "That boy has been a problem for quite a while," Lesley began. "Mrs Owens has had a lot of problems with him in class and I'm not going to let him bully my children. Darcy is such a gentle natured boy, he wouldn't hurt anyone. The school is also making a big issue of bullying and we are trying to stamp it out." (Lesley, Interview)

The key issue here is that both teachers understood the children they were working with. Care involved knowing about the children as individuals and about their home life. They were both willing to confront issues of values and demonstrate this to the children.

The final issue concerns the practice of storytelling to embed the lesson into a familiar experience with which the children could identify. Lynley used stories to illustrate the dangers of inhaling spores. She used stories based on her previous class to show that exposure to the mould had been dangerous to her personally and that she did not wish the same to happen to these children. This experience motivated her to secure the mould samples for the lesson. When the children were asked to grow their own moulds at home Lynley again related a story from her past experience to warn the children of the dangers of growing moulds.

> "Just a word of warning about growing moulds at home," Lesley began. "At my last school a girl used a piece of cheese to grow her mould. Her mother allowed her to put it in the pantry on a plate. When her Grandmother came to visit she thought it was a piece of blue vein cheese and ate it. Although the family had a laugh about it later they kept an eye on the Grandmother for a few days to make sure she did not get ill. Please be very careful and label your food."

In Lesley's class, the story telling revolved around a fairy story about Goldilocks and the Three Bears. The lesson began as with many language lessons with the story setting the scene. The children were very familiar with the story line and the reasons the three bears had different requirements for their porridge, chairs and beds. Indeed the children were able to chant along with the familiar lines in the story. When the task was set to make the mattresses the children were well aware of the qualities of the beds they would have to create just right, soft and hard. Lesley reinforced this further with a detailed session on how to tell if the plastic bags fitted the criteria. She also emphasised the need for the groups to talk about what would go into the mattress and the need to decide together. Lesley ended by likening the process to that of making a sandwich, an everyday activity for the children.

> "You and your partner need to talk and decide together," said Lesley. "Firstly which bear do you want to start with? If it's Father Bear you will be looking for things that would be hard. You might put in layers of more than one thing. You might put some foam at the top, pop-sticks or straws in the middle and then tissues or paper on the bottom, like a sandwich."

Story telling is a tool that these two experienced teachers used to get children to focus on new ideas. By connecting with a past experience, piece of literature or item of everyday life the teacher was able to help the children by bridging the gap between the old and the new information.

In summary, the two teachers used strategies from other learning areas to solve problems that arose in the science lesson and hence show care for their students. Both Lynley and Lesley used praise and public remonstrations to reinforce what was acceptable behaviour in the classroom. They also spent a significant amount of class time explaining and reinforcing the need to for the children to carry out their roles in

group situations. As the teachers moved around the room they responded to situations as they arose encouraging the children and restating what was acceptable behaviour. Both teachers were supportive of children who were at risk because of personal problems. Finally, the art of story telling was a strategy used by both teachers to help enable students to connect old information to new understandings.

6.4 KNOWLEDGE OF SELF

Teachers' knowledge of self is based on their beliefs and values that are drawn from past experiences ranging from childhood through to educational experiences as learners and in teaching. Three aspects of the teachers' past experiences informed their caring approach - childhood experiences and family expectations, experiences during the pre-service years and previous experiences as classroom teachers.

In understanding the teachers' attitudes to caring for others it is important to look at their childhood experiences and family expectations. In Lynley's childhood her father had always encouraged her love of nature and she was aware of how these values informed her teaching.

> I've always had a very stable lovely sort of atmosphere and home life. I couldn't say there is a day that goes by that hasn't been happy for me. I haven't experienced any of the traumas of separation or life threatening disease, not even cross words or anything. I have always been very conscious of damaging things. I remember a time when my father and I found an unusual animal in the bush and I went with him when he took it to the museum for identification. My father won't touch an ant or a fly and this has been ingrained into us that you respect and look after everything. I think I impart that a lot in my teaching to the children. If there is a spider in my room and the children go to attack it I just put a jar over it and take it outside. You do all those things because you train them that way to respect life. (Lynley, Interview)

Lesley grew up on a farm, aware that both her parents worked hard to provide for their family. Her parents valued education and encouraged the children to develop their abilities. As children they learned to share and make the best of the resources they had available.

> My father wasn't able to get a higher education and he wanted his four children to do well. He encouraged us to go through to year 12 and three of us finished our degrees. Dad didn't mind what we did so long as we did well. I always wanted to be a teacher but I started off doing a business course when everyone told me there weren't jobs for teachers. I stayed long enough to know I'd failed a business math's exam. My mother did not want me to do nursing because she thought I'd get too involved and she's right, I'd get too attached to the people. We didn't have a lot but we always had holidays by the sea. I remember building cubbies and exploring the bush with my friends. (Lesley, Interview)

For both teachers, the family expectations were of sharing and caring about each other and the environment. Education was supported through exploration of their natural environment and encouragement to remain at school to complete a higher education. Both teachers also came from stable family backgrounds where values of honesty, hard work, sharing and caring for others were encouraged.

The second set of experiences deals with pre-service teacher training. On completing their secondary education both teachers graduated with senior biology. Lynley enjoyed science but had never felt that she had enough ability to study chemistry and physical sciences to a higher level. During her two years of pre-service training she had many positive memories of science lessons. Most of these lessons were based around environmental studies.

> During my training years we did a nature study option and I mean we were always on the dunes on the beach or on the grounds of the College doing wonderful things and we just loved it. I reinforce a lot of that with my children which is why I probably tend to do science. (Lynley, Journal)

Lynley developed her love of nature in a supportive educational environment and brought this care and nurturing of the environment to her children when she became a teacher.

Lesley's education choices provided her with different experiences and career choices. During Lesley's three-year teaching training course she completed science units but quickly decided that she preferred teaching the younger grades.

> When I trained as a teacher I chose junior primary and languages as my options because I felt that I did not know enough to teach the older children, especially maths and science subjects. I remembered doing lots of nature walks around the school as a child and having a nature table. That part of the science course was great but I didn't think I could teach older grades. (Lesley, Journal)

Lesley was aware of the need to learn about science but never considered herself scientific because she had never been overly interested in science as a subject. Lesley focused on language subjects and the junior primary grades to overcome her feelings of inadequacy with content knowledge. Lesley enjoyed the nurturing, caring aspects of dealing with smaller children because her mother had identified Lesley's 'softness' of character.

For both Lynley and Lesley, the pre-service years gave them the opportunity to develop their major interest areas in teaching. Lynley had conformation and support in developing her love of science and caring for nature. Lesley was able to identify her need to work with younger students because of her caring nature and lack of confidence in her abilities to teach science and mathematics to older children.

The third source of development of attitudes to science teaching originates in the teachers experiences as classroom teachers. Lynley enjoyed the opportunity to teach science as a specialist teacher and with the help of the district supervisor she became a focal point for science in the district. At her new school she took on the role of science coordinator when it became available and encouraged the school to take up the new *Primary Investigation* science program. She was aware that the school needed to review the science being taught and it was her duty as the science coordinator to ensure the teachers were well equipped. Lynley also believed she had a duty to prepare the children for their future which would require them to be technologically - orientated and able to look at many different ways of solving problems.

> With science I think I have always had the feeling that we need the knowledge of science so that we can plan what is best for the world, what is best for our environment. I've always loved science and I've always tried to fit it in with my overall program. Years ago it was the district supervisor who showed us how to develop our science in the four areas of energy, matter, plants and animals. He was very influential

> and showed us that although you were doing plants you were still doing energy, matter and all the other things as well. The children need to learn specific skills and how to think in a logical sequence that I think is far more valuable to them in the long term than knowing facts. I picture the lesson in my mind, how I'm going to deal particularly with special children and I'm always aware of what and how they react. If something jolts, such as a misunderstanding, I answer them. I still follow the plan that I visualise but the rest fits into place. I would defy any child at the end of the year to not have an understanding of systems and analysis. (Lynley, Interview)

Lesley's major interests were in language and she developed her skills to become a language focus teacher for her school. Lesley was able to avoid teaching science for the previous five years because there was specialist help in her school. When the new science program was offered she saw this as an ideal way to upgrade her science teaching skills. Lesley previously taught science according to the themes she developed in her language areas. Lesley viewed learning as engaging the children in interesting activity based activities.

> The science I remember doing years ago was theme orientated. I remember using *I Do Science* but I never used to enjoy it, it was boring. Getting all the equipment was difficult because it was not always in the school. With themes I did things that were science orientated as part of the language so any little experiments were fitted in. My teaching followed a problem solving approach, doing topics that I enjoy. I suppose I weight my day with language as a personal preference. If I'm enthusiastic and excited about things the ideas go across better. If this is boring me it must be boring the children and bored kids aren't very productive learners. While some of the themes I do are the same, I think of new ideas that I can slot in. (Lesley, Interview)

The two teachers come to science teaching via different pathways. Lynley pursued science as a teaching career choice because her childhood and educational experiences fostered her love of nature. Lynley also felt an overwhelming responsibility to ensure the children in her class and in other classes would have the opportunity to learn science. Lynley cared that the children would develop skills and abilities to help them deal with the new technological age. Lesley favoured languages because she had never seen herself as being scientific and was unsure of her background knowledge in science. Lesley also believed that her programs had to provided stimulating lessons to motivate the children to learn. Lesley believed that if she was bored she did not learn and transferred this

attitude to her children. She was concerned and cared about the children's learning and she tried very hard to keep her teaching exciting and maximise learning by making cross curricula links.

6.5 CONCLUSIONS

This chapter examines how these two experienced teachers dealt with the issue of care in their science teaching. The two vignettes are analysed in terms of teachers' pedagogical content knowledge, pedagogical knowledge and knowledge of self. The teachers' pedagogical content knowledge centred on safety issues and the correct procedures to use when working with potentially hazardous equipment. Both teachers made a point of discussing the reasons for exercising care when handling equipment and reinforced this in the lesson. The children were given a strong message that the teachers cared for their safety and would look out for them.

In relation to the teachers' general pedagogical knowledge, the issue of care was evident in many ways. They had an ongoing commitment to good discipline within the classroom, and used several strategies to ensure appropriate behaviour. They offered praise for good group work, disapproved of inappropriate behaviour and removed children from the class to allow them time out for reflection. The science lessons used small group work reinforcing the roles assigned to children and the need to cooperate. The teachers utilised storytelling to motivate the children. Stories built on experiences to illustrate and reinforce safety considerations.

Teachers' knowledge of self was informed by their childhood and throughout their educational experiences. From the family, the teachers learnt how to nurture, care and share with others. Both teachers remember caring for the environment through their early education. Family life actively supported the value of education as a worthwhile endeavour. The teachers' experiences during pre-service training allowed them to build upon their interests and abilities in teaching science. For Lynley this enabled her to increase her knowledge about caring for the environment. For Lesley the caring for younger children was valued. Caring about children's educational opportunities was also influenced by the teachers' pre-service experiences. Lynley pursed her science interest to influence not only the children in her class but her colleagues as well. Lesley developed

her love of language in the same way. The teachers were constantly modifying their science teaching for the benefit of the children in their care.

CHAPTER 7

SOCIAL MILIEU

This chapter examines how the social milieu impacts on primary science teaching. Teaching is not performed in isolation and Giroux (1989) suggests, "Schools are not merely instructional sites designed to transmit knowledge, they are also cultural sites" (p. 181). Social milieu involves the social interactions between the various participants within the school community including school authorities, principals, teachers, children and families. Milieu is one of Schwab's (1973) curriculum commonplaces that include subject matter, milieu, learner and teacher.

Teachers develop their pedagogy of teaching through years of experience. Teachers construct their knowledge of teaching in response to the students, parents, colleagues and personal constraints making up their worlds (Hargreaves, 1994; Wildy & Wallace, 1995; von Glasersfeld, 1993). Schools develop a culture incorporating these aspects that give structure to many ideals and issues that are negotiated and established over time. Science, like other subjects sits within this school culture and as Wildy and Wallace (1995) suggest science teachers "cannot underestimate the importance of understanding the cultural context of the school, having a clear and consistent view of the subject matter, building a learning community of trust, and adapting the curriculum to accommodate the knowledge, needs and aspirations of the students" (p. 154)

Putnam and Borko (2000) argue that teachers' "professional knowledge is developed in context, stored together with characteristic features of the classrooms and activities, organised around the task that teachers accomplish in classroom settings, and accessed for use in similar situations" (p. 13). In achieving this, the paradox is that teachers can become isolated within their classrooms as they deal with the complexity of their teaching role (Baird, 1988, Hargreaves, 1995, Kosunen, 1994; Lortie, 1975; Wallace & Louden, 1992). Many teachers view change as an intrusion upon their hard won

established work patterns and teaching strategies. The ability to collaborate about changes to work practices is limited because teachers' are busy with preparation and teaching. When change is bought into the school it is often at the request of the principal who in turn is responding to demands from the educational department. These kinds of changes often bring an increased workload for teachers who may not see their value because they are not driven from their needs (Haney & Lumpe, 1995).

Hargreaves (1995) suggests, "To speak of the realities of teaching is to address the nature and organization of teaching not in terms of ideals, fantasies, models, or rhetoric, but in terms of the complex actuality of the work, and the day-to-day shape it takes with real teachers, in real classrooms, in real schools" (p. 80). The school culture sits within the wider community culture that includes teachers' families and friends. Teaching is a demanding occupation and often outside designated work hours requiring a balance of personal and professional commitment. In the year of this study the government education system was undergoing a period of rapid change and dislocation. Teachers were engaged in union bans that restricted their hours of work at school and limited their involvement in school-wide activities. These circumstances placed additional pressures on teachers' work.

7.1 VIGNETTES ABOUT SOCIAL MILIEU

The two vignettes in this chapter illustrate the complexity of interrelationships in teachers' social milieu. The first vignette is about Lynley's Year Five class and their involvement in a district level science competition. The children were asked to create a catapult at home that was then trialed to find the best catapult to represent the school in the district competition. Lynley gave up an opportunity to attend a professional development course so that she could help with the trials because she felt it was important that the children were supported and assisted. The second story follows Lesley's Year Two class as they investigated and classified mini beasts. Lesley had great difficulty finding the small creatures in the middle of winter and spent a lot of time over the weekend trying to collect insects. As the lesson progressed the principal came to the class to collect a student survey that Lynley should have previously completed.

7.1.1 Ebb and Flow

Lynley was been very busy during the first half of the year helping her colleagues implement *Primary Investigations*. The task had been both challenging and frustrating for her because some staff resisted the changes in spite of her efforts. Lynley also had the opportunity to document the school's progress on the implementation through the use of a portfolio. The principal heard about this form of reporting on school development at a principals' meeting. When he suggested it to Lynley she saw the opportunity to show other schools in the district how to implement the program. This meant collecting evidence from each teacher about how the science program was working for them. Most teachers submitted work samples, tests and reflection on their teaching. The principal visited each class and video taped the science lessons. Lynley was eager to show me the portfolio but she needed to get through the trialing of the catapults to select children for the district science challenge.

The staff at the school had always participated in the district science challenge and this year the task was to create a catapult capable of projecting a ping-pong ball. The children were given a plastic desert spoon and told that there were no limits to their design. They were given a month to make sure the catapult functioned effectively and class trials would determine who would represent the school at the district challenge day. Lynley did not have to organise materials for this activity because it was managed by one of her male colleague.

The challenge day was originally scheduled for a Thursday but was changed to Tuesday. The change in days clashed with Lynley's attendance at a special science course at a local university. The course, funded by the education department, was designed to help primary teachers to upgrade their scientific content knowledge. Lynley decided to miss her lecture so that she could be on hand to help her students during the challenge.

Lynley assembled the class and marched them out to the quadrangle. Not all of the children had completed the task but the array of catapults was impressive. Some had produced simple machines with a ruler attached to a block of wood and the spoon strapped to the top, while others had created catapults that looked as if they came out of medieval times.

"All right class, we will sit along the edge so that you can see how far the ping pong ball goes," said Lynley. "I will ask Rachel and Judy to mark where the ball lands with these markers. They will then measure the distance using the tape measure we used for long jumps and I will record the distance on this class list. I would like to say how wonderful the catapults look and you all must have worked very hard on them."

The children with catapults lined up and were each given three turns to ensure that the testing was fair. Two children placed markers to record the distance travelled and Lynley recorded the distance of the longest shot on her sheet. The process went very smoothly with the line of cheering children watching and offering much encouragement. With each catapult the child was given time to explain how he or she had constructed the catapult. Rodney had an amazing story to tell about his catapult.

"Rodney would you like to tell the class how you managed to get your piece of wood to bend so well," asked Lynley.

"Well I started testing with my piece of wood and found that if I wet the wood it would bend further," Rodney said. "In the morning the wood stayed bent but it still worked really well so I left it."

"Well done Rodney," said Lynley. "You must have done quite a lot of work trialing your catapult and you certainly experimented with the materials to help maximise your chances of winning. It shot the ping-pong ball a long way this morning. Did you know class that in furniture making they will steam strips of wood so they can bend them into position?"

Rodney set up his catapult making sure that it lined up properly. He loaded it up with the ping-pong ball and bent the wooden arm back as far as it would go. With a sharp crack the wooden arm broke about 2cm from the base. Rodney burst into tears as he realised that his chance of winning the competition was over. Lynley quickly put her arm around Rodney's shoulders and shielded him from the class so that he could retain his composure.

"It's all right dear," consoled Lynley. "I'm sure Mr Beck the gardener will help you modify your catapult. We still have six catapults to test and if you hurry we will fit you in because we don't have to decide who goes through to the whole school competition until later this afternoon. Mike, you and Len go with Rodney. I'm sure you will find Mr Beck in his shed."

The boys helped Rodney gather up his broken catapult and went to find Mr. Beck. Lynley quickly started the process again and Rodney returned before the end of the session. Mr. Beck had been very helpful and, after cutting the broken piece, Rodney was able to fasten it to the base. When Rodney's turn came around again his catapult worked better than in the morning, ensuring him of a place in the competition. He later went on to gain second place in the overall school trials held later that day and represented his school the following week at the science challenge day.

At the end of the day Lynley was very keen to show me the portfolio of how the school had implemented the new science program. Before we could look at it properly Anthea, the year six teacher, burst into the room excited about her attempts to build and fire up the volcano with her class. When Anthea left, Lynley expressed frustration about how difficult it had been to get her to get involved in the new science program. Anthea only used those lessons she thought worked in with other class topics and then complained when the lesson did not work well. She had not been a willing participant in the professional development sessions and had failed to appreciate the need to offer the lessons in sequence to develop the concepts.

"If the teachers had worked through the lessons in their groups using the materials I supplied, then they would have seen the pitfalls," Lynley began. "They would have been all over the hurdles they come across and this is why they won't teach it because so many times they come up against a brick wall."

Lynley told me the following week that the days after the catapult trial Rodney's mother thanked her for helping her son through his crisis. She said that he had worked very hard on his catapult over a long time and that it meant a great deal to him to enter the competition. He had felt such a sense of achievement having been able to succeed in the competition. Lynley beamed as she recounted this episode. Knowing how much it

meant for Rodney justified her decision to miss out on the special university course. It certainly had made her week seem worthwhile despite all the extra work.

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The story of the catapult challenge reveals a few elements of the social milieu. Lynley was willing to give up her day at university so that she did not disrupt her students. Lynley felt that because the children had put such a lot of effort into building the catapults they needed her support when the final choices had to be made about who would represent the school. When Rodney broke his catapult she knew how to help him overcome his problem. The comment from his mother the next day further strengthened her belief that she had made the best choice for the sake of her class. Other people in the school needed Lynley's help and encouragement in teaching science that added to the complexity of her teaching task. Lynley also held the belief that her role of science coordinator carried with in a responsibility to provide whatever support the teachers and children required to help them with their science.

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7.1.2 Mini Beasts

Lesley was not her usual calm self when I arrived for the lesson. She had spent a great deal of time looking for insects over the weekend but had been unable to collect enough for the lesson. The lesson was based on sorting four mini beasts according to characteristics chosen by the children. Some children bought earthworms and a few beetles. Lesley had collected some snails and slaters however she still needed four beetles. Before the lesson Lesley took the children into the school grounds looking for insects, with little success. When I arrived, the children ran up to tell me what they were doing, very excited about being outdoors. After the recess break the children lined up outside the building in a noisy and high-spirited state.

"I just can't find enough beetles," Lesley began. "Next year I will have to start earlier and keep them in an aquarium. My spare time was taken up with a parent interview last week. The parents were worried about the amount of homework I gave their child but if

they had come to the parent meeting at the beginning of the year they would know how I like to run my class. My time is too precious to spend on parent interviews like that especially with the reports coming up soon."

As the children settled on the mat Lesley made a final check of the ice cream containers to make sure the insects had not escaped. Lesley found the science coordinator had not supplied enough magnifying glasses, so some of the children would have to share. Monday was a full teaching day with lunch duty in the middle of the day. Lesley usually made her final preparations on Thursdays in the previous week when she had free time, but she had been caught up with the parent interview.

Lesley began the lesson by reading a couple of poems about animals and how they moved. The poems were lively and familiar because the children had learned them earlier in the year. Lesley encouraged the children to talk about mice, fish, kangaroos, tigers, snakes and tadpoles to generate the list of words about movement. The list of words included crawl, slither, wriggled, swam, crept, scamper, hump and hop. The children happily participated, excited about the similarities of some animals movements. Indeed the lesson became more about language than science.

"Now if we thought about how animals move that's only one characteristic of those animals," Lesley began. "We are not describing how they look, it's just how they get from one place to another. The animals we collected are like mini beasts, big creatures would be too hard to catch. Using the magnifying glasses you are going to have a close look at these animals and try to collect as much information as you can about them. After you have looked at your animals you are going to sort them depending on size, colour or how they move. Don't poke, pull, or squeeze the animals because animals are alive. We will be using our eyes only today."

Lesley reminded the children of the need to share the beetles and snails because there were not enough for every group. She suggested the children use the ice cream container lids as tables to closely observe their creatures with the magnifying glass. Lesley allowed the children 10 minutes to explore while she moved around encouraging them to talk about their animals. At the half way mark she reminded the children to

share the beetles with others. When it appeared that everyone had spent enough time looking at the creatures, Lesley spoke to the class.

"Right, everyone stop please and listen to me," Lesley began. "I have given you four mini beasts on paper like the animals in your container. Our little creatures don't have nice big smiley faces like the ones on these pictures. Now listen to the next part before you move. It will be much easier to sort the pictures than it will be to sort the animals. What would happen if we try and sort the little mini beasts, Alice?"

"They would all run away," said Alice.

The children thought it would be funny to see the creatures trying to stay in one place. The creatures were put back into the containers and covered with the plastic wrap. Lesley gave each group the pictures of the creatures pre-cut and pinned together with a paper clip. The children quickly settled into their groups and sorted the pictures of the creatures according to an agreed characteristic. Lesley walked around listening and encouraging.

"How have you sorted your animals, Jenny?" asked Lesley.

"Well these have got a shell and this one hasn't got any shell," Jenny said.

"We sorted ours into legs and no legs," Edward said.

"I know another one," said Jenny. "Those ones can wriggle and those ones have to walk with their legs."

"You are exactly right," encouraged Lesley. "Here is Mr Gregory. Say good afternoon to the principal everyone."

The class sang good afternoon to the principal who had just arrived in the room. After listening to a couple of the children talk about the differences between their creatures the principal asked Lesley if she had finished the survey form he had requested teachers to complete. Lesley explained to the principal that she had not finished the survey but

would do so that evening and return it in the morning. After the principal left, Lesley called the class together to discuss how the mini creatures had been grouped. The criteria included creatures that could be killed easily or not, slippery and not slippery, those that had lines separating the body parts and those that did not, creatures with legs and without legs, shell and no shell and burrowing and not burrowing. Lesley realised the time had expired and said they would finish gluing their pictures the following day. Lesley thanked Edward and Jenny for bringing in the beetles and earthworms then asked for volunteers to release the creatures in the school garden.

After the children were dismissed, Lesley said she could not believe how hard it was to find the mini beasts. She thought she would have to start collecting earlier and keep the creatures in an aquarium. Lesley said that she had such a lot of things to do at the moment and the collection of mini beasts only added to her workload. The children's reports had to be written within a week or two and her preparation time the following week was again taken up with parent interviews. She also needed to collect material for the children's sample folders to help with parent interviews and reports. Lesley had also forgotten the survey Mr Gregory needed for the superintendent. I suppose I'll have to get it done tonight she said.

"The children appeared to be very lively today," I commented.

"Well with everything going on at the moment they perceive the tensions in the air," Lesley answered.

* * *

The story of Mini Beasts illustrates the many issues that Lesley faced while engaged in teaching science. Lesley used time over the weekend to collect creatures that the children had been unable to supply. The cool winter weather made the task more difficult and the class could not find many animals the school grounds. Lesley had a full day teaching on Monday, with duty at lunchtime. Lesley had not had time to check her equipment because of a parent interview the previous week and the lack of equipment compounded her frustrations. Despite the set backs the lesson proceeded well with the children motivated about sorting their creatures. An interruption by the principal

reminded Lesley that she had not completed a survey about the children's learning areas. After the lesson Lesley spoke about the workload at this time of the year with reports and work sample files to be completed before parent interviews.

* * *

These two stories illustrate how the social milieu impacts on the teaching of science. For both teachers the role of teaching is part of the fabric of their lives. Teachers lead busy lives as they work within their school community and support their colleagues to develop the new science program for the school. This extra work also impacted upon their personal lives as they juggled around the work commitments. Above all the stories reflect the complexity of teaching when one considers the array of demands and influences bought to bear on teachers' time. The manner in which each teacher responds to this situation will be discussed through the teachers' knowledge categories of knowledge of self and knowledge of the milieu.

7.2 KNOWLEDGE OF SELF

Teacher's personal values and beliefs inform the decisions teachers make about ways of conducting themselves when teaching (Hargreaves, 1994). A central issue for both teachers was the dilemma of balancing work with personal commitments. In Lynley's case, she was troubled by the attitude of her husband who did not understand why Lynley needed to bring work home.

> Mind you my husband manages to get all his work done at school because he goes in an hour earlier and everyone knows not to interrupt him. He is always telling me to relax at home but if I don't do the work, I'm not prepared and the day is much harder. Sometimes I wish he'd go out more often on the weekend so that I could catch up. (Lynley, Interview)

For Lynley this became an issue when the amount of work escalated during the report writing weeks. Lynley used most of her spare time of an evening to maintain her marking of work.

> I rarely watch television because I have been sitting next to the fire down stairs doing all this reporting. Larry watches it for something to do but he flicks it from channel to channel, which drives me crazy. (Lynley, Interview)

When Lynley gave up her university course she placed the children's needs above her own personal requirements. Lynley knew how much effort the children had put into their catapults and was willing to stay at school to support them during the trials. Lynley was aware that the children may have been supervised by other staff who may not have appreciated the importance of the catapult trial.

> "The children have spent a lot of time on their catapults and I needed to be here if they needed my help. Other teachers wouldn't know what to do."

As the session progressed her decision to stay at the school was vindicated because when Rodney's catapult broke she was able to offer him assistance. The decision to remain was later positively reinforced when Lynley was thanked by the mother who told her how much it had meant to Rodney to be part of the school challenge.

Lesley also gave up her leisure time for her children. When it became obvious that the children were not able to find enough mini beasts for the science lesson Lesley spent part of her weekend looking for mini beasts in her garden. Lesley had also given up class time before the science lesson to search the school grounds. When I arrived at school Lesley was obviously frustrated.

> "I just can't find enough beetles," Lesley began. "Next year I will have to start earlier and keep them in an aquarium."

Both teachers worked at home in order to keep up with preparation and marking. Often Lesley used her weekend to collect material for the science lesson. Lynley opted to attend school rather than her university course. For both teachers their discussions about teaching science are intractably linked to personal values and beliefs.

7.3 KNOWLEDGE OF THE MILIEU

The knowledge of the milieu of teaching involves teachers' understanding of the impact of the wider community and the school community in their classroom. There were three examples of how the milieu of teaching impacted the work of these two teachers. The first example is participation of the teachers in district level initiatives. The second example deals with the teachers' collaboration with their colleagues about science matters. In a third example, I look at parent impact on classroom practice.

The first example relates to the teachers' participation in district initiatives. Lynley shared the role of school science coordinator with a colleague, David, because she had taken over the position when he was on leave. David remained in charge of the district science challenge and provided a focus for the district science week in the school. The district activities were an established tradition and the teachers at the school had always participated. Lynley experienced the positive aspects of involvement at an earlier school and was aware of its value in encouraging children to participate in science.

> The first year I helped one of my children entered the talent search we started it not knowing the method to follow. A young lass called Amber took it on, a year seven, and she wanted to develop a barbecue that was safe out in the bush. It had to be an environmentally friendly one. She developed one using the cool drink bottle by cutting it in half. She used alfoil inside and we went into parabolic curves and all these sorts of things. She was a pretty cluey kid. At the same time we photographed it, documented the steps she took and created a fold out stand with the information on it. Amber ended up winning her year level and she, and I, got such a terrific boost out of it. Amber has gone on right through the sciences and now she has gone into that area in university. So from that talent search she grew to love science and although it was hectic I just loved it. (Lynley, Interview)

Lynley also recognized the value of working at a district level to raise the awareness of science through her earlier experiences as a teacher setting up a district science topic box system. Lynley worked two days a week as a science specialist and she was encouraged by the district science specialist, Bruce, to help in establishing science topic boxes around the four science topics of energy, matter, plants and animals.

> I followed the '*I Do Science'* series because they were available in the school. All the student books were there and it saved me a lot of time photocopying. It was a lot of work to create the boxes but we had wonderful parents. All the equipment was housed at my school because I had a spare room and the teachers would call in to pick up what they wanted. Bruce also developed cell schools and we had wonderful sessions when he showed us how the science topics related to each other. (Lynley, Interview)

Bruce's enthusiasm and leadership made the project seem worthwhile and exciting. When Lynley became aware of the new science program her previous experience enabled her to see the change as necessary and worthwhile.

> This school is seen as a leader in science. Mr. Webster heard about the idea of a portfolio so he asked the teachers if we could video tape them working. Mind you we got so wrapped up in working with the children we forgot to monitor if the objectives were being covered. Mr. Webster said that if this had been around 20 years ago teaching would have been so much more fun and satisfying for him. We also asked the teachers to supply tests, assessment lists, photographs and some of the children's work sample. The end result was fantastic because some teachers also wrote comments on the lessons and how they went. (Lynley, Interview)

A second example of knowledge of the milieu looks at the relationship between Lynley and Lesley and their colleagues. In both schools the science program was implemented on a whole school basis involving collegial discussion of the content and pedagogy of teaching science. Lynley made herself available to her colleagues to talk about how science was progressing. In her conversation with Anthea it became apparent that Anthea's excitement did not extend to the science program.

> I've read it all but I've cheated and got the SciTech space station coming to the school. They give you workbooks that go with it which have absolutely fantastic experiments in it. We are going to camp next week and I'm going to suggest the children go and gaze at stars when we are there. (Lynley, Interview)

Lynley shook her head when Anthea left the room. Anthea believed she had a successful science program built around topics that related to what the class found interesting.

Lynley was frustrated with Anthea's lack of interest in the professional development and subsequent implementation of the new science program.

> If the teachers had worked through the lessons in their groups using the materials I supplied, then they would have seen the pitfalls. They would have been all over the hurdles they come across. This is why they won't teach science because so many times they come up against a brick wall. (Lynley, Interview)

Lynley had invested a great deal of time and effort into assisting the staff. The school science portfolio entries had focused some of the teachers on the positive aspects of the new science program. However, Anthea felt uncomfortable with the change and Lynley was unsure how to encourage her to stay with the program.

The final example points to the impact of parents on decisions made by teachers in the classroom. This impact can be seen in two ways, in a positive, supportive way or as a constraint felt by teachers on their professional autonomy. Lynley knew the parents at the school were generally supportive of the children and that they valued education. At the parent interview evening she had been impressed with the way that the parents had been interested in their child's progress.

> I'd say that over 80 per cent of the parents are in business or achieving higher studies. Some of our children come from the next suburb where goal setting and incentives are not instilled into them. They find working with these children they are quickly swept up into that atmosphere of having to work to get anywhere. For the children from split homes, both parents have a centred interest in the child and make sure they're there for them. There was a common interest and drive to see that the child does well and achieves well. Even if there was another partner they were just as interested in the child. (Lynley, Interview)

These impressions about the parents reinforced her own belief that the children needed her support. The incident involving Rodney's mother helped Lynley to justify her actions.

Lesley, on the other hand, was finding parental expectations a constraint to her lesson preparation. Lesley relied on her preparation time on Thursday to double check

equipment because sometimes it was inappropriate or insufficient. At the beginning of the year Lesley and the other teachers set aside an hour before lunch to discuss with parents her methods of teaching, homework commitments and how parents could help at home. I attended that meeting because Lesley wanted me to talk about the science program and it gave me an opportunity to answer questions about my study.

> The group of parents were mainly mothers, one father, and there were about 15 people altogether. Lesley went through her philosophies, preferred method of teaching in all subject areas, her discipline, parent interview times, and the need for a parent liaison person. The information was very good but the parents did not interact very much. It was when the issue of home reading and merit certificates were mentioned that the parents became animated. Lesley has been a collaborative teacher for First Steps and so inspired a lot of confidence. Lesley was very relaxed and the parents were not shy in putting questions to her at the end of the talk. (Pearson, Journal)

Lesley gave the parents an opportunity to question her about the way she operated her class. She was very clear about each subject area and answered all their questions fully. Lesley knew that the parents were very keen to help their children. They were a very close-knit group because the children had been through pre-school and year one together. A week earlier she had complained about the parents trying to dictate to her about the reading program.

> I've had parents asking me why I don't listen to the children read every day. I've already explained my reading program so I'm just about ready to ask them to back off and leave me alone. (Lesley, Interview)

Lesley was happy for the parents to be informed about how their child was progressing. She provided parent information session at the beginning of the year, reports and interviews half way through the year and also individual parent interviews on request. However, Lesley became frustrated when some parents were too demanding, questioning her approach to particular subjects and using her preparation time to discuss matters she had already covered.

Lynley acknowledged that the parents were interested in their children and that they supported her efforts to provide a safe learning environment. Lynley had been at the school for seven years and she had taught siblings within families so the parents knew her well. Lesley spent valuable time informing the parents about her philosophies of teaching and resented the time taken to go over this information again when it impinged upon her preparation time.

7.4 CONCLUSIONS

This chapter examines how the social milieu impacts on science teaching. The two vignettes illustrated some of the connections between teaching and the milieu and are analysed using two of the five categories of teachers' knowledge. The central issue in the chapter was how the teachers balanced their personal and professional lives. In the Year Five story the teacher elected to stay with the children instead of attending her university course because she knew how much effort the children had put into building their catapult. Both teachers were also willing to use part of their weekend to ensure that their preparation and marking was up to date.

The vignettes also illustrated examples of how their science teaching was situated with the district and understanding of the district community, school community. Lynley was convinced of the value of having students involved in the district science talent search. Her previous experiences of co-operation at a district level also taught her the value of sharing ideas about science. When asked to create a portfolio to show the school's progress in the new science program she was happy to do so because then she could share this with other schools. Lynley tried to be as helpful as possible when her colleagues approached her about their successes or problems with the science program. She was always willing to listen and offer positive comments. Lynley was given positive feedback from an appreciative parent about the support of a child during a stressful time. Lesley provided parents with an opportunity to understand her philosophies and methods of teaching earlier in the year. However one particular request from a parent for an additional interview before the reports were issued disrupted Lesley's preparation and added to her stress levels at a busy time of the year.

CHAPTER 8

PROPOSITIONS

This study examines the manner in which two primary teachers implemented a new science program into their teaching practice and is guided by the following broad research question: How do experienced primary teachers incorporate a new science program into their teaching? In conducting the study I have tried to come to an understanding of experienced teachers' abilities to adapt their teaching strategies. Five different issues emerged as consistent and recurring themes – managing equipment, language of science, teachers' certainty, caring and the social milieu. The themes have been used in the preceding five chapters to construct vignettes of practice and analyses based on a teachers' knowledge framework (Adams & Krockover, 1997). In this chapter, I revisit the themes, vignettes and preliminary analyses to construct several overarching propositions about the study. These propositions serve as tentative assertions, highlighting those issues that may have applicability beyond the boundaries of this study.

8.1 Proposition 1

Explicit teaching notes are a vital, though problematic, tool in helping teachers change their practice.

The provision of explicit teaching notes in the form of a teachers' resource book, called *Primary Investigations*, was an integral part of the new science program. The teachers in this study relied upon the resource book when implementing their science lessons but they differed in their degree of dependence upon the document. The resource book, containing structured lesson notes, was sometimes like a double-edged sword for the teachers. They used the information in the book as an essential implementation tool but

were at times thrown when confronted by unanticipated difficulties with equipment and content.

The *Primary Investigations* teachers' resource book included many features to provide assistance for teachers. The book included suggested time for the lesson, lesson summary, lesson outcomes, equipment and preparation required, teaching strategies, background information and extension lessons. Additional features included a reminder about the stage of instructional model being developed. There were also questions to stimulate and focus the children, written in bold type, with supporting italicised information giving answers the children may suggest and additional information about the question. The text from the children's book was also included in the lesson plan eliminating the need to juggle two books. The features were tagged by the use of icons providing a visual clue about the section in the lesson plan. The resource book also provided explicit information and instructions about best practice in small group teaching strategies. As a package, the teachers' resource book was developed as a comprehensive set of instructions on all aspects of the new science program.

The teachers' resource book provided a prescriptive series of lessons following a particular instructional model based on constructivist principles. For Year Two and Year Five, the programs differed according to the level of science concepts taught and the complexity of the activities in the lesson. While both teachers relied heavily upon the resource book, each utilised the book in different ways in their planning and lessons delivery. Lynley never had the book in hand during the lesson but studied the lesson plan in detail a few days earlier. She would visualise the major teaching points of the lesson to familiarise herself with the flow of the lesson. Lynley then went through the steps of the activity at home and discussed any misunderstanding with her husband.

> Once I've focused on exactly what it is I'm doing I read through all the lesson format and picture in my mind exactly how I'm going to do it. I visualise what the groups will be doing and I consider the time aspect. With preparation I make a model if there needs to be one…. If something jolts, such as a misunderstanding somewhere then I follow the plan that I visualised and the rest will fit into place. (Lynley, Interview)

During the lesson Lynley left the resource book on her desk and rarely referred to it unless she needed background information. When Lynley was discussing the compost bins with the children she was unsure of her definitions of micro-organism because some of the children had included the terms protozoa, organisms and bacteria to suggest what is found in soils. She referred to the background information in the teachers' resource book and read aloud the passage about the composition of the soil.

> "I will have to leave it there Denis, I'm sorry," said Lynley. "Let's go to our background information and we will very quickly skim these notes. We are now talking about our mini bins and the compost."

Lynley also used the book to read through passages of instructions about activities. *Primary Investigations* embedded the children's written instructions within the teachers' resource book. This feature made it convenient for teachers because they did not have to handle two books during the lesson. When Lynley felt that the children were having trouble reading their instructions in the small groups she stopped the class and read through the instructions in a lecture mode. In the lesson on making a bottle diver the children became preoccupied with reproducing what Lynley had previously shown them in a demonstration. They needed constant reminders to bring them back to the written instructions.

> "How about you try it first," Lynley suggested. "Read the instructions and try it because it will work without the nail sometimes, other times you need to put the nail in. See if it will work without the nail first and if it won't, come back and I will help you for sure. Who is the reader?"

Lynley found, in the earlier part of the year, that the children tended to rush into the activity without reading their instructions. The children were unfamiliar with the techniques of reading informational text. This was a source of frustration for Lynley because she was constantly stopping the class and reading the student instructions.

Lesley, who was less experienced with science than Lynley, was unsure of her ability to teach science and expected a lot of support from the science coordinator in making sense of the teachers' resource book. Lesley started her preparation the week before the lesson by reading through the plan thoroughly and giving the list of equipment to her

teachers' aide to assemble. Lesley read through the lesson plan again on the morning of the lesson, checked that the equipment was available and collected anything not provided.

> The week before I'll read through the resource book and get an idea of what materials and things need to be set up and get things organised. Then, usually on Monday morning, I read through the whole of the lesson plan again before school and get all the materials and things set up. After lunch I have another read of the lesson again in silent reading time so that it's fresh in my mind. I also need to refer to the lesson plan during the lesson because I'm always frightened I'm going to miss the point. (Lesley, Interview)

Lesley kept the book on her knee like a security blanket throughout the lesson. She read from the book at each stage of the lesson and sometimes held up the discussions as she found her place, read the next section quickly, then moved on in the lesson. This was evident in the lesson on sorting natural and man-made landscapes. Lesley went through the list of suggested topics for discussion to motivate the children about sorting the features of their immediate environment. It was evident that she did not want to miss any steps in the sequence of the lesson.

> The teachers' resource book then suggested discussing how they organised their bedrooms. After discussing their clothes, books and shoes it was obvious that the children knew about organising their room and most of them agreed that it was hard to keep them tidy. The main objective for the lesson was that the children recognise and decide what made a landscape natural and what made it man-made. (Lesley, Interview)

When asked about her reliance upon the resource book Lesley admitted it was like a bible she followed closely because she was conscious of not missing a step of the lesson in case she jeopardised the children's learning.

> Yes, I stick very close to the lesson plan. Next year I might read through and remember what we did and how it went, but this year I'm definitely following it step by step. (Lesley, Interview)

Although the teachers found the teachers' resource book to be supportive in supplying information during the lessons there were times when the explicit notes caused dilemmas. Lynley experienced problems with the lesson on bottle divers because she was able to reproduce a working model at home without understanding the concepts of air pressure. However Lynley was unable to reproduce the model at school and did not understand why there were problems. Even so she relied heavily upon written instructions and the illustrations to puzzle out which part of the picture was not accurate. Lynley did not understand fully the bottle diver model and her understanding of air pressure was not developed enough to overcome the problems.

> "When I did this last night it worked the first time," Lynley said. "I should have left it together for the demonstration."

Lesley experienced similar problems in the lesson using magnets. She relied upon the science coordinator to supply the equipment. The school had one set of magnets used by all classes. The set of magnets were bar magnets of variable age, with many scratched and worn. The lesson preparation notes suggested using small round ceramic magnets to disguise the properties of the 'magic sorter' the children would use to sort their objects. When I questioned Lesley on the suitability of the magnets she replied that these were the only ones supplied by the school and she assumed that the science coordinator knew what she was doing. As we waited for the class to return from their break we tested the magnets to find that they varied in their magnetic properties.

> "This was all Jessica could find in the school," Lesley said. "My Monday is very busy and I had to run all over school for these anyway. Jessica agreed to help us out with the material otherwise I would find it too hard."

To some extent, these problems with equipment arose because of the equipment lists supplied in the teachers' resource book. The master lists of equipment for the entire year's program is found at the back of the book. The school science coordinator referred only to the master list when determining the equipment each teacher needed. It is only in the teachers' preparation notes that the magnet is defined as 'a small round, ceramic magnet'. The science coordinator had assumed the magnets were non-specific, compounding the problem. Lesley proceeded with the lesson because she had no opportunity to change the magnets and felt that the lack of good quality magnets would

not impact too adversely upon the children's task of sorting the collection of objects. Lesley was confident that she had followed the lesson plan and the children had sorted the objects well enough.

Another problem created by the use of explicit notes is the apparent lack of flexibility to pursue avenues of investigations that result from the children's interests or as a result of a teaching opportunity. While Lynley experienced some problems with this aspect of the science program, Lesley was comfortable that the younger children were fully engaged in the activities. For Lynley the lesson on mini bins highlighted this teaching issue. Lynley ran out of time to continue with a discussion initiated by the children on two occasions. In the previous lesson the children had prepared their mini compost bins and Lynley wanted to focus on what soils are made up off and the importance of compost to soils. The class discussed the reasons why mini bins were placed near the window and the possible impact on the earthworms. This lead to a discussion about the effects of sunlight on human eyes and on earthworms.

> "Good boy," Lynley answered. "It might be a temperature thing because in light they might be able to have that very fine sense of telling whether it is hot or cold. Alright, so we had better leave that there because that was an excellent perception."

Although Lynley encouraged the children to talk about their ideas and had agreed that it would be wonderful to do other experiments on earthworms she felt that she had to focus the children on the importance of compost to the soil. Later when Lynley wanted to know which organisms assisted in breaking down the plant material found in soil, there was a lively discussion about bacteria and protozoa. The conversation was restricted to a few students and after a couple of minutes Lynley again directed discussion to the lesson plan by reading the background notes on the importance of compost. After the lesson Lynley felt frustrated about not having time to explore the issues that arise from the lessons.

> "I couldn't believe it when Mike wanted to go on about the sound and light rays," I laughed.
>
> "Yes, I didn't know how to answer that one," replied Lynley. "Veronica and the others tuned into him and were ready to really get their teeth into the discussion.

> These kids that know all about protozoa and all these things. If we could just halve the class and put those that are really interested together it would be great. The gardeners' heaps amazed me."
>
> "I know," I said. "I had my money on the black heap."
>
> "Yes," Lynley said. "But it was the grass clippings because they break down rapidly. It's hard to find enough time to go into everything that comes out of these lessons. Maybe we should spend more time on micro-organisms when we look at the milk experiment next week."

The teaching notes in the resource book dictated the sequence of the lesson and the steps were structured to a particular time frame. This meant that when the children wished to develop a discussion about a topic that was not relevant to the lesson plan the teacher was obliged to steer the discussion back to the main focus of the lesson if she wanted to keep up with the program. Lynley was always conscious of running out of time to complete the lesson within the time allocated and found it hard to maintain the pace of the program.

> The main concepts I wanted to get across was basically why we set up the mini bin. What was going to happen within that compost bin and the variables they may have come across. I didn't really round it off as well as I wanted to today because we just ran out of time. (Lynley, Interview)

In summary, the provision of explicit teaching notes does not guarantee teachers will successfully change their teaching practice. The two teachers in this study interpreted and utilized the resource book in different ways. These differences could be seen as a reflection of their understanding of the material, their background knowledge and experience of science and science teaching practice. Dilemmas during science lessons were sometimes due to the teachers' misinterpretation of equipment. The explicit teaching notes did not allow time to discuss topics suggested by the children because of time constraints created by following the structured program.

8.2 Proposition 2

Gaps in teachers' science subject matter knowledge affected children's science learning opportunities.

This study identified several areas where teachers encountered teaching and learning problems associated with gaps in their own science knowledge. The teachers' past experiences with learning and teaching science were limited, as they had only studied senior biology in secondary school. At times, the teachers were unable to answer questions and elaborate on lines of inquiry initiated by the children, preventing them from recognising and maximising the teaching moment during lessons. Gaps in the teachers' subject matter knowledge meant that they had difficulty identifying the correct terminology for science concepts used by the children. This lead to an over-reliance on the teachers' resource book. The lack of subject matter knowledge also created problems around the use of equipment that further caused teaching dilemmas.

Both teachers revealed that they had consciously elected not to pursue physics and chemistry courses in high school, as they were not essential for their career choices. Lynley found that science at teachers' college was an extension of her experiences with biological science, a comfortable and familiar association with the natural world. When Lynley became the science coordinator she acknowledged her lack of science knowledge and enrolled in a course at a local university designed to increase primary teachers' confidence in teaching science. Lesley considered a career in nursing, teaching or business but after attempting a course in business she changed to teaching. She selected early childhood and language as her focus because she lacked confidence in mathematics and science and felt she would not be jeopardising the learning of younger children. Lesley had avoided teaching science for five years at her previous school by taking advantage of a science specialist to teach her class.

Both teachers managed to adjust to their lack of subject matter knowledge during science lessons. They often experienced situations where they were unable to answer questions or elaborate on lines of inquiry initiated by the children. This failure to respond prevented them from maximising the 'moment of teaching', resulting in lost opportunities to consolidate new knowledge. Both teachers acknowledged the children's

questions and tried to provide some form of answer but typically they redirected the question back to the class. Sometimes they would postpone a definite answer to the next lesson, refer to the teachers' resource book or move on in the lesson because there was no time to develop an answer.

Lynley encouraged the children to engage in discussions about concepts she was trying to cover but she lacked the knowledge to direct their line of thinking. When the children were investigating the mini compost bins their discussion included the reactions of earthworms to sunlight. Lynley encouraged the discussion but, unable to answer their queries with any certainty, she eventually moved the lesson along to the next step.

> "Good boy," Lynley answered. "It might be a temperature thing because in light they might be able to have very fine sense of telling whether it is hot or cold. Alright, so we had better leave that there because that was an excellent perception."

Lynley went on to encourage the children to discuss the organisms that help break down the layers of materials in soil, but was again unable to direct the discussion to establish a working definition of micro organisms. The children suggested that bacteria and protozoa were responsible for breaking down materials and were found everywhere. Lynley agreed with the children's comments but could not provide a definition and postponed the need for a definitive answer by reading the teachers' notes on compost heaps. At the end of the day Lynley showed frustration at not being able to follow through with the children's questions. Lynley believed that through these discussions she modelled the process of thinking through problems. Although she was unable to give them the correct answer, she felt that it was important that the children could see how she arrived at her conclusions. Lynley's explanation of how a Hovercraft operates illustrates this point very well.

> "Yes, a surface that will help to trap the air between it and the craft," agreed Lynley. "It needs to be able to hover above but it still needs the air trapped. Now if you have huge swells it's going to be lifted onto a swell and the air is going to escape isn't it so it's not going to be that efficient. Now whether my theory or my analysis of that is correct I don't know, but that's what I'm assuming. Mike presented me with this huge problem with this big swell and to me that is what will happen. Also I haven't read enough on this and maybe you people can read about it."

Lynley encouraged the children to engage in discussions but when she was unable to answer the questions directly she used a range of strategies to postpone a definite answer. Lynley believed that modelling how to think through a problem was important. The lack of accurate information was unfortunate but not critical in her view.

Lesley did not anticipate having problems with her subject matter knowledge because her children were of junior primary age. During first term Lesley felt that there was very little science content, rather the science lessons were more about establishing rules for working in groups. She saw her role as reinforcing the collection of materials, reminding children about tasks and sharing the activities. Lesley often ran out of lesson time that inhibited discussion about concepts. At times, the nature of the questions raised by the children challenged her belief that junior primary children would not require a high level of science content knowledge. The children had a natural curiosity and store of beliefs about science concepts that Lesley had not anticipated. Lesley was also unsure how involved discussions should become at this level because, for her, the issue was getting through the lesson plan in the time allocated and ensuring that all the children had an opportunity to engage in the activities. When the discussion in a group turned to the existence of God, Lesley was not sure how to respond.

> "So we are constructed are we, we are built?" Lesley asked. "How did we get built?"
>
> "By God, because he's got special powers," said Jenny.
>
> "Well he has," Lesley said. "People think he does."

Lesley was unsure of the need, and lacked the time, to pursue the theory of creation at this level. She decided that as long as the children were happy with the choices they had made the lesson was a success. When Lesley spoke to the parent about the child's belief that "God made it" she found out that the father used this standard phrase when he didn't want to answer the child's questions. He had helped her to establish the belief that this response resolved some questions that appeared to have no answer. Both teachers provided opportunities for exploration of concepts through the hands-on activities but, during discussion times, the level of questioning and the pressure of time constraints made it difficult for them to advance their students understandings about concepts covered.

Teachers' also have difficulty in determining whether the children's terminology was appropriate in scientific terms. A lack of science content knowledge meant that the teachers' were unable to provide definitions or to question children to help them arrive at an acceptable scientific definition. Lynley, in one example, provided the children with sealed mouldy bread and prompted them to observe and record what they saw. The children completed the activity and described the mould according to the shape, colour and growth. During the discussion there was confusion about the terms bacteria, fungi and mould. Lynley encouraged the discussions but was unable to give a definition to help clarify the differences between the three terms. Instead she closed the discussion because time was running out and asked the children to find out the difference for homework. Later she admitted that this tactic was really to give her time to look up the information.

The teachers made heavy use of the teachers' resource book to supply the answers to questions raised during lessons and thus compensate for any deficiency in their knowledge base. The teachers assumed that the new science curriculum would provide lesson plans, material lists, and information to help them to answer questions asked by the children. Both teachers diligently read through the material before the lessons to familiarise themselves with the outline of the lesson and materials required. Lynley was able to reproduce a working model of a bottle diver, a pep bottle full of water with a suspended eyedropper, after reading through the lesson plan. When she was unable to reproduce the model for the lesson she re-read the book expecting the answer to be obvious. It was only after many attempts to create the model that she resorted to using the diagrams to solve the dilemma. Lynley was unable to make sense of the written words because she did not understand the principles of air pressure. In a later lesson air pressure was again explored when the children created a Hovercraft. Although the children were able to discuss the way air pressure behaved during the activities, Lynley was unable to provide them with a definition of air pressure. The teachers' notes accompanying the lesson plan only covered the need to assess and modify the Hovercraft to ensure that it was able to move over a surface. Lynley also read the student information to the class to try to explain how the Hovercraft worked but this information only covered the mechanical aspects of pushing air into a confined space with the use of engines. When one of the children asked how Hovercrafts behaved on

oceans, Lynley could not adequately answer that question or find an answer in the teachers' resource book.

Lesley experienced a similar problem during her lesson on Oobleck. She remembered, during a previous training session, being fascinated by the behaviour of Oobleck but had not formed any ideas about why Oobleck was able to change from runny to solid and back again. During the lesson Lesley was able to focus the children on developing the language about the way Oobleck behaved. When the children asked why it was different she redirected them to think of descriptive words. Eventually Lesley asked me for an explanation which I attempted using my limited experience of handling the substance. When I suggested reading the background information in the teachers' resource book it was obvious that Lesley did not make a habit of going through this section, rather she concentrated on the lesson sequence and materials. At the end of the day we both read through the page of background information and that did clarify some points for us. For both teachers, the resource book was a vital part of their lesson preparation. They relied upon the information provided but on occasions this information did not address their needs. Often the teachers did not know where to find information and were unable to construct their own understandings of the concepts they would cover in the lesson.

At times, the use of equipment exposed teachers' lack of subject matter knowledge. The teachers were responsible for providing the materials needed for the lesson. Lynley was also responsible for providing equipment for other teachers at her school and had a good knowledge of what was available in the school supplies. Lesley relied upon the science coordinator and her teacher's aide to ensure that she had received the equipment listed in the resource book.

When Lynley conducted a lesson on bottle divers, the poor quality of essential pieces of equipment impacted upon the learning opportunities for the children. Lynley had seen the eyedroppers in the school supply, but when she collected them on the day of the lesson it became obvious that the rubber tops were perished, making it difficult for the children to remove them to insert a nail if required. Allowing the children to experiment with the eyedroppers had to be discouraged to preserve the equipment. The use of glass jars, instead of plastic jugs, also meant that extra time was needed to instruct the

children about safety issues related to working with glass. The focus of the lesson changed from exploring flotation to a preoccupation with equipment and safety issues.

For Lesley the lesson on magnets highlighted her lack of subject matter knowledge about magnetism. The science coordinator worked from the master list of equipment found at the back of the teachers' resource book. The lesson plan suggested round ceramic magnets but the school set turned out to be an ancient set of bar magnets. The magnets had lost much of their magnetism but Lesley did not have time to find an alternative source. Lesley was not concerned about how well the magnets would work because the activity asked the children to sort objects and she felt they would achieve this anyway. One group of children identified the magnet because it was hard and made of metal but were surprised when it could not pick up some metal objects. In another group one of the children completed the activity using a poor quality magnet only to find he had to revise his results because his partner borrowed a good magnet to check his objects.

For both teachers the lack of appropriate equipment made the lesson difficult from a planning perspective. What they had not anticipated was the impact of such incidents on the children developing concepts and the potential for misconceptions.

In summary, gaps in teachers' science content knowledge contributed to lost opportunities to develop the children's scientific understandings as well as the development of scientific misconceptions. At times, teachers covered over their gaps by reading information directly from the teachers' resource book or postponing the discussion until a later date. Sometimes the implications of their poor science content knowledge only became apparent to the teachers after the lesson.

8.3 Proposition 3

Teachers use classroom discourse as a strategy to build children's science knowledge and to manage the class.

The teachers utilised the discourse within the science lessons for a variety of purposes. Firstly, the teachers used brainstorming, summative discussion sessions and small group

work as strategies to develop understanding of science concepts. However, they were unable to reinforce correct terminology because of their lack of knowledge about science concepts. Secondly, the teachers were very comfortable when the format of the lesson resembled a language lesson and they used many language techniques to enhance children's use of new words. Thirdly, the teachers used discourse as a means of controlling the group behaviour during science lessons. The teachers used questions during discussions as a form of discipline when faced with behaviour problems in whole group situations.

The first purpose deals with how the teachers developed the children's science language using strategies of small group work, whole class brainstorming and summative discussions. The new science program was structured to allow children opportunities to discuss activities as they carried out their investigations through the deployment of small group work. The use of small groups assumes that children will have an opportunity to engage in meaningful discussions about the activity. Lynley found it difficult to promote discussion in small groups because the children were unfamiliar with having to read through a set of instructions, carry out an investigation and then respond to a set of questions. The task of keeping the group on track was given to one group member but, for the children, this was an unfamiliar method of working. Lynley found she spent a lot of time encouraging the children to use their student books properly. Lynley often stopped her whole class during science lessons to re-read the instructions when she felt that she had answered the same inquiry for several groups or when she felt that the class was not as advanced in the lesson as she wanted them to be.

> "Right, very interesting watching you do this because I actually only saw two people doing it correctly," said Lynley. "I will read through the instructions and you just listen."

The children were not used to the format of this type of lesson and relied upon Lynley to provide instructions and worksheets. For Lesley the use of small group work was also an unfamiliar science teaching strategy. Lesley found much of her efforts during science lessons were spent reinforcing the skill of working together as a group and she became concerned that the children were not doing any real science. On occasions children with strong characters were able to dominate the group work, excluding others from participating in activities.

> "You have to decide in your group because you have to be able to say why you chose it. What does your partner think? said Lesley.
>
> "Jenny makes all the decisions," said Grace.
>
> "Alright, take them all off then," muttered Jenny. "Well this one goes here because it is a beach."

In Year Two, children did not have student books so Lesley also needed to stop the groups, at intervals, to reinforce the next step in the activity. For Lesley much time was taken up with reinforcing group behaviour and giving explicit instructions about aspects of the activity.

Typically both teachers began their science lessons with a brainstorming discussion to introduce the activity and allow an opportunity for the children to exchange their views about the science concepts in the lesson. The teachers also grouped the children on the floor at the front of the room and used a whole-class discussion as a strategy to engage the maximum number of students. The teachers believed that, in this way, they could keep an eye on all the children and focus them without the distractions of their desks. While the teachers did engage the children in discussions about prior experiences related to the new topic they were unable to expand upon ideas and terminology resulting from these sessions. For example, during the Year Five lesson on mini bins, the discussion was diverted to explore the manner in which earthworms reacted to light. Although Lynley allowed the discussion to proceed for a while, time was running out and she was unable to give a definite answer to the children.

> "Good boy," Lynley answered. "It might be a temperature thing because in light they might be able to have that very fine sense of telling whether it is hot or cold. Alright, so we had better leave that there because that was an excellent perception."

Lesley usually spent between 12 and 15 minutes setting the scene for the science lesson. She would incorporate discussion of previous science lessons to help focus the children on the new activity. The discussions resembled a lecture format because Lesley followed the suggested lesson plan very closely and was reluctant to deviate from the pre-selected series of questions. Much of her time was also taken up with giving explicit instructions

about the lesson and meticulously demonstrating parts of the activity so that the children would be very clear what they had to do in their groups. Lesley also used this session to reinforce children's group responsibilities and the rules related to working in groups.

> "Oh! You definitely have to cooperate for this activity," Lesley answered. "You need to share ideas with your partner and not take over. You have to do one mattress at a time. You do not do one for Baby Bear and your partner does one for Mother Bear. I like you working together to make these mattresses, that's very important. The whole idea is sharing ideas with your partner and solving the problem together. Return any materials you don't use so that others can use it if they want to."

For both teachers, the initial discussion times were spent in setting the scene for the lesson, eliciting the children past experiences and giving instructions about how the lesson would proceed. The teachers lacked the time and science subject matter knowledge to explain and explore, in detail, new terminology or emerging concepts.

Both teachers also used summative discussions at the conclusion of their lessons as a strategy to consolidate what the children covered in the lesson. These sessions were conducted at the front of the room with the children seated on the floor. The teachers led the discussion using questions from the teachers' resource guide. Lynley found that, as with the brainstorming sessions, some children dominated and steered the discussion onto subjects for which she was unable to provide answers. Lynley was not intimidated by her inability to respond, but rather saw it as a challenge. In endeavouring to supply answers Lynley thought if herself as a role model for the children on how to reason through the questions. When she was unable to provide answers she directed the children to do their own research in the library. Lynley also found that at the end of the lesson a lack of time inhibited further discussions and she was often rushing to wrap up the lesson properly.

> When Veronica and Karl get into a discussion with Mike it gets really interesting. Half the children can't keep up with them but I like them to talk about the concepts. Today I had to admit I did not know, which is why I told them to look up the words bacteria and fungus for homework. It gives me time to check it out. (Lynley, Interview)

Lesley also grouped the children at the front of the room at the conclusion of the lesson. The children were given an opportunity to recount what they had done in their activities and to share their results with the class. Lesley followed the suggested follow up questions supplied in the teachers' resource book but lack of time often limited discussions. Typically she only had time for short answers about the results of the activity and to check that the materials had been returned.

> For the sharing and discussion it is better in a group rather than spread out. I often feel as though I don't wrap up well enough. Often this is because we are rushing in the end and we run out of time. (Lesley, Interview)

Both teachers acknowledged that a summative discussion session was a good pedagogical strategy but their lack of science content knowledge inhibited in their ability to expand on the children's ideas.

The second purpose for which the teachers used discourse relates to their use of language lessons strategies to encourage the children to understand new words. Both teachers taught the language component of the curriculum to the same children and often transferred strategies used in language lessons to social studies, health education, mathematics, art and also science lessons. In science, for example, during the brainstorming sessions, the teachers wrote new words on the board and referred to them during the lesson. The activities conducted in small groups were a way of providing concrete experiences, enriched by language, to facilitate new understandings. Both teachers were familiar with this method of developing language because they employed it in many subjects. The teachers had also been part of 'First Steps', an innovative language program, which recognised the need to link oral language and written language using purposeful activity.

The teachers used repetition and expansion to establish new understandings of science words and concepts. By encouraging the children to express their views about the science activities and phenomena the teachers tried to consolidate the use of terminology. This goal relied upon the teachers being able to construct appropriate questions to redirect the children's discussion towards appropriate understandings. As both teachers had poor science content knowledge, their ability to effectively support

the children in this way was limited. They were able to employ familiar pedagogical knowledge to encourage the use of language but were often limited in their ability to consolidate the correct scientific terms.

Lynley, after participating in the university course to improve her science content knowledge, became conscious of the need to allow time to explore the language attached to phenomena. After discussing the meaning of particular words with her colleagues and finding that the group of teachers needed time to establish their understandings, Lynley realised how hard it was to be sure of the meaning of words, concepts and phenomena as a result Lynley tried to allow the children time to interact as a group to consolidate their understanding of new terminology. While exploring the nature of air, for example, Lynley was able to help the children build up a list of words related to how the air behaved when trapped. This list was used later in the lesson and as part of the spelling list for the week. Lynley often finished discussion sessions with her own wrap up of the major points she felt they children had made or should have made.

Lesley had been a focus teacher for the 'First Steps' program and was, by her own admission, more comfortable teaching language than science or mathematics. A whole language approach was a familiar strategy that Lesley used in her previous science teaching when she based her science lessons around her language program topic. Lesley also linked with other learning areas to consolidate language across the curriculum. She used every opportunity to reinforce what the children had learned in order to consolidate their language. Lesley used a portable whiteboard to write words and phrases generated in the initial brainstorming sessions as the lesson progressed. She used these lists of words as her reference and added words suggested by the children about their investigations. Lesley was experienced in eliciting descriptive words about the activities and used repetition and expansion strategies to develop lists of words. Lesley typically used the children's suggested words in a descriptive whole sentence when responding to embed the words in context.

> "Watery," added Lesley. "So it felt watery to you like as though it was, you were putting your finger in some water. So runny, water. Any other words Steven."

Lesley successfully transferred her pedagogy from the language areas to science because it was familiar and provided another opportunity to reinforce the words the children were adding to their vocabulary. Lesley did not have the science background to expand on the concepts being covered but she was able to conduct the science lessons successfully because many lessons involved developing descriptive words and phrases.

Both teachers were able to transfer their language teaching pedagogy to their science lessons with ease and elicit words and phrases to describe what the children had experienced. The teachers used the questions supplied in the teachers' resource book to help them generate discussions and conclusion statements incorporating the new terminology.

The third purpose of discourse relates to the teachers' use of language as a way of controlling group behaviour during science lessons. The teachers used familiar teaching strategies to control the movement of the large and small groups during lessons. Both teachers used lecturing to the whole group as a way of controlling their learning. Lynley was aware that the children were unfamiliar with working in small groups and she relied heavily on their student book. During initial discussions with the class about the science lesson she would read through the information re-enforcing issues of safety and procedure. This strategy assured Lynley that the children had not missed critical information. She was concerned about their lack of familiarity with reading instructions and poor motivation in the small groups. Lynley also used questioning sessions to keep the children occupied when she had not completed her preparation. Lynley asked children to recount what they had learnt in the previous lesson and was able to hold the attention of the group as she finalised her preparation. When some children became distracted she asked them for their input or asked them to clarify points about the lesson. In most cases, this strategy did not add to the understanding of the group, as the person often had little to contribute, but it singled them out as not attending and put on notice for others in the group that Lynley was watching. This was evident in the lesson on Hovercrafts when Lynley was gathering materials.

> "Is there anything else you could say Mike? Lynley asked. "Neil can you just let him talk please. Linda would you like to answer that? What was one thing that made the Hovercraft work?"

Lynley drew the class together by reading through the students' notes, making the children aware that she was unhappy with what they had achieved the previous week. By controlling the discussion in this way, Lynley was able to stop inappropriate behaviour, raise the children's awareness that she was unhappy with their past performance and indicate that she was watching their efforts for this lesson.

Lesley also used questioning during discussions to correct the children's behaviour. When the children were together on the floor they were often distracted by those around them. When Lesley held discussions she liked them to be attentive and often reminded them of this. At times during discussions many children would put up their hand, ready with the answer, but Lesley selected an inattentive child rather than one who was ready to answer. In this way she was able to re-focus the children on the lesson and make them aware that she was watching their behaviour. Lesley often resorted to lecturing to regroup the class and reorganise the progress of the lesson. The Year Two class did not have a student book to refer to so Lesley often stopped the children at regular intervals to instruct the children about the next phase in the lesson. When the children investigated the Oobleck, for example, Lesley needed to establish her list of words.

> "Who has got a word?" asked Lesley. "A word, Gina, were stopping and listening in together. You will have lots of time to experiment and feel it and do other things with it in a minute. I want some words you thought off. Sandra when you touched it how did it feel? What did it feel like when you touched it? Casey?"

Lesley also used discussion sessions to praise the good behaviour of the children. Most of the children were very keen to stand at the front of the group to talk about their work. Lesley used this strategy as a reward if she knew they were working well. She often stopped the group to praise positive behaviour by pointing out what she saw as the good behaviour exhibited by the children. In this way Lesley rewarded the children with time at the front of the group and highlighted acceptable behaviour.

> "Look at Angela and Crystal," Lesley said. "I must make a comment about how beautifully those two work together. They obviously remembered all their jobs they had to do, the manager jobs and the speaker jobs and they work together very well. Would you like to share with the group how you sorted your things Crystal?"

In summary, the discussion sessions before, during and after the activities tended to be teacher-dominated, used to acquaint the children with the concept to be covered and also to give instructions about the procedural steps of the lesson. The use of lecturing about the main points of the lesson, safety issues, behaviour and keeping on track were major strategies used by the teachers to control the groups. Both teachers called upon children to answer questions when they were inattentive to focus their attention on the lesson. Often, this meant that the teachers ignored the children who were attempting to add to the discussion. There was limited time for children to contribute to whole class discussions and develop their language associated with the science concepts. Both teachers acknowledged that the children needed to engage in oral and written language to develop their science knowledge, but discourses were more often used to control children's behaviour.

8.4 Proposition 4

Experienced teachers are able to maintain seamless science lessons in spite of their poor subject matter knowledge and pedagogical content knowledge.

Notwithstanding the problems encountered by the teachers as they implemented the new science program they were able call on well-established teaching strategies to maintain the flow of their science lessons. Two examples are discussed here. The first involves the way that the teachers handled the science equipment. The second example describes how the teachers compensated for their poor science content knowledge.

The supply and organization of equipment provided problems for both teachers. Each teacher had different expectations about the supply of their equipment. Lynley was responsible for collating equipment for her entire school and she set up boxes of the materials that would prove difficult for teachers to find. The teachers then collected simple equipment and material from the pool or bought supplies from home.

Previously, Lynley had created and maintained a similar boxed topic science system for the district. Lynley took her role as science coordinator seriously and felt that it was important to provide as much material as possible for her fellow teachers. She was aware that some of the teachers were feeling unsure about the new science program and needed as much support as possible. In spite of Lynley's experience, she still came across problems in her science lessons because the school supplies were of poor quality. Lynley was aware of the materials in the science store cupboard but had not inspected the quality of the individual items. When Lynley needed to supply eyedroppers for her class to make bottle divers, she was not aware that the rubber tops had perished. Lynley was also unable to supply plastic jugs or nails, instead she used glass jars and pieces of wire. Therefore, Lynley discouraged the children from removing the rubber stopper to insert a nail during their investigations. The use of glass jars instead of plastic jugs raised the issue of safety in the lesson. Lynley was able to accommodate the necessary changes at short notice but the effect on the lesson meant that she had to allocate time explaining the reasons for the changes. This shifted the focus of the lesson away from investigating the properties of air pressure to remembering conditions for using the equipment. The time taken up with explaining the new conditions also meant that valuable lesson time was wasted.

> "Boys are you listening? Rodney you don't know if you need it yet dear. Your eyedropper may not need a small nail but today you have a small piece of wire. To take the rubber off the glass stem it should come apart. Now if you have difficulty in taking the top off yours would you please give it to the speaker to bring to me so that I can help you. I don't want you to tear the rubber top if it can be avoided."

Lynley proceeded through the steps of the lesson and the children were able to complete the investigation, but the discussion session at the conclusion of the lesson was brief. She found that valuable time was lost explaining how to use the alternative equipment safely.

Although Lynley generally had the equipment for each group lined up at the front of the room, on some occasions she used the first few minutes of the lesson to find items in the classroom. Lynley used the strategy of a discussion group to revise what the children had learnt in the previous lesson and to keep them focused. Without direct questioning from Lynley the children became distracted and were unable to reflect upon their

investigations from the previous week. When Lynley had finished preparing the equipment she established order by lecturing them about what they should have achieved in the previous week.

> "So where you have the base," Lynley added, "we now add a skirt to trap the air that is sent downwards through that central cylinder so the actual craft comes up and hovers above the surface. When you have another look at the diagram in your book you can see that clearly. Last week we really didn't achieve that."

The use of class time to gather materials found in the classroom impacted upon the class discussion. Lynley was not able to guide the group discussion with carefully considered questions and when the group became distracted and unable to continue with their discussion she drew them together using the familiar strategy of lecturing to re-establish control.

In Lesley's case, she relied upon the teacher's aide to complete the preparations, using equipment from general school supplies. Both the science coordinator and the aide were not experienced science teachers and were not familiar with the new program. Adding to the confusion was the limited experience Lesley had received during the training sessions. These sessions had been designed to allow the teachers to work through each lesson, manipulating the equipment and discussing the concepts. Although Lesley found the lack of the appropriate equipment frustrating she was able to accommodate the necessary changes in her lessons. When the set of magnets was inadequate Lesley was unable to exchange them. The science coordinator was also unaware that the condition of the magnets was unsatisfactory. Lesley chose to proceed with the steps in the lesson plan unaware of the impact of the poor quality magnets on the children's emerging ideas about magnetism. Lesley believed that the focus of the lesson was sorting objects and the magnet was just another way of achieving this. The properties of the magnet were not a main feature for her and therefore not a great concern. However, I noticed that when the poor quality of the magnets challenged the children's ideas about magnetism.

> "It's a magnet because they just do this," said Nancy. "They don't pick it up and fall down again it just picks it up because magnets can pick things up if it picks this one up. Oh! It can't pick this one up, but its metal."

Lesley encouraged the children to exchange magnets but this added to their frustrations because they had to wait their turn. Time ran out for the children to complete a worksheet and some had to start again because their results were incorrect. However the lesson proceeded relatively smoothly because Lesley was able to move the children on using tried pedagogical strategies.

Sometimes, however, Lesley was unable to accommodate the lack of appropriate equipment. In one lesson when the children were asked to construct a puff machine, the equipment list specified the size of the foam but the science coordinator had supplied a single large piece of foam that a parent had donated. The teacher's aide then cut this into equal sized pieces unaware that the children needed foam the size of half a car sponge. Lesley had not had an opportunity to check the equipment until lunchtime and realised that the lesson was impossible to complete without the correct size of foam. She had no option but to cancel the lesson, leaving her and the children frustrated. In another example Lesley had to supply insects for a lesson. She spent a week encouraging the children to bring in slaters, snails and bugs. She had also used part of her weekend to look in her own garden. On the day of the lesson, she still had not located enough specimens for each group and used part of her maths lesson walking around the school grounds with the children. When the lesson was due to start, Lesley was agitated and spent time explaining to the children that they would have to share some of the creatures. Lesley stopped the class half way through the lesson to ensure that the children exchanged creatures. The children completed their worksheets and seemed to enjoy observing the creatures. For Lesley the lesson was frustrating, adding to her belief that science lessons were difficult because of the need to gather resources and equipment. When we discussed the lesson later her suggestion was to change that unit of work to the spring term rather than winter.

> The idea of having all the equipment and resources for a unit of work in a box in your classroom is wonderful, until something like this happens. (Lesley, Journal)

The second example deals with the way that teachers compensated for their poor content and pedagogical content knowledge. The teachers were able to maintain the sequence of their science lessons despite their difficulty in answering questions raised by the children. When the teachers were unable to provide the necessary guidance, they reverted to their general pedagogical strategies.

Lynley was not personally challenged by her inability to answer the children when they raised issues and ideas during science lessons. She believed that it was important for the children to understand that she was not always able to answer all their questions. Indeed Lynley believed that it was important for the children to see how she worked out answers to these types of questions, thus modelling her thought processes. During the lesson on Hovercrafts, the discussion turned to how a hovercraft would behave when travelling over waves. The children established that the hovercraft needed to travel over a flat surface to make sure the air remained trapped under the skirt. Lynley encouraged the children to contribute their ideas about how this could be achieved, but then ended with a summary of what she thought were happening.

> "Now if you have huge swells it's going to be lifted onto a swell and the air is going to escape isn't it so it's not going to be that efficient. Now whether my theory or my analysis of that is correct I don't know, but that's what I'm assuming. Mike presented me with this huge problem with this big swell and to me that is what will happen. Also I haven't read enough on this and maybe you people can read about it."

Lynley happily admitted she was unable to provide an answer and directed the children to look up the information for homework. Allowing the children to pursue different topics during the discussion often meant that Lynley was unable to respond with authority to their enquiries. She frequently employed a strategy of summation, in lecture format, in response to a discussion where she was unable to come up with a definitive answer.

> "Good boy," Lynley answered. "It might be a temperature thing because in light they might be able to have that very fine sense of telling whether it is hot or cold. Alright, so we have better leave that there because that was an excellent perception."

There were times when Lynley believed the children needed to know the technical information related to the science lesson. If the children had not understood a particular concept, she would read directly from the students' book to make sure they had heard the information correctly. Having the children seated at the front of the room listening quietly reassured her that she had focused their attention on the important points they needed to understand. In the lesson on mini bins for example, Lynley read directly from the resource book to impart technical information about compost heaps. Although

Lynley encouraged the children to explore their ideas she was often unable to direct their discussion because she could not support them with what she considered to be the 'right' questions.

Lesley assumed that she would not be challenged about her own science content because the children were young. Lesley was not often challenged directly by the children about subject matter. However, during the lesson on magnets, when the children were perplexed about the behaviour of the magnets, there was no discussion about the nature of magnetism. Lesley saw this as a practical rather than a conceptual problem that she resolved by getting the children to swap magnets. During the lesson on Oobleck the children were given the water and cornflour mixture to investigate. Lesley developed this lesson along the lines of a familiar language lesson by encouraging the children to suggest words to describe the behaviour of the Oobleck. Lesley was very comfortable in this role because her teaching strength was in the language areas. When the lesson plan asked the children to compare the properties of Oobleck to water and plasticine, Lesley was concerned about her lack of knowledge about the behaviour of Oobleck. While the children were busy, Lesley turned to me to provide the answer and after a brief discussion we consulted the teachers' resource book looking for clues. This search led us to a section called 'Background Information' which gave a lengthy explanation about the visco-elastic properties but left us non-the-wiser about how to explain this to the children. The lesson concluded and Lesley moved into 'tidy-up' mode, thankful that she had a week to think about her explanations.

Lesley found herself faced with a dilemma during the lesson on the difference between natural and man-made. One of the children asserted that if God made it, it was natural. Following the lesson Lesley encouraged the children to develop their own criteria for sorting the pictures but when she was asked to adjudicate between two children she found it difficult to resolve their naïve 'God made it' theory. Lesley was unwilling and unable to pursue the discussion because time was running out. She resolved the issue by asking each child to take a turn at selecting a picture. If the children were undecided the picture went in the middle of the page. Lesley used the strategy of sharing and task completion to overcome her reluctance to engage in a discussion about the role of God in constructing landscapes.

As the above examples show, the teachers' limited subject matter knowledge did impact upon the outcomes of their lessons. Teachers sometimes lacked the knowledge to formulate questions to lead the children to a deeper scientific understanding. Faced with students' questions, they would often postpone a definite answer or refer to the teachers' resource book. However both teachers relied on their tried pedagogical practices to compensate for any inadequacies in their science knowledge. The lessons appeared to flow seamlessly as the teachers were able to move through the lessons ensuring the children completed the activity and had plenty of opportunities to interact and discuss the activities.

8.5 Proposition 5

In primary science classrooms, caring for children underscores teachers' pedagogical decision making.

For both teachers caring was a central feature of their practice. The teachers were constantly concerned about the health and well being of their children and developed a caring attitude in their classes by reinforcing and acknowledging care towards on another. They were also particularly conscious of the safety aspects of science lessons and stressed a need to take care while doing activities.

The two teachers also took account of the impact of home life on the performance of the children. For example, Lynley agreed to take children from a split class to include the Year Fives in her science lessons. This not only increased the class size but also added a robust group of boys, with one boy in particular who liked lots of attention. Normally Lynley was able to establish her quiet authoritive discipline but during the science lesson when the children explored the mouldy bread she removed Len from the class on three occasions for his disruptive behaviour. Lynley was anxious about the children working with the mouldy specimens and watched the children very closely. When Len persisted in his rowdy uncooperative behaviour she used the strategy of withdrawal to give him time to think about his what he was doing. At the end of the day I commented that Len had been holding his stomach and complaining of feeling unwell. Lynley was most concerned that she had not thought to ask him about this.

> "I am glad you mentioned it," Lynley said. "If I'm aware of that then next time he's unsettled I'll ask him is he feeling alright because he might react in that way when he's in pain."

Not only did Lynley care about the physical well being of her students and she was also aware of their emotional needs. One example was Lynley's reaction when Rodney's catapult broke during the preparation for the district science challenge. He immediately burst into tears but Lynley was quick to shield him from the class when she stepped to put her arm around him. She also helped him resurrecting his catapult by enlisting the aid of the school gardener.

> "It's all right dear," consoled Lynley. "I'm sure Mr Beck the gardener will help you modify your catapult. We still have six catapults to test and if you hurry we will fit you in because we don't have to decide who goes through to the whole school competition until later this afternoon. Mike, you and Len go with Rodney. I'm sure you will find Mr Beck in his shed."

Lynley's need to protect and care for her children was evident in the way in which she reacted to situations that caused them discomfort. She knew her children well enough to be aware of the influences from family and school life upon their performance. The parents valued Lynley's attitudes. Rodney's mother, for example, made a point of thanking Lynley for the way she handled the situation with the catapult.

Lesley's decision to teach junior primary could be construed as caring because she was unwilling to jeopardise the learning of older children through her lack of expertise in maths and science. The children identified strongly with Lesley as their protector and did not hesitate to share their problems with her. For example, when Alan accused Trevor of saying untrue things about him, Lesley reassured Alan and promised to speak to Trevor. In another incident, when Darcy reported that a Year One child had bullied him in the line. Lesley immediately swept out of the room to speak to the year one child in a loud voice.

> That boy has been a problem for quite a while. Mrs Owens has had a lot of problems with him in class and I'm not going to let him bully my children. Darcy is such a

> gentle natured boy, he wouldn't hurt anyone. The school is also making a big issue of bullying and we are trying to stamp it out. (Lesley, Interview)

In a further example the children were asked to share the task of making beds for the three bears. When one child complained that her partner had refused to work cooperatively Lesley stopped the whole class while she forcefully pointed out that this was not the right thing to do.

> "I'll be telling Ralph who is the boss of the class if he is going to talk like that, where is he," growled Lesley. "I'm a little it tired of this attitude Ralph. If we all work together and cooperate there shouldn't be a need for a boss."

The two teachers also reinforced and acknowledged care towards one another during science lessons. Lynley rarely raised her voice when she needed the children's attention. If the children were restless she would ring a bell to gain their attention. When the children were examining the mouldy bread Lynley was anxious that they were not harmed by inhaling the spores and warned a particular group of boys to settle down. Unwilling to risk the safety of the group she was forced to isolate one of the boys to reinforce that this type of behaviour was unacceptable.

> "Len you have been very disruptive, I want you to stand outside for a while and think about your behaviour. I don't think having you boys together in a group is a good ideas," Lynley said.

Lynley congratulated the class on their written descriptions and drawings of the mouldy bread before moving onto the discussion session at the conclusion of the lesson. Before the discussion began Lynley reminded them that they should listen carefully to what people said and not to fidget. Lynley often made a point of congratulating the children when they offered their ideas.

Lynley had a high expectation that the children would behave in a caring way and used gently authoritive strategies. By isolating those children who were not contributing, Lynley reinforced in a non-confrontational way that this behaviour was unacceptable. Lynley always acknowledged the children's contributions to discussions by encouraging them.

In Lesley's case, she was aware of the need to reinforce sharing with the children. She was positive and encouraging, and often rewarded and reinforced acts of kindness. Sometimes, when they had bee particularly well behaved, she would ask them to stand in front of the class to tell the others what they had been doing. Lesley often changed the groups around so that the children had to work with each other and praised individuals whenever she saw them performing well.

> "Look at Angela and Crystal," Lesley said. "I must make a comment about how beautifully those two work together. They obviously remembered all their jobs they had to do, the manager jobs and the speaker jobs and they work together very well. Would you like to share with the group how you sorted your things Crystal?"

Both teachers were particularly conscious of the safety aspects of the science lessons. During the initial discussion stages of the science lessons the teachers highlighted any safety issues. They also reinforced these issues during the lesson as they moved around disciplining any children who failed to observe the need for safety. During a lesson on growing moulds, for example, Lynley was particularly cautious about the safety aspects of exposure to mould spores. She related to the children a story about her previous experience with using moulds.

> "At another school I let the children grow moulds but when we wee looking at them on of the children opened her bag and I breathed in a lot of spores. I ended up with a very sore throat for a long time and you can become very ill if you inhale the spores. Please do not open the plastic bags. Use the magnifying glass to observe the mould then write what you observed."

All through the lesson Lynley checked to make sure the specimens were intact and when she challenge the children to grow a mould specimen at home she again warned them of the perils of the spores.

For Lesley the use of scissors created a safety issue in one of her science lessons. Lesley did not discuss the use of scissors at the beginning of the lesson but when she walked around the groups she publicly acknowledged correct and safe practice. In this way she was able to acknowledge the children's efforts to work safely and reinforced the correct way to use scissors.

> "Tear it, that's a good idea," said Lesley. "Some people were using their scissors in a safe way and other people were hacking away with their scissors. I was waiting for a little finger to drop down on the carpet. I'm pleased to see most people were using their scissors in a safe way because you have to be careful cutting through things like that. I'm glad you thought of a safer way to do it, thank you for sharing with us."

For both, caring for children was an overriding consideration during their science teaching. Lesley and Lynley shared content concerns about the physical and emotional well being of their children and the impact this would have on their ability to learn. They promoted, modelled and reinforced the image of their classrooms as caring places. All of their pedagogical decisions are made with this in mind.

8.6 Proposition 6

Beliefs about teaching science stem from prior experiences.

The two teachers came to their science teaching through their experiences of life, learning and teaching. Here, I discuss three sets of influences on the beliefs that the teachers hold. Firstly, the significant people in their childhood, secondly, the experiences the teachers had during their own schooling, and lastly, the impact of their previous experiences in teaching and teacher.

The first sets of influences were the teachers' childhood experiences. Both teachers experienced a loving childhood supported by concerned parents who reinforced a middle class set of moral values. For both teachers these values included the belief that education was a worthwhile goal. Lynley was greatly influenced by her father, who was a teacher. She recalled many occasions when he would take her walking through the countryside and talk about what they saw. One time in particular she remembered finding an animal that her father did not recognise so he suggested they take it to the museum for identification. Her father was able to explain and develop her understanding of the natural world and a love of learning in a caring way.

> I've always had a very stable lovely sort of atmosphere and home life. I couldn't say there is a day that goes by that hasn't been happy for me. I haven't experienced any of the traumas of separation or life threatening disease, not even cross words or

> anything. I have always been very conscious of damaging things. I remember a time when my father and I found an unusual animal in the bush and I went with him when he took it to the museum for identification. (Lynley, Interview)

Lesley was influenced by a childhood spent on a farm, very aware of how hard her parents worked to support them all. Her father was unable to pursue an education because he had to feed a young family. He encouraged all of his children to gain higher education and three of the four children graduated with degrees. The children were encouraged to explore their environment around the farm.

> My father wasn't able to get a higher education and he wanted his four children to do well. He encouraged us to go through to year 12 and three of us finished our degrees. Dad didn't mind what we did so long as we did well. I always wanted to be a teacher but I started off doing a business course when everyone told me there weren't jobs for teachers. I stayed long enough to know I'd failed a business math's exam. My mother did not want me to do nursing because she thought I'd get too involved and she's right, I'd get too attached to the people. We didn't have a lot but we always had holidays by the sea. I remember building cubbies and exploring the bush with my friends. (Lesley, Interview)

The second sets of influences were the teachers' own learning experiences at both primary and secondary school. These early experiences laid down the foundation for their beliefs about science learning and teaching by providing a model of expectations and associated behaviours. For both teachers their primary years were remembered for the nature table, collecting items from the environment and drawing diagrams in their science books. On entering secondary school the teachers struggled to understand physics and chemistry. During their senior years they both studied biology, providing them with a general science unit required to enter higher education. Both teachers had also decided that their careers lay with teaching or nursing and this did not require physics and chemistry.

> I remembered doing lots of nature walks around the school as a child and having a nature table. (Lesley, Journal)

The final set of influences involved previous experience and choices the teachers made in their teaching careers. Lynley always wanted to be a teacher like her father but was

concerned about her faulty knowledge in science and mathematics and chose to train for primary teaching. During the two-year pre-service course Lynley remembered many positive experiences associated with science lessons. The science course was biology-orientated reinforcing her belief that science at the primary level was closely associated with the natural world.

> During my training years we did a nature study option and I mean we were always on the dunes on the beach or on the grounds of the College doing wonderful things and we just loved it. I reinforce a lot of that with my children which is why I probably tend to do science. (Lynley, Journal)

Lesley came to primary teaching via a business course. This experience demonstrated to her that she was uncomfortable with higher-level maths. Lesley elected to work in the junior primary years specialising in language development. During the three-year pre-service course she managed to complete the compulsory science units but she preferred the languages aspects. Working with small children also appealed to Lesley because of her caring, nurturing nature.

> When I trained as a teacher I chose junior primary and languages as my options because I felt that I did not know enough to teach the older children, especially maths and science subjects. I remembered doing lots of nature walks around the school as a child and having a nature table. That part of the science course was great but I didn't think I could teach older grades. (Lesley, Journal)

When the teachers commenced their teaching careers they made deliberate choices about their involvement with science teaching. For Lynley an opportunity to teach science arose when she returned to teaching. A part time position was created for a teacher to teach science throughout the school. Lynley was keen to resume teaching and saw this position as a challenge. This bought her into contact with a district science supervisor who encouraged her to develop a district science activity system that she housed at her school.

> Years ago it was the district supervisor who showed us how to develop our science in the four areas of energy, matter, plants and animals. He was very influential and

> showed us that although you were doing plants you were still doing energy, matter and all the other things as well. (Lynley, Interview)

Lesley, on the other hand, approached teaching science from a language perspective and arranged for her science lessons to complement the topic the class was covering in the language program. This effectively meant that the children completed discrete lessons rather than develop concepts. She also remembered using the "I Do Science" series supplied by the education department but she found that experience boring. For the last five years Lesley had been able to avoid teaching science altogether because the school had a science specialist. Changing schools meant that she once more had to provide a science program for her class. She agreed to take on the new science program because she wanted to bring her science teaching up to date.

> I wanted something new and inspirational and this sounded like it was really something more interesting. Something more meaningful to the children and more child based, activity based. I had also been assured that we would get support from the science coordinator for materials. Plus I don't class myself as being scientific, you know having a lot of science knowledge, were as this just makes sense. I don't have to have a lot of science because it's all organised for me. (Lesley, Interview)

The science talent search, run annually by the local science teachers association, also influenced Lynley's beliefs about the value of science. The talent search was conducted state-wide and schools were encouraged to have their children submit investigations. Lynley was able to help the children create successful entries. She recalled one girl in particular who achieved some success and that experienced boosted Lynley's confidence about science. The girl went on to study science throughout her school years and at university. Lynley saw it as her duty to prepare the children for a future that was changing at a rapid rate and becoming more technologically focussed.

> Amber ended up wining her year level and she, and I, got such a terrific boost out of it. Amber went on right through the sciences and now she has gone into that area in university. So from that talent search she grew to love science and although it was hectic I just loved it. With science I think I have always had the feeling that we need the knowledge of science so that we can plan what is best for the world, what is best for our environment. The children need to learn specific skills and how to think in a

> logical sequence that I think is far more valuable to them in the long term than knowing facts. (Lynley, Interview)

During their teaching careers both teachers had opportunities to lead their colleagues in professional development. Lynley's enthusiasm for science and the knowledge that her colleagues were uncomfortable teaching in this area encouraged her to suggest that they look into the new science program. Her principal supported her because he wanted the school to be seen as a leader in science for the district. After they both attended information evening about the new program they were persuaded to adopt the program. Lynley was keen to support her colleagues and provide materials, information and emotional support where required. Lesley also led her school colleagues in a language – related professional development program called First Steps. Lesley enjoyed helping her colleagues develop a deeper understanding of developing children's language skills.

The two teachers beliefs about science learning and teaching were formulated through their life experiences as learners and teachers. During the formative primary years of schooling the teachers remembered science as being informal, fun and mostly nature studies. During the secondary years science was more of a struggle with the teachers unsure of their capabilities to understand the harder chemistry and physics, opting to study senior biology. Later during the teachers pre-service course the teachers remembered science as nature studies and were comfortable with their level of expertise. Early in her teaching career one of the teachers elected to teach science, while the other avoided the subject.

8.7 Proposition 7

Teachers balance work with personal and family pressures in order to teach science.

During the school year it became evident that the teachers were prepared to forgo personal commitments to accommodate their classes. For Lynley this meant giving up a session of her university course to be on hand to help the children during a special science challenge. Lynley was aware of the amount of energy the children had put into producing their catapults. She was unwilling to allow a new teacher to supervise her class during the challenge. Her students had spent many hours out of class preparing for

the big day and she was as excited as they were about the outcome. Lesley was very aware of using her time outside of class hours. In the year of this study, the union called for a ban on work out of hours but Lesley found that she still needed to use her weekends to find material, such as the insects.

The teachers were also aware of the need to be involved in extra loads of work during peak times of the year and made adjustments to their personal life to accommodate this. For Lynley the pressure of being the science coordinator meant that her workload was significantly higher than previous years because of the support she had to give the teachers. She was also asked by the principal of the school to compile a portfolio about the progress of the implementation of the new science program. This meant visiting each class at least twice, video taping a particular lesson and encouraging teachers to submit examples of work and student results for the portfolio. Lynley worked very hard out of school hours to finalise the document at the end of the school year. She was also under pressure to complete her sample book of the children's work during the semester. The principal allowed her an extra weekend to complete this work. Lesley also found her weekends and evenings taken up with school related work which placed pressure on her personal and professional life.

8.8 Proposition 8

Teachers lack certainty in science teaching because of epistemological confusion in their understandings of the nature of science.

This proposition examines the uncertainty generated by primary teachers' epistemological confusion about the nature of science. While primary curriculum materials are built around constructivist underpinnings, teachers' past experience of learning science has schooled them to believe that science is a body of received knowledge. On the one hand, primary teachers are led to believe that science is uncertain; on the other hand they suspect that science is certain. This confusion is further confounded by different approaches to certainty in other subject, mathematics and language arts, for example. Here I examine three aspects related to this proposition about certainty. The first aspect deals with the kind of prior experiences that determined the teachers' epistemological beliefs about science teaching. The second

issue deals with the beliefs the teachers hold about science as a body of received knowledge. The third aspect deals with the teaching dilemmas faced by teachers as a result of their epistemological confusion.

The first aspect deals with the teachers' learning experiences at high school and during teacher training that framed their epistemological beliefs about science teaching. Recalling their primary years, both of the study teachers talked about nature tables and walks around the school grounds. Lynley remembered one occasion when her father was unsure about an animal they found and she went with him when he took the animal to the museum for identification. Lynley attributes much of her love of nature to these experiences and she believes they strongly influenced her approach to working with children.

> My father won't touch an ant or a fly and this has been ingrained into us that you respect and look after everything. I think I impart that a lot in my teaching to the children. (Lynley, Interview)

During the secondary years of schooling, both teachers elected to study biology, having decided that physics and chemistry were not necessary for a career in primary teaching. Later both teachers had fond memories of their time at teachers' college where the science was largely based on nature study activities. This meant that both teachers continued to experience success and the course allowed them to be comfortable in a familiar, attainable science program. The focus on natural science during their primary teaching training course reinforced their belief that the 'hard' sciences were not required at a primary level. They felt that they had made the right decision to study biology and were confident that they would be reasonably successful in their teaching practice.

> During my training years we did a nature study option and I mean we were always on the dunes on the beach or on the grounds of the college doing wonderful things and we use to loved it. I reinforce a lot of that with my children, which is why I probably tend to do science. (Lynley, Journal)

> When I trained as a teacher I chose junior primary and languages as my options because I felt that I did not know enough to teach the older children, especially maths

> and science subjects. I remembered doing lots of nature walks around the school as a child and having a nature table. That part of the science course was great but I didn't think I could teach older grades. (Lesley, Journal)

Both teachers were aware of the need to teach science if they were to become primary teachers. They had enjoyed the inquiry aspects of science from their previous experience, but understood the limitations of their content knowledge. For example, they thought that physical and chemical aspects of science would be too difficult for them to understand, let alone teach. Their lack of certainty arose from conflicting ideas about the inquiry-based character of the 'soft' sciences and the content-based nature of the 'hard' sciences.

The second and related aspect of this issue deals with teachers' beliefs that science is a body of knowledge that can be transferred to children as a complete package. Both teachers believed that science (and mathematics) comprised, to some extent at least, of absolute truths to be learned, memorised and recalled at a later time to solve problems. This view differed from the assumptions the teachers made about learning in languages, social studies, health, crafts and music. In these subjects, they understood that children acquire knowledge and skills over periods of time and generally rely upon many experiences to consolidate understanding. The teachers were also more likely to accept that it is okay to make mistakes in these subjects because children developed at different rates. Science, on the other hand, was viewed as too important to get wrong and, to some extent, both teachers were less comfortable about possibly 'getting it wrong'. Both teachers acknowledged that science was an important part of their children's education. Lynley felt that she had a duty to her children to prepare them for technologically-oriented world. However, also acknowledged that although science provides answers it is important for the children to think about the process of science.

> With science I think I have always had the feeling that we need the knowledge of science so that we can plan what is best for the world, what is best for our environment. I've always loved science and I've always tried to fit it in with my overall program. Children need to learn specific skills and how to think in a logical sequence that I think is far more valuable to them in the long term than knowing facts. (Lynley, Interview)

In summary, the study teachers held different assumptions about teaching and learning in different subjects. While they were likely to accept some content ambiguity in some subjects, they were less comfortable when doing so in science and mathematics.

The third aspect deals with the teaching dilemmas faced by teachers as a result of their epistemological confusion. One example concerned the way in which Lynley's colleagues approached the new course. Lynley found that her colleagues were nervous about taking on the new program because it represented a departure from the previous approach, which was based on workbooks. The new inquiry-based approach was clearly a concern for the teachers who did not know how to deal with their lack of content knowledge. Lynley found that her colleagues' lack of belief and support very frustrating. When a particular colleague chose to ignore a complete section of the course and bought in a space station for astronomy that supplied workbooks, Lynley did not know how to deal with the issue.

> If the teachers had worked through the lessons in their groups using the materials I supplied, then they would have seen the pitfalls. They would have been all over the hurdles they came across. This is why they won't teach science because so many times they come up against a brick wall. (Lynley, Interview)

Lynley, herself, embraced the new science program with enthusiasm and endeavoured to follow the lesson plan explicitly. Lynley always encouraged the children to raise questions about what they were investigating in the belief that discussion about the issue helped them develop an inquiring mind. Lynley also shared her thoughts with the children to demonstrate how she arrived at her understandings about the concepts of the lesson. However, during some lessons Lynley experienced problems in reconciling her belief that the children should construct their own knowledge with her need to supply definite answers at times. For example, when Lynley was unable to assist the children to develop a definition for fungi and bacteria she finalised the discussion by instructing the children to find the answer for homework, reinforcing the idea that science has definite answers and definitions. At a later point in the lesson Lynley encouraged discussion about the compost heaps that the children were investigating. As Lynley was unsure of her understanding of how compost functioned she chose to read the teachers' background notes to the children in lecture mode. The information

became very specific, referring to the nitrogen and carbon content of the materials used to make compost. Although the children listened quietly many of them were unable to understand how this information was related to their mini compost bins. At the end of the lesson Lynley expressed her frustration at not being able to make the important points in the lesson to reinforce what was happening in the compost bins.

> The main concepts I wanted to get across today were why we set up the mini bins. What was going to happen within that compost bin and the variables they may have come across? I didn't really round it off as well as I wanted to because we just ran out of time. What I would have said to them afterwards is that the compost is returned to the soil and becomes part of the nutrients in the soil but is not actually the soil itself. Now I don't know if they are going to discover between compost and nutrients in the soil. (Lynley Interview)

While Lynley followed the lesson plan, she was unhappy with the 'results' because in her opinion the children had not 'got the right idea' about the major concept of the lesson. She was unwilling to leave it to chance and used the lecture format to reinforce and disseminate, what she saw as, vital pieces of information. Although Lynley followed the new science program explicitly and agreed, in principle, with the inquiry approach she struggled to overcome her deep-seated belief that science is a body of received knowledge.

Lesley also believed that science was a body of knowledge that needed to be learned, therefore making it a 'hard' subject to teach. Lesley's preference for teaching the language arts meant that she developed her programs from major themes in her language program and relating other subject areas to this program. She called this a cross-curricular perspective. Science, therefore became an adjunct to her major themes, supplying topical, interesting, one-off lessons. However, Lesley was very careful to follow the lesson plans from the science program explicitly in case she missed out some vital steps. She also came up against the dilemma of how to deal with content in an inquiry-based approach. For example, when faced with the problem of poor magnets during a lesson, Lesley focussed on working through the steps of the lesson. She was unaware that some children were challenged in their beliefs about the behaviour of

magnets. The frustrations created by the supply of poor magnets reinforced Lesley's belief that science is complex and difficult, requiring specialist equipment.

In summary, the two teachers in this study experienced epistemological confusion about the nature of science. They were conflicted by competing views of science - one view being that science is a way of inquiring about the world and another view that science is a body of received knowledge. These two different views were encountered by the teachers in their past dealings with science and also influenced their decision to teach at the primary level. In this study, while the teachers expressed a preference for inquiry-based science and were in tune with the constructivist underpinnings of the new program, they were frequently faced with pedagogical dilemmas about the importance of science content knowledge. This uncertainty in the minds of teachers, about what to do with content, and how to reconcile content with inquiry, stands as one of the more important findings from this study.

8.9 SUMMARY

This study examines the manner in which two primary teachers introduced a new science program into their teaching practice. In this chapter I have made propositions arising from my research.

The first proposition is 'explicit teaching notes are a vital, though problematic, tool in helping teachers change their practice'. The provision of explicit teaching notes was viewed as an essential support for the teachers. However an over-reliance on the resource book meant that the teachers had difficulties when the lesson did not proceed as expected.

The second proposition is 'gaps in teachers' subject matter knowledge affected children's science learning opportunities'. The teachers' lack of science content knowledge contributed to missed opportunities to develop the children's science understandings. Often they reverted to reading background information to the class directly from the teachers' resource book or deferring answers to the children's questions until well after the lessons.

The third proposition is 'teachers use classroom discourse as a strategy to build children's science knowledge and to manage the class'. Many discussion sessions before, during and after the activities tended to be teacher-dominated and dealt with rules and procedures. Lecturing was used to reinforce the main points of the lesson, safety issues and behaviour. There was limited time in science lessons for the children to engage in oral discussion about the use of science language.

The fourth proposition is 'experienced primary teachers are able to maintain seamless science lessons in spite of their poor subject matter knowledge and pedagogical content knowledge'. While the lack of subject matter knowledge impacted upon the children's science outcomes, both teachers were able to use tried pedagogical practices to produce smooth flowing lessons.

The fifth proposition is 'in primary science classrooms, caring for children underscores teachers' pedagogical decision making'. Both teachers were concerned about the well being of their children and the impact this would have on their ability to learn. Both teachers also promoted, modelled and reinforced appropriate classroom behaviour.

The sixth proposition is 'beliefs about teaching science stem from prior experiences'. The teachers' beliefs about science learning and teaching were formulated through their previous experiences as learners and developing teachers.

The seventh proposition is 'teachers balance work with personal and family pressures in order to teach science'. Often the teachers placed the needs of their children and the role of teaching before their personal needs. During busy times of the year they were willing to trade off personal commitments against teaching commitments.

The eighth proposition is 'teachers lack certainty in science teaching because of epistemological confusion in their understandings of the nature of science'. The teachers held competing views of science – as a form of inquiry and as a body of received knowledge – creating epistemological and pedagogical confusion. While the teachers emphasized the inquiry aspects of their lessons, encouraging their children to explore phenomena, they would often revert to lecturing the children about the 'facts' of the lesson.

CHAPTER 9

SUMMARY, CONCLUSIONS AND REFLECTIONS

9.1 AIM AND STRUCTURE OF THE STUDY

The aim of the study was to examine the way in which two experiences primary teachers introduced a new science program into their teaching. The study focused on the various content and pedagogical issues faced by these two experienced teachers. The research question guiding the study was: How do experienced primary teachers incorporate a new science program into their teaching? The thesis is organised around several recurring themes, each illustrated by two narrative vignettes of practice. The use of a hermeneutic dialectic process during the data collection (Guba & Lincoln, 1989) ensured that the themes and vignettes are grounded in the beliefs and experiences of the participating teachers. Analysis of these themes and vignettes lead to a number of propositions about the teaching of primary science. In this chapter, I present a summary of the findings from the study, discussion of conclusions and implications of the research, and finally my reflections on the research journey.

9.2 SUMMARY OF FINDINGS

The findings of the thesis are organised around five themes — Managing Equipment; Language of Science; Teachers' Certainty; Caring; and Social Milieu. Each theme is illustrated by a narrative vignette, or story, using what Polkinghorne (1995) calls narrative analysis and analysed using elements of a teachers' knowledge framework developed by Adams and Krockover (1997). The framework used five knowledge areas; pedagogical content knowledge; subject matter knowledge; general pedagogical knowledge; knowledge of self and knowledge of the milieu of teaching. The final stage

of analysis employs Polkinghorne's (1995) analysis of narrative. This involved a cross-case analysis of the vignettes to identify several overarching propositions.

The first proposition was 'explicit teaching notes are a vital, though problematic, tool in helping teachers change their practice'. The provision of explicit teaching notes was integral to the new science program and professional development was organised to assist the teachers in understanding the sequence of lessons and the philosophies underpinning the constructivist approach. The explicitness of the teachers' notes caused dilemmas when the teachers did not understand the scientific concepts behind the experiments. They were able to proceed through the steps of the lesson but were sometimes unable to provide answers to the children's questions or did not anticipate when the equipment was inadequate. Paradoxically the teachers' notes sometimes inhibited teachers from exploring children's ideas. The teachers felt that the sequenced lessons restricted time for them to develop topics unrelated to the notes. Thus the explicitness of the program was like a double-edged sword – an essential implementation tool providing detailed guidance but also fostering over-reliance and reducing teacher flexibility.

The second proposition was 'gaps in teachers' subject matter knowledge affected children's science learning opportunities'. The teachers lacked adequate background and experience in science subject matter. While they were able to maintain the structure of the science lessons, many teaching opportunities were lost because they were unaware of deficiencies in their scientific explanations. The teachers made use of the teachers' notes to supply information to the class and at other times simply giving the answers. During the lessons the teachers were often too busy to reflect on the implications of their lack of subject matter knowledge.

The third proposition was 'teachers use classroom discourse as a strategy to build children's science knowledge and to manage the class'. The control of discourse primarily rested with the teachers as they directed discussions to achieve the outcomes of the lessons. Much of the discussion revolved around procedural matters ensuring that the children progressed through the steps of the lesson and were aware of issues of safety and time limits. The teachers used lecturing to bring a sense of closure to what they wanted the children to understand. The teachers also used discourse to control

discipline during the lessons. The opportunity to engage in meaningful 'science talk', reinforcing terminology and science concepts, was limited because of time restrictions and the teachers' lack of subject matter knowledge.

The fourth proposition was 'experienced primary teachers are able to maintain seamless science lessons in spite of their poor subject matter knowledge and pedagogical content knowledge'. The flow of the lesson was maintained by the teachers because of the depth of their pedagogical knowledge of teaching. This was evident when the lesson resembled a language lesson. Even when the supply of equipment was inappropriate or the teachers struggled with the science, they managed to maintain a smooth lesson flow.

The fifth proposition was 'in primary science classrooms, caring for children underscores teachers' pedagogical decision making'. Both teachers held the health and well being of their students as central to their teaching. This caring attitude permeated their pedagogy. They also extended their care of the children to incidents outside of the classroom.

The sixth proposition was 'beliefs about teaching science stem from prior experiences'. The teachers are the sum of their experiences as learners and teachers in schools. While both teachers had fond memories of science in primary school, they were less enthusiastic about learning science in their high school years. Significant people in their childhood and teaching careers influenced their attitudes about teaching science. Both teachers conscious career decisions based partially on their attitudes to science.

The seventh proposition was 'teachers balance work with personal and family pressures in order to teach science'. The teachers were part of the wider community within the school including their peers, parents and principals. The influence of these different groups caused the teachers to alter their teaching practice to accommodate others' expectations. This was reflected in the way the two teachers were willing to forgo personal commitments to complete preparation and administrative work for the class. The teachers were also members of their family structure with associated responsibilities. Over the year there were times when teaching demands intruded upon the personal lives of the teachers. Both teachers accepted that their commitment to their class means that they were prepared to give up personal needs to meet this demand.

The eighth proposition was 'teachers lack certainty in science teaching because of epistemological confusion in their understandings of the nature of science'. Both teachers thought that science is a body of knowledge with truths to be transferred to their children to equip them for later learning. This products-of-science stance conflicted with other constructed beliefs about how children learn. When engaged in language or mathematics, for example, both teachers understood that children develop at different rates and require time and different experiences to develop their understandings. Consequently, the teachers provided experiences to help children construct their science understandings on the one hand, but often turned to lectures to try and ensure that the children had 'covered' the science content. Teachers were constantly balancing an inquiry approach to science teaching with a didactic approach.

9.3 CONCLUSIONS AND IMPLICATIONS

9.3.1 About Teacher Notes

In this study the provision of explicit teachers' notes was an integral part of the new science program. There are several issues that both support and caution teachers and educators of teachers about the usefulness of such documents.

Firstly explicit, well-structured, teaching notes provide a blueprint for the lesson. The teachers in this study relied heavily on the teaching notes to help them implement the new program.

Secondly the level of dependency upon the teaching notes linked with the degree of teachers' confidence in teaching science. The more confident the teacher the less she referred to the teachers' notes during the lesson. Lynley, for example, was able to memorise the sequence of the lesson and felt confident that she understood the science concepts being explored. Lesley, the less confident teacher, kept the explicit teaching notes open on her lap during class discussion and often stopped the class to check the progress of the lesson. Confidence in knowing the subject matter and familiarity with subject specific pedagogy means that teachers are less reliant on explicit notes.

Thirdly, despite careful adherence to the explicit teaching notes, there was no guarantee about the success of the lesson. The major reason for any lack of success can be attributed to the teachers' poor of science subject matter knowledge. The teachers were unable to understand the implications of using outdated equipment, alternative equipment or predict the outcomes of certain experiments. This caused confusion during science lessons adding to the teacher's belief that science teaching is fraught with difficulty. Finally the explicit teachers' notes did not allocate time within the lesson plan to explore ideas suggested by the children as a result of investigating activities during science lessons. The explicit teachers' notes did allow for discussion of issues, but teachers felt that the finely sequenced lessons prohibited in-depth discussions of emerging topics. The teachers did not know how to develop a scope and sequence set of lessons to provide children with experiences to consolidate the learning of particular science concepts.

This study has shown that providing finely wrought teachers' notes is not a guarantee that teachers will use it as intended. Primary teachers have always been encouraged to develop programs from a variety of resources to meet the interests and needs of their children. It is almost instinctive for them to alter any documents they view to suit their teaching style, interests and the learning style of their class. Primary teachers, used to picking out 'experiments' that fitted their topics, interest and abilities, will find it difficult to change these habits. Nonetheless, the conclusion from this study is that explicit materials provide a vital role in getting teachers started on the path to improving confidence and reforming practice.

9.3.2 About Equipment

Several issues were raised in this study with respect to equipment. Firstly, provision of equipment in primary schools depends upon the expertise and time available for the teacher who has volunteered to coordinate science equipment for the school. The primary schools in this study were not allocated technical support for the purchase and preparation of equipment. Science coordinator positions were taken up by teachers as part of their 'other duties', and were often not a reflection of their expertise in this field. This meant that such teachers did not recognise when equipment was inadequate for a specific task and made inappropriate substitutions. This meant that teachers were

sometimes frustrated at having to 'make do' and that science concepts not being properly reinforced.

Secondly, the teachers' lack of science content knowledge inhibited their awareness of the inadequacy of key equipment. The science lessons often employed concrete experiences to enable children to develop their science concepts. The equipment was specifically designed to facilitate this process. In choosing to use alternative equipment, the teachers did not always recognise the implications for the children's development.

Thirdly the provision of equipment in primary schools is often controlled by the allocation of funds at the school level. While subject areas such as reading, maths and sport enjoy realistic allocations of funds many primary schools science is under-resourced making it difficult to purchase quality science equipment. This aspect of the science curriculum therefore is often seem by teachers to be outside the control.

What this study does show is that equipment in primary schools needs to be resourced adequately. Equipment has important pedagogical and safety implications. Teachers need assistance to build their confidence in using equipment and matching appropriate equipment to written teaching notes. The maintenance and supply of equipment is closely connected to issues of curriculum and pedagogy and cannot be easily given over to students, parents and teachers' aides who may not have an adequate understanding of pedagogy. Teachers also need time to manage equipment without compromising other duties.

9.3.3 About Teacher Certainty

There are several issues related to teacher certainty. Firstly, teachers are a product of their past experiences in learning and teaching. Teachers' lack of science knowledge originated in childhood learning experiences. Primary teachers, predominantly women, are less likely to have engaged in the physical and chemical aspects of science than their secondary counterparts (Appleton, 1991; De Boo, 1989; Symington, 1980; Yates & Goodrum, 1990). It is therefore unrealistic to assume that all primary teachers have an adequate level of knowledge and confidence in understanding science concepts.

Secondly, teachers are faced with a central dilemma – how to assist children to develop their own understandings about science concepts, while at the same time, teaching science as a set of 'truths' that have to be learnt. Frequently teachers revert to delivering lectures because there is a compelling sense of obligation to provide the children with the 'right answers' in science (Goodrum, Cousins & Kinnear, 1992). While teachers understand that children develop at different rates, they struggle with the notion of allowing students to construct their own theories about scientific phenomena.

Finally, many primary teachers are concerned about their level of science content knowledge and pedagogical content knowledge. Lack of science content knowledge affects confidence to teach science. The lack of knowledge also prevents teachers constructing appropriate questions and using questioning techniques to facilitate children's investigations. While teachers clearly need ongoing support to develop their science content knowledge, the profession will always suffer unless some systematic attempt is made to break the cycle of teacher preparation. Like many of their colleagues, neither of the study teachers experienced great success in learning science in their own schooling. Improving science education requires improvement at all levels, primary, secondary and tertiary. In this way, teachers will come to primary teaching with a solid background in the content, processes and philosophy of science, and have greater certainty about those things worth doing in their science classroom.

9.3.4 About Caring and Science Teaching

Several issues were raised in the study. Firstly, both teachers constantly and consistently reinforced safe practices during science lessons. The teachers also reinforced these occasions when the children acted in a caring manner towards each other. The teachers implicitly and explicitly encouraged, modelled and reinforced an 'ethic of care' in their science lessons and outside the classrooms. This study confirms the work of others, that schools are sites of moral struggle (Bricker, 1993) as teachers and children engage in relationships (Gilligan, 1982; Noddings, 1988; Sockett, 1990; Thomas, 1990). The study teachers also displayed an 'ethic of care' towards other staff members by providing support for ideas, opportunities to work out issues and provision of expertise to assist them with change. Primary teachers clearly care as much about each other as they do for their children and will support those who are struggling to achieve set goals.

When primary teachers are asked why they take up teaching they often remark that they care about children and their futures. This need to care and nurture informs many choices teachers make with regard to physical, emotional and educational needs of the children. Teachers protect their class, their children, from the inappropriate behaviour of others. Primary teachers develop possessiveness about their classes that has elements of a parenting role. I believe that teachers will always use this criterion in their decision-making in particular when the children are engaged in activities that have safety issues. Primary teachers also take this 'ethic of care' into what they choose to teach children because they believe that it is their responsibility to provide a good education and equip children for the future. Teachers at times feel overwhelmed with the responsibility to 'get it right' when making such decisions. Teachers will also extend this 'ethic of care' to each other as they band together to share stories, experiences and ways of improving science teaching.

9.3.5 About Leadership and Professional Development

Whole school implementation was a condition placed upon schools taking up the new science program called *Primary Investigations*. Whole school professional development has the potential to be a very effective strategy for reform because it allows for reforms to be seen in the context of the school and its needs. In the two study schools, the principals and teachers' did not invest enough time to understand the new program. The teachers were also uncomfortable with the need to peer teach the lessons because they risked exposing their lack of subject matter knowledge to others. This meant that the leadership role taken up by one of the teachers in the study was made more difficult as she had imagined the teachers would be appreciative of her efforts. This experience highlights the need for schools to build a culture of support where teachers feel comfortable talking about and demonstrating their skills to others. Such a culture allows teachers to make mistakes in the knowledge that others too are learning. Leadership plays a very important role here. School leaders, such as principals, need to demonstrate a balance of pressure and support for teachers as they grapple with new ideas in the context of their classrooms. Teachers also have a responsibility to themselves and their colleagues to take initiatives and show leadership. In this study, we have some examples of the challenges and the possible benefits that are obtained when teachers try to change their practice and help others do the same.

9.4 FINALLY: SOME REFLECTIONS OF A TEACHER RESEARCHER

I came to this study as a primary teacher, teacher leader and in-service provider. As an in-service provider, having been closely involved in the implementation of the new science program in Western Australia, I was a promoter and advocate of the *Primary Investigations* philosophy and related reform agenda. As a teacher, I was sympathetic with practical dilemmas faced by the two study teachers. Having been a teacher leader in my own school, I could also identify strongly with the frustrations faced by the study teachers in trying to help their colleagues. However, I now found myself in quite a different role, that of a researcher. I struggled with some aspects of that role, particularly the thought that my role might, to some degree, be a critical one. I felt some disloyalty to the teachers who invited me into their classes and was unsure how to write about teachers without appearing to criticise their performance. Another dilemma was how to manage the dual roles of participant and observer. I was (and am), at heart, a teacher and enjoyed participating and engaging with the children and their learning. I found that the teachers appreciated having another experienced teacher to work alongside. Leaving the comfortable role of helping the teaching and learning process, to observe, record and interpret the teachers' attempts to teach science was unfamiliar and discomforting at times. I was unsure about how to collect the 'correct' data to make informed connections to the emerging themes. This dual role of being a faithful recorder as well as an interpreter of events was a considerable responsibility at times.

Participating in this study has, nonetheless, been a cathartic experience. As a researcher, I have been given the opportunity to explore the stories and beliefs that have shaped my teaching philosophies. While the three major participants in the study, the two teachers and myself, are uniquely different in the way that our experiences have underpinned our beliefs about teaching, it could be said that we share a common ancestry or cultural group. As a participant and observer in these two classrooms, I was privileged to be included in the process of change as the teachers implemented the new science program. I was privy to the teachers' reflections upon their beliefs about teaching pedagogy and their place in the culture of education. As the teachers agreed to my accessing their 'ways of knowing' it provided me with the opportunity to examine and refine my own beliefs. Taking time away from the task of teaching my own primary class, and having access to colleagues and my supervisor, allowed me to reflect about my

own journey. My metaphor for this process is the 'monkey ball' — a device that sailors use to throw a light line to shore, followed by a progression of heavier lines and ropes to tie off the ship. Being the 'monkey ball' of interwoven beliefs about teaching, it was my task to draw alongside the 'ship' containing the stories of how these two experienced teachers changed their practice. This has been a significant learning experience for the three of us and hopefully our work will help others to imagine ways of improving their own teaching of primary science.

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APPENDIX A

LETTER TO THE PRINCIPAL

January, 1996

Dear Principal,

This letter is requesting permission to work with one of your teachers involved in the new science program, *Primary Investigations*. This new program is the basis of my Doctoral Studies at Curtin University.

The intention of the research is to observe a teacher teaching the new science program over an entire year. It is hoped that this will allow issues about how and why teachers find changing their teaching practices a challenge.

I have been involved in the new science program in my own class and have also provided training for schools wishing to implement the program into their schools. If a teacher in your school agrees to become part of my research I will be able to support them as they implement the new science program.

The research will involve observing the class each week and recording the event on an audiotape. This will then be transcribed and given to the teacher to verify the accuracy of the information. It is also anticipated that the teachers will be able to participate in interviews about what emerges from the lessons to further clarify issues. At all times the teachers will have access to all the information that is gathered. Also all names will be replaced with a pseudonym to ensure your school, staff and children remain anonymous.

My research will provide a wealth of knowledge about the manner in which teachers' approach science teaching in primary school and I sincerely hope that your school will be able to accommodate my request.

Yours sincerely,

Jennifer Pearson

APPENDIX B

TEACHER QUESTIONNAIRE

SCIENCE EXPERIENCES

The following questions are designed to provide information about the science you have learnt throughout your education. It also asks questions about your attitudes to the science and choices you have made with regard to further studies in science.

Thank you for supplying this information and if you wish to add anything that you feel has significance about you attitudes to teaching etc. please do add them at the end.

1. From your childhood can you recall an incident that you feel reflects your earliest memories of a science lesson, either good or bad.

My father found a dead "wamberger" in our front yard. Noted as being extinct then in our area he took it to the W.A. Museum for identification and this to me was extremely important. Visits to the Museum in those early years (5 - 8) had a huge impact on me. (Other school lessons - The Life Cycle of the Frog + Butterfly. (Years 3 or 4) Clouds - Year 6/7. I loved clouds.) (I was about 6 yrs old)

2. During High School which science subjects did you study? In particular which science subjects did you graduate with.

Physics and Chemistry Year 8 (I didn't achieve very highly 58%.)
Biology Years 9. 10. 11. + 12.

Geography (?)

3. Which science courses did you undertake during your tertiary studies?

Nature Study Option (Graylands T. College)

4. What influenced the age group you prefer to teach?

Perhaps always being a sporty person I preferred to take the Upper grades having majored in Phys Ed. Year 4 - 7 children are much easier to communicate with, discuss topics of interest, can do projects and generally are more self-sufficient - independent. Coaching sport has always had a strong influence on the age group I teach.

5. Have you ever considered teaching science as a specialist subject? Why or why not?

Not specifically, although I thoroughly enjoyed teaching Science to Years 1 – 7 for two years in Brunswick in a very well equipped Science Room – (thanks to the hard work of volunteer mothers who gave hours to the making up of box kits). It is a very involved subject area to teach with loads of preparation – however a most enjoyable one with great rewards.

6. Please list the four subjects you enjoy teaching the most.

Maths, Science, Technology, Written Expression (Opinions/Story Writing), Reading (Novel approach)

7. Do you feel confident teaching science in your class and have you always felt this way?

Yes. I have always loved science and taught it confidently to my students. However, it possibly has always been weighted towards the biological sciences and very simple content areas of energy, plants, animals and matter – not the more sophisticated technological side – eg. transference of energy through systems

8. Can you remember an incident or person who has influenced your science teaching?

Several people have influenced my love for science, my dad – who just loves nature and the way things work, my Biology teacher – Years 11 + 12
Lea McKenna – Graylands T. College
Brian Devereaux – District Office (E.O) Bunbury (terrific impact in recent years) + Melville.

9. Could you make any suggestions about how teachers would effectively increase their skills in teaching science?

Develop a respect for Science and its importance to this generation of children.
Be ready to be reprogrammed through inservicing
Accepting new materials/methods from the experts on how we need to equip our pupils for an everchanging, technical world.

Thank you very much for the time you have spent completing this questionnaire.

Yours sincerely
Jennifer Pearson.

SCIENCE EXPERIENCES

The following questions are designed to provide information about the science you have learnt throughout your education. It also asks questions about your attitudes to the science and choices you have made with regard to further studies in science.

Thank you for supplying this information and if you wish to add anything that you feel has significance about you attitudes to teaching etc. please do add them at the end.

1. **From your childhood can you recall an incident that you feel reflects your earliest memories of a science lesson, either good or bad.**

- Nature walks around the bush school I attended
- Nature table

2. **During High School which science subjects did you study? In particular which science subjects did you graduate with.**

* Human Biology
* Biology

3. **Which science courses did you undertake during your tertiary studies?**

Primary Science units

4. **What influenced the age group you prefer to teach?**

Enjoy that age level
(Don't feel confident teaching upper primary maths)

5. **Have you ever considered teaching science as a specialist subject? Why or why not?**

No - Never thought of myself as being scientific
- Never been overly interested in science

6. **Please list the four subjects you enjoy teaching the most.**

Language related subjects

7. **Do you feel confident teaching science in your class and have you always felt this way?**

Don't mind teaching at my level, however the organisation and collection of materials has often been a problem.

8. **Can you remember an incident or person who has influenced your science teaching?**

9. **Could you make any suggestions about how teachers would effectively increase their skills in teaching science?**

- Using Primary Investigations /
Focus on teaching rather than sorting collecting equipment & material

Thank you very much for the time you have spent completing this questionnaire.

Yours sincerely
Jennifer Pearson.

APPENDIX C

TEACHER INTERVIEW TRANSCRIPTS

INTERVIEW WITH LESLEY

16TH MARCH 1995

JP: Well I thought if I just asked one or two questions, that way it doesn't hold you up too long and it's sort of things that crop up as I'm reading or as I'm reflecting on what we are doing. So what I'd love to know is, can you remember or relate the type of lessons you did last for science or whenever you taught science last?

LC: Yes. See we had M do the science here last year, before that it would have been one, two, three, four years ago. Actually its ages ago, because we even had someone do science at B.

JP: So you have managed to avoid teaching science for a while?

LC: I have yes. That's well done isn't it? But before that I'd say that the science I remember doing, years ago would be very on a, um, I suppose not as involved or as well linked as what the lessons are here, like the common thread. They would be linked in the fact that you might do plants, or very much 'on the topic' oriented and the curriculum and the departmental curriculum.

JP: Is that 'I Do Science'?

LC: Light and yes, things like that And doing like, the fabrics. I know there was one with fabrics and fibres and those things, so it was very much following kits that the school. I think it would have been when I was done at C, kits that the school had made up and having to work through and yes, I remember now using those I Do Science books but I never used to enjoy it.

JP: They had teachers' guides and kids books so you could actually have them have their own little book.

LC: Which they did.

JP: You didn't like it?

LC: No, I never used to enjoy doing that. Something maybe more than others but it was just, it was boring.

JP: They always seemed dry to me like the teachers guide wasn't. I know you shouldn't rely on what it looks like but it didn't present well and there wasn't a lot of supporting material for the teacher or information.

LC: And getting all the materials too. You know you have to know you'd suddenly have this lesson and discover that you need all sorts of bits and pieces, unless, like at least here, we know the materials are in the school. And like we have A every term put together all the main bits and pieces that you need. You've still got to do some running around and get bits and pieces but if you just have to read it a week ahead and get yours organised in that way, but at least you know that the materials are all here and you've got your box and it's more or less, well sort of half way there. Where as it was just never, I've never really seemed to gel and it never, because I'm very much thematic to it, never used to really fit in with, you know, what I was doing. Sometimes you could plan it from the science but it just... I think also the sort of children too.

INTERVIEW WITH LYNLEY

2ND JULY 1995

We talked about the story I gave her to read about Thingamajig, the story about ethical issues in teaching science.

L: Now if you want we can talk about it today and you can give me a really good idea where you want to go. I'm going to Shark Bay and when I'm in the tent that's when I do my best thinking.

JP: Good so leave it until then.

L: Well for me to write it up if I know exactly what you want.

JP: I suppose what I want ... I'm trying to get a handle on is, how you think the program is impacting on your kids. So in choosing Thingamajigs, do you see where it has, in your mind, a good representation of a way of dealing with ethics through science? It even gets back to why do you personally want to teach science to the kids and you have said that a couple of times.

L: Yes the importance of it and as you say, the ethics of this particular Thingamajig session is how it relates to them in their everyday living and their lives and just how important, like we were just saying about the dam with the water. You know how to solve problems we have created really and also extend on existing inventions or whatever that was done to make them more economical or with the resources we can recycle and do all that, because this is all recycling, wasn't it.? They had to do it form recycled materials.

JP: Yes, I called it Found Materials and JW wanted to know what did you mean by 'found,' so I rephrased that to 'easily available materials' or 'readily available scrap materials' so that would cover that wouldn't it? Do you think kids nowadays are more aware of good and bad or ...?

L: Recycling?

JP: Yes.

L: Oh, yes definitely. They are very conscious of it as far as the plastics go and then, you know, I suppose if they can collect money on things like the aluminium cans and that, well they do because they know it's going to a good purpose. But recycling their own things, I mean they reuse things that they have got. They do a lot more than we ever did as kids. Not that we had a lot to play with we didn't because we didn't have a lot of those items.

JP: Do you think they have come through the swing? We have been through an abundance were it was a real throw away society. People might be just now moving back towards considering our resources. It has come through the parenting too I think.

L: It is very interesting that came up the other day when we were talking about using paper at school at the moment. We have to really cut back because we have used a lot of photocopying paper and I just said to the children, it was lap tops because my friend has just got a job with P and she was quite taken aback because all those girls, the parents bought them lap tops or that was the requirement.

JP: There is an expectation that you will.

L: Yes, that's right. That's what is expected and so she is going to be teaching with this lap top and she is quite horrified. She is mortified because she really doesn't know a lot about it, but she wanted the job there because she needed a change and all the rest of it, so the challenge is there. But I said to the children that while they are in school, that in a few years time we might not have paper. Just imagine how many trees that we would save, you know, if we don't have paper. We do it all on lap top and have it at our desk and so forth. I said 'do you ever visualise that could happen?' Then they started talking about the film where they burn the book and you weren't allowed literature and that entire thing.

APPENDIX D

STUDENT LESSON TRANSCRIPTIONS

'MINI BEASTS' LESSON

12TH JUNE 1995, YEAR TWO

The children had been outside collecting animals for today's lesson and we were inside, beginning the lesson.

L: Have a listen to this poem I'm going to read and if you hear any word in the poem that tells how this animal moved. What is that J? Can you get rid of it please while we are working down here? So I want you to think of words that in this poem that tell how the animal moves. "Huffy wuffy caterpillar crawling all about. Would you be a real good friend and help a fellow out? My shoes get scuffed and dirty when I go out to play but drive yourself along my shoes and brush the dirt away." (Many hands went up.) Did you hear any words that described how that animal, first of all what was the animal L?

L: Worm.

L: Not quite but what was the word that described how it moved, N.

N: Crawl.

L: It did say crawl yes, crawling all about and we know what crawl is. It's usually when you are down close to the ground and it stays very close to the ground. If a baby crawls, it stays very close to the ground or on the floor. There was another word there that described how it could move. J?

J: Slithers.

L: Not quite slithered, but a very good word to describe how an animal moves but the word that it is – slid. Who knows an animal that we would say would slither, C?

C: A snake.

L: A snake, definitely any others that you know that we could describe them as slithering animals, K?

K: Slug.

L: Slug, slithers.

JP: Slowly slithers.

L: Slowly slithers, sluggishly slithers. What about this poem? Listen to this one? "Tommy tadpole wriggled, Tommy tadpole swam, in and out among the reads he wriggled and he swam." Now what words told us how he moved? M.

M: Swam.

L: He swam, and we know what sort of movement that is it's a movement through water and another word? There was another very good word I thought S?

S: Ripple, (Class oh!) I forgot.

L: It starts with 'r' S.

S: Wriggled.

L: Wriggled, well done. What word if I said the word crept, can you think of an animal that we could describe that would be a good word to describe if the animal crept across something, G?

G: Mouse.

L: Yes a mouse a mouse could creep, I can think of another word that describes how a mouse moves which is a very fast run that starts with 'sc'. Can you think of it S?

S: Scurry.

L: Scurry is a good one but I'm thinking of another one but that was good, A.

A: Scatter.

L: Scatter is usually when like a group of animals run of in all different directions but that is a good word that's more of a group go off in all different directions. A.

A: Scamper.

L: Scamper. What about crept? What other animals would creep? (Many put up their hands and sucked in their breath.) S.

S: Tiger.

L: Oh, yes it creeps. Is it a fast movement or a slow movement? (Class said slowly together.) He creeps through looking for his prey most likely. What is another animal that might creep A.

A: A cheetah.

L: A cheetah similar to the tiger, yes he does a lot of creeping about. A

A: A rat.

L: A rat, yes he tends to move faster he maybe creeps to begin with maybe but then he starts moving faster. We would probably say that he was scurried or scampered. What about a Kangaroo? Here is a song up here. "Old jumpedy bumpedy hop and go one was lying asleep on his side in the sun. This old Kangaroo, he was whisking the flies with his long lofty tail from his ears and his eyes Jumpedy bumpedy hop and go one laying asleep on his side in the sun. Jumpedy bumpedy hop." Some words to describe how that animal moves. We used to know this really well (An old poem on the wall chart.) G.

'MOULD' LESSON

30TH JUNE 1995,YEAR FIVE

J: If you are happy that your group has almost finished, why don't you read the next step?

B: Write down some of the places, apart from bread, where you have seen mould growing.

J: So where have you seen mould growing apart from here?

R: Apple.

J: You told me about the apple, so you write apples.

B: Any fruit that is wet and sloppy is eh!

L: Rang the bell. I'm very pleased to see you writing down and very pleased to see you drawing with your diagrams. I know it is very difficult to see a lot with the little magnified glasses. Now I wish that we had a room with microscopes all set up around benches where we could take a sample of what you are looking at and putting it under the microscope. Now I'm going to see if I can set that up for next week so that we can actually see under the microscope. Now it's going to show you 100 times more than you can see at the moment. So you will really be able to see what these moulds are. Now you have time to discuss the moulds with your group, now I would like you to describe it to me, and I will just ask one person per group. It need not be the speaker, so if you might like to volunteer to see if you came up with the same idea as the rest of your group and please what you really believe it is. Describe to me what you saw. It's shape, colour whatever, what your group decided it was, if they did make a decision in your discussion and what is it really. What is this mould? I have had several views given to me. It's quite surprising what you think it is. You need to listen to everyone's views on that.

While we are doing this, no one is to speak or move and fiddle because I want you to focus on what people are saying. We will start with the group here, a spokes person? R would you like to speak on it? Describe what it looks like or what it is or how you perceived it and then what you thought it was.

R: Well it was speckled, green and white mould that has developed in the middle of the bread. Oh! It hasn't developed in the middle.

L: Only on the edges?

R: It looks like it's green and blue outside on the small pieces of bread and it's got no white mould and the brown bread is just than the white bread.

L: Well done R, thank you.

R: And it's bacteria.

L: So you feel – that group there – think or feel that it is bacteria. Can you tell me what bacteria is? Do you know what bacteria is? All right will you please tell us then D? What is bacteria? Can you describe it, dear?

D: I can't really.

L: Okay that's what I was after. Next group quickly.

J: We found the mould on the bread looked like a little tiny plant and it's eating off the food.

L: I like that answer, good girl. Anything else J?

J: Yes, we also thought it was bacteria as well.

L: Is that what your group discussed? So plants eating off the bread. K group.

L: Australia is an old and dry continent. The driest continent in the world actually and many of our soils are poor compared with countries that have had more recent volcanic activity. Why do you think that might be? (Indistinct voices.) Plants eating off the bread. Okay now K group. (Again hard to hear.) Good boy, it looks furry, well done and what do you think it is actually?

K: Bacteria

L: And you think its bacteria. M group.

M: It looked a bit like we had sort of a white on the centre of the bread and a round white. ...indistinct...I'm not sure but it looked like .....it looked sort of creamy and um.....and we think it is more of a fungi.

L: Fungus, well done that group. Is it well discussed, did you all discuss that in your area? That's excellent well done. (A class of students went past in the concrete corridor, yelling etc, very hard to hear.) We thought it was bacteria of more cells. So we thought it was and the bread .....

L: Was that for both of your samples? Both soggy?

M: No only the brown bread.

L: Excellent that group. Well said.

J: Excuse me Mrs B? I was wondering where V got the idea that bacteria is a single celled animal?

V: Well when I was in the library I was flicking through books and I saw it there. Hard to hear!!!!

L: So you found out dear, well done.

J: Great V.

APPENDIX E

NOTES

LESSON NOTES

17TH JUNE 1995, YEAR FIVE

17th June
Beginning of a cold so feeling drowsy. Had to take a class frog to the zoo on the way - had come on the Ramsay. They got lots of them. When I got to school the group were working on their responses to last week because L—— had managed to get them early. Their class teacher was away. She got the class to group according to last weeks new groupings then asked them to look over what they had done and add to it if they wanted. She got selected groups to re-iterate what they had discovered. Especially the group which had found / investigate a particular variable very easily. This was used to reinforce that you have to be precise when investigating things. She apologised for not having the mouldy bread experiment ready for them - she had told me earlier that to hasten the growth she had warmed it up in the microwave but then thought this probably killed the fungi. At the end of the day we discussed the best conclusions needed and that she would do the introduction next Wednesday from 1½ to 3.00 if L—— agreed. She will let me know for sure. That way the two lessons needed on Friday could be used to good effect. This meant that L—— went onto the 'evaluation' lesson the last Mouldy Bread, had been the 'elaborate' lesson. This brought up the notion of assessment and I had an interesting conversation about that at the end of the day. I said I'd noticed that she'd used to take records of the students last week and that this lesson was the one that should be used that way. I congratulated her on her use of the celery activity which captured the essence of what the students should look for in a system. I also noticed that she was beginning her reports so at this time they are all very busy (teachers). L—— is also being asked by her Principal to help him compile a Portfolio of how the science is going in the school. This means she has to spend time collecting photo's, surveys and helping him write those class sessions. Also going into classes and teaching while he walks around with the class teacher observing the class. This is amazing to me that he is able to get them to agree. L— says that when she & L—— walk around they both get caught up in what the students are doing and forget to be critical about objectives covered. L—— also said to her that if this had been around 20 years ago teaching would have been so much more fun & satisfying for him. He seems to be

a dedicated, interested principal willing to understand what the teachers are going through by observing at first hand. L—— also found that for herself she finds it hard to stay on task and assessing the students according to the checklists because the chn ask questions and she is so interested in how it turns out & what they are discovering she forgets to check them off. That's when I said her recent lesson was a good one but in reality the evaluation lesson should be treated like that. It is always a hassle assessing and my personal response is to have someone come in to do that job only and you reciprocate. Maybe it will come ??

Anyway the students were asked to glue their plane experiment in and draw the model on the blank sheet then sent out to recess. L—— did not do this at all – just flung it in. Some asked a couple of times what they had to do. After recess the students were shown the model of the lung they would construct first before this L—— went over the types of system we have in our bodies. She chn did a wonderful job of identifying – then she concentrated on just the lung. The chn were genuinely interested because it looked exciting lined up at the front. Very bright balloons L—— had done a lot of the preparation work in that she had put the sticky on the base with a hole drilled through. Each lung was then set up with a straw & balloon & sticky tape around the cup. This meant that the chn had more time on the activity once they had the lung completed. The lung they had a great time discovering how it worked. This was when they discovered the use of the diaphragm in relation to the lungs. This meant that when it was time to question they were able to contribute very well.

*** During this session the library lady came in with 2 extra books to give L—— if she wanted them. She will keep them from now on. I asked L—— how she can remember the pattern of the lesson and not refer to the book every step. She said that she keeps a mental map of the main features and what you she is finishing so that she will forget but this is hard to remember. At the end of the lesson she did ask the questions from the book to be sure.

LYNLEY'S REFLECTIONS

Sunday 20th. July 1997

Dear Jennifer,

Here is my attempt to relate to you what I think, Why I think ethically, I teach Science to our students.

Our students live in an everchanging world. Those that we teach in our classrooms today are not experiencing or learning about their future adult world, for that world is unknown to us all. One wonders therefore why it is, that we teach Science as we know it, believe it or perceive it, as it is today? Logic suggests that this is irrational. However, one major, significant and over-riding factor becomes apparent. Everything must have a base, a starting point upon which to build an idea, theory or decision so that progress can be made. Students need to be given a base or a scaffold upon which to gain the confidence to make a decision, solve a problem or just take a simple step forward. Students need to understand, that in a world of constant change they must challenge existing knowledge by questioning, testing and analysing, showing that man must be prepared to change his views and perspectives on what he perceives and accepts to be the truth.

Through the teaching of Science we can provide our students with this most valuable resource which allows them to observe, predict, hypothesise, analyse and evaluate purposefully, ethically, toward developing a better environment in which to live. The student needs to be aware that there are a multitude of solutions, or pathways to a solution, and through sound, positive moral instruction be awakened to the importance of choosing an outcome that is least harmful to the environment, does not rob it of its natural resources nor be a "quick fix, low cost, suffer later" decision. Sound ethical practise must be a major part of the teaching of Science to our students today.

LESSON NOTES

12TH JUNE 1995, YEAR TWO

Monday 12th June

When I arrived the class was outside looking for insect creatures. The children were very excited and raced over to tell me what they had brought in and what they needed to look for. Lyn was not as excited / happy but very pleased to see me. She was frustrated at the lack of creatures and had spent a lot of time trying to find them on the weekend. Harvey found mine. Lyn told the children they were rowdy and she growled at them. She also said that she didn't like Monday afternoon because all she seemed to do was to growl all the time. After school we talked about the issue of materials and she said that most of her material had to be prepared the Thursday before or Friday or in class on Monday. She acknowledged that she relied on Jan (the science co-ordinator) to supply her the material but had found that she still needed to check this as it was sometimes not what she needed. She did say that some lessons were light on as maybe they were one off ones. At this time there is a need to gather material for a sample book which will take a week to generate, collect & mark ready to go out with reports in a week & ½ time. The pressure is coming down with staff meetings & all the D.O.T.T this week going on interviews with parents about their child. She resents this as her time is limited and she has already spent time with the parents at the beginning of the year. Her frustration are real and her loose pattern of the Monday science. I am still waiting for her to take the bull by the horns and change the day. The materials are still the most difficult aspect for Lyn and her reluctance and dread of science may be being transmitted to the children. I'm sure Lyn appreciates the learning that is going on and copes with the group most really well. It is noisier and the children more. I will have to ask her if these aspects bother her at all.

I spent time outside looking for bugs to no avail. After the rush the children settled to the task but the instructions were long and by the time they had settled in their groups most had forgotten what it was they were looking for. All had a great time looking at

the creatures through magnified glasses. Those that didn't have all the creatures shared with other groups. The chn were then given pictures of the creatures and asked to sort them according to a criteria/characteristics. They did this very well and came up with credible characteristics. Lyn couldn't finish the lesson in time so said she would get them to complete the last piece the next day.

I noticed that the chn are much better at gathering resources & budgets and that they do not fiddle with the budgets as much. They are able to keep an eye on materials and return them well. I also noticed that they are able to talk about their experiences fluidly which for Eve was impossible at the beginning of the year. The chn are able to stay on task and when they do need to consult each other it is mostly about their science.

Lyn gave me the writing the chn had done on science and they are almost all positive. I asked about doing a small knowledge questionnaire next week and she agreed so I can of some tally sheets ready for that. I have 6 books of both science & language nature for them to select from. I have stapled this to their writings because I will get them to explain what they are about.

Lyn also brought up the point about needing room to set out / store the materials and how this made the room seem cluttered. The dishes being cluttered and by the end of the day feels completely swamped and in a mess. We talked about how important it is to feel comfortable in your own environment. I feel that Lyn has a great room with not a lot of clutter but more space to store & display items would be better. I also think the kids are fantastic & not too noisy. Lyn really feels 'particular' about the materials (I'm sure given half a chance she would revert to her 'normal' science.

1. Have the children developed orally since the beginning of the year
2. Could you describe your science programs from last year & what are the major changes you see between the two.

LESLEY'S REFLECTIONS

Monday 20th February
First lesson went well.
Pleased with how the chn worked in their groups. Some interesting fish were made. Took time to organise - cutting up coloured shapes and putting into envelopes

Monday 27th February
The lesson went well, although I felt as though the children were not at their best - rather ratty! Felt as though we didn't have enough time to discuss the results. Had some interesting criteria for sorting before I gave out the magnets.

APPENDIX F

AUSTRALIAN ACADEMY OF SCIENCE

AN INVITATION

Appendix F: Australian Academy of Science: An Invitation

Note: For copyright reasons Appendix F has not been reproduced.

(Co-ordinator, ADT Project, Curtin University of Technology, 05.08.03)

APPENDIX G

SCIENCE TEACHERS' ASSOCIATION OF WESTERN AUSTRALIA

LETTER EVALUATING PRIMARY INVESTIGATIONS

Appendix G: Science Teachers' Association of Western Australia: Letter Evaluating Primary Investigations

Note: For copyright reasons Appendix G has not been reproduced.

(Co-ordinator, ADT Project, Curtin University of Technology, 05.08.03)

APPENDIX H

CHRONOLOGY OF LESSONS OBSERVED

CHRONOLOGY OF LESSONS OBSERVED

YEAR FIVE CLASS (LYNLEY)

DATE	LESSON
17th March 1995	Bottle divers
23rd March 1995	Bottle divers (revised)
31st March 1995	A telephone system
7th April 1995	A telephone system (revised)
10th April 1995	No science, early close for term.
5th May 1995	Living at the bottom of the sea
12th May 1995	Which one would you buy? (roller blades)
19th May 1995	Which one would you buy? (washing powder)
26th May 1995	Which one would you buy? (washing powder concluded)
2nd June 1995	What would happen if…?
17th June 1995	What would happen if…? (concluded)
	A breathing system. (bread not ready for lesson on Mouldy oldies
23rd June 1995	Teacher test for test file. Mouldy oldies.
30th June 1995	Mouldy oldies. (teacher extension activity)
28th July 1995	A communication problem
3rd August 1995	A communication problem, investigation 2
11th August 1995	Hovercraft , investigation 1
18th August 1995	Hovercraft, investigation 2
25th August 1995	Observed District Challenge Day
31st August 1995	Hovercraft, investigation 2 concluded.
7th September 1995	Problem Solving, Thingamajig
14th September 1995	Observed class at Curtin University with Dr. Jean Hillier.
	Children designed and built their ideal community
21st September 1995	Problem Solving, Thingamajig, investigation 2
28th September 1995	Foam follies
19th October 1995	Ways of solving problems

26th October 1995	What rubbish
2nd November 1995	What rubbish, extension work
15th November 1995	Settling down
24th November 1995	Dripping through
29th November 1995	Too much salt
4th December 1995	Soil interactions

YEAR TWO CLASS (LESLEY)

DATE	LESSON
20th February 1995	Team Games: Paper shapes
27th February 1995	Magnet mystery
6th March 1995	Labor Day, no lesson
13th March 1995	Sorting our world
27th March 1995	Float or sink
5th March 1995	The sorting game
8th May 1995	No Lesson, material not supplied to teacher
15th May 1995	Oobleck
22nd May 19954	Oobleck, completed lesson
29th May 1995	Let's sort leaves
6th June 1995	Foundation Day, no lesson
12th June 1995	Animal characteristics
19th June 1995	My day
26th June 1995	Our shop
4th July 1995	Teacher away, no lesson
31st July 1995	I'll huff and I'll puff
7th August 1995	I'll huff and I'll puff, session 2
14th August 1995	Material matters
21st August 1995	Material matters, conclusion
28th August 1995	Teacher away, no lesson
4th Septembers 1995	Materials for structures
11th September 1995	Beds for bears
18th September 1995	Beds for bears, session 2

25th September 1995	Puffy Pig
28th September 1995	Puffy Pig, session 2
16th October 1995	Colours in bubbles
23rd October 1995	Colours at work
30th October 1995	Changing colours
20th November 1995	Colour in our world
27th November 1995	Teacher extension lesson, coloured jellies