Supporting inquiry in the primary years - Children's science questions and how teachers deal with them

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B. Teaching
Grad. Cert. En. Ed.

A thesis submitted in partial fulfillment of the requirements of the degree of Master of Education (Research)

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May 2013

Statement of Authorship and Sources

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

No parts of this thesis have been submitted towards the award of any other degree or diploma in any other tertiary institution.

No other person's work has been used without due acknowledgement in the main text of the thesis.

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

Acknowledgements

This thesis would never have been completed if it were not for the support of my loving husband who took over everything else while I sat in front of my computer every night for years.

Thank you honey.

Prepare yourself for the PhD....

My thanks also to my Mum who typed all the teacher transcripts even though she doesn't know 'teacher talk'.

Finally, grateful thanks to my supervisors at ACU who supported me and pushed me even when it looked like it would never be finished.

Abstract

From 2013, Australian teachers of Preparatory Year to Year 10 will be required to fully implement the new Australian Curriculum: Science. An insight into what science questions children may ask would be beneficial in light of teachers' interaction with this new curriculum over the coming years. This study investigated the types of science questions children have in response to a visual stimulus of lunar phenomena. It also examined teachers' responses to those questions. A review of the literature highlighted the importance of children's questions, however, there had been considerable research about teachers' questions and proportionally little about children's questions.

Data were gathered through classroom observations of children posing questions, teacher observations and interviews, and teacher questionnaires. One hundred and forty-five teachers completed the questionnaire. Part 1 of the questionnaire asked teachers about their responses to children's science questions. Part 2 was a multiple-choice test using five children's questions about the Moon. Six teachers and their classes (Year 6) participated in the study group. The children were shown three pictures of the Moon and asked to share questions they had about the relevant phenomena. Some children asked no questions and others asked several.

Twenty-seven percent (89) of the children's 329 questions were found to be questions that required a Yes or No as an answer. One of the classes in the study group asked only one question requiring a Yes/No answer, another class didn't ask any Complex Questions. More than half of the children's questions (54%) were questions that could be answered with a short statement. Only 19% of the questions asked required a complex answer or explanation in response and there was a wide variation in the frequency of Complex Questions asked in the classes.

Significant findings from this study were that children in Year 6 ask more questions that require a brief answer than questions that require complex scientific answers, research from secondary sources or investigations with materials. Classroom culture, access to digital information and the physical layout of the classroom were shown to be influences on the categories of questions the children asked in each class. Many questions about the Moon from each classroom were similar.

This study also confirmed that teachers' lack of science background knowledge is still an issue in science education. Teachers indicated that they wanted to be able to answer the children's complex questions with a scientific explanation but many teachers lacked confidence about having the necessary understanding of science background knowledge to do

so. Only 45% of teachers' answers to children's complex science questions were full scientific explanations. Moreover, length of teaching experience was shown to have no relationship to the ability to answer the children's questions. It was also found that teachers had varied levels of competency with Science Pedagogical Content Knowledge (PCK). It is possible that good PCK can help teachers to deal with poor science background knowledge.

The analysis of teacher observations and teacher interviews, which examined teachers' responses to children's science questions, indicated that the teachers responded in a variety of ways. These responses included: grouping questions together to answer them; involving the children in answering their own questions; breaking Complex Questions down into simpler versions; asking further questions to clarify understanding; and giving brief scientific explanations.

Although teachers agreed on the value of children's science questions they believed that using those questions in their classrooms created issues for them. The four most frequent issues nominated by teachers were: children's questions deviating lessons from the intended curriculum; not knowing the answers to children's questions; time pressures; and only a small number of children wanting to ask all the questions.

Finally, the implications from these results for classroom practice were discussed and suggestions were made for further research in this area.

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CHAPTER ONE: INTRODUCTION

There is strong agreement about the importance of children's questions in science education (Chin & Osborne, 2008; Kur & Heitzmann, 2008; Pedrosa de Jesus, Teixeira-Dias, & Watts, 2003; Spargo & Enderstein, 1997). These authors agree that children's question-asking is beneficial to both the learner and the teacher. Children's questions help them develop scientific explanations and understandings, are motivating and can provide a starting point for investigations. However, it seems that very few studies have explored the question-asking behaviour of children in primary science classes or how teachers respond to those questions (Chin, Brown, & Bruce, 2002; Cuccio-Schirripa & Steiner, 2000; Rop, 2002 & 2003; Spargo & Enderstein, 1997). Chin and Osborne (2008) suggest that this apparent lack of research is a result of question generation being viewed in typical classroom settings as a teacher's role with students more often expected to answer questions rather than to ask. This is perhaps why children's science questions appear to be an "undervalued domain of inquiry among the research community" (Chin & Osborne, 2008, p. 2). In contrast, there have been many studies investigating the question-asking behaviour of teachers (eg. Chin & Osborne, 2008; Rop, 2002, 2003).

Current research about children's science questions is particularly important because of the implementation of a new national science curriculum. In 2011, the Australian Curriculum, Assessment and Reporting Authority (ACARA) released syllabus documents for all primary and junior secondary year levels in four Key Learning Areas, one of which was for Science (ACARA, 2011). The new science curriculum has an emphasis on pedagogical change, with a focus on "a model of student engagement and inquiry" rather than on traditional teaching approaches, such as a 'transmission model' (ACARA, 2009, p. 13). As children's ability to pose and investigate questions is an "important part of science inquiry" (ACARA, 2009, p. 13) teachers will need to be able to deal with these questions and promote a culture of questioning in their classrooms.

Unfortunately, barriers exist to teachers utilising children's science questions but they still need to be valued in the classroom because children's science questions benefit both the teacher and the students and they have a prominent position in curriculum documents. Teachers also need to be able to address children's science questions because of their presence in the Science Inquiry Skills strand of the Australian Curriculum: Science and yet, despite their importance, they appear to have been undervalued in past research. Research about teacher responses to children's science questions is also limited. Thus, an exploration of these problems by reviewing the literature in this area and gathering data from teachers and children should contribute to discourse in the education community about children's science questions as a resource for teaching and learning in science.

1.1 The Importance of Children's Science Questions

'Posing questions' is a required skill in the science curriculum (ACARA, 2010) and so it is desirable to develop this in an on-going way throughout the primary years so that students can ultimately pose research questions independently. Children benefit from posing questions because it can help to develop and refine their understanding of concepts (Chin & Osborne, 2008; Pedrosa de Jesus et al., 2003). Questions can also help children monitor and reflect on their own learning and can foster debate and in-depth discussion in the classroom (Chin & Osborne, 2008). If the answers to the children's questions are found through investigation, the result can be very motivating and satisfying for them (Harlen, 2006). Children are not alone in this as similar results, indicating more beneficial engagement in science, were found in a study exploring the effect of student-generated questions in undergraduate chemistry (Pedrosa de Jesus et al., 2003).

Teachers also benefit from children posing questions as they can inform teaching practice. Using children's questions as a starting point for learning in science can result in children behaving well and showing interest in science (Chin et al., 2002; Kur & Heitzmann, 2008). Children's questions can also provoke a change in teaching practice. Watts, Alsop, Gould and Walsh (1997) noted the case of a primary teacher whose children's questions caused her to reconsider her own understanding of science concepts and prompted her to fill those gaps in her knowledge. Children's questions are also of benefit to the teacher as a diagnostic tool (Chin & Kayalvizhi, 2002) as questions reveal what the children know and the gaps in their conceptual knowledge (Pedrosa de Jesus et al., 2003). Similarly, Harlen (2006) explains that children's questions are the 'cutting edge' of their understanding and this information helps teachers identify children's alternative conceptions. Alternative conceptions are the common-sense explanations devised to explain to ourselves new experiences of a phenomenon. These alternative explanations are tenacious and do not correspond with current scientific views (Wandersee, Mintzes, & Novak, 1994). Knowing that alternative concepts exist, and being able to identify them, could be the key to successful teaching in science or lead to a successful change in teaching practice. Thus children's questions can be an important diagnostic tool for teachers and as a consequence it is in both teachers' and children's best interests for questions to be encouraged in the classroom.

1.2 Children's Questions in the Science Curriculum

Prior to the Australian Curriculum: Science, schools in the state where this study took place used an outcomes-based syllabus. That syllabus focused on conceptual change in the learner and referred to children's questions only as a minor part of one of the overall Key Learning Area (KLA) outcomes. The KLA outcome included "refine knowledge …… and pose new questions" (Queensland Studies Authority, QSA 1999, p. 8). The science syllabus also incorporated 'formulating questions' as part of investigating when the learners were working scientifically (QSA, 1999, p. 33). A change of curriculum documents for schools from an outcomes based syllabus to standards based syllabus that encourages children's questions should create a change of focus for teachers in their planning and a need for teacher support in this area.

Children's questions in the new Australian Curriculum: Science begin in early childhood with a focus on their own world and experiences. These are useful questions to help children to develop explanations for themselves about the world they live in. For example; What is it made of? How does it move? Why does my dog have fur? Their questions increase in an awareness of the community and the world around them as they progress through school until in the upper primary years until they can independently pose scientific, testable questions, rather than those that arise purely out of their own interests (ACARA, 2010).

An insight into the types of questions children are asking now would seem useful in light of teachers' need to devise and implement teaching units from the new Australian Curriculum: Science. Teachers interpret curriculum documents for their local context and the needs of their learners by devising units of work for their class. School-based and system-wide support is available to teachers to implement changes in their teaching (ACARA, 2010). Consequently, children's questions could influence the development of units of work from the new science curriculum and possibly lead to areas of study that interest the children rather than those decided by the teacher. Likewise, Baram-Tsabari and Yarden (2005) examined questions posed by children on an online 'Ask a scientist' database and found that different age groups and genders had particular interests, often different to topics chosen for study in classrooms by teachers.

Given the importance of children's science questions for teachers and learners, questioning by students has been incorporated into a range of contemporary teacher resources and education documents. For example, in the Primary**Connections** – linking science with literacy programme children's questions are the focus for investigations planned by the children and the basis for developing scientific explanations (Primary**Connections**, 2008).

The importance of questions is also illustrated in other documents: the National Scientific Literacy Progress Map states that Australian children in Year Six of primary school should be able to 'formulate scientific questions for testing and making predictions' (Department of Education, Science and Training, 2004 p. 129, 130). Also, in a national report (Rennie, Goodrum, & Hackling, 2001) into the status and quality of science teaching and learning in Australia it was explained that developing scientific literacy is the purpose of science education in the compulsory years of schooling and identifying questions to ask in science is an important part of developing scientific literacy. The authors defined scientific literacy:

> Scientific literacy is a high priority for all citizens, helping them to be interested in, and understand the world around them, to engage in the discourses of and about science, to be skeptical and questioning of claims made by others about scientific matters, to be able to identify questions and draw evidence-based conclusions, and to make informed decisions about the environment and their own health and well-being. (p. vii).

Children's questions become a focus for science in the curriculum where questions are posed, investigations are conducted and valid conclusions are made (ACARA, 2009). Questions have a prominent position in science inquiry and are linked closely with the purpose of investigations. Inquiry plays a central role in the new Australian Curriculum: Science. As one of the three curriculum strands, 'Inquiry Skills' was designed to integrate with the other strands and be developed in two-year bands, hence, teachers need to focus on providing 'context, exploration, explanation and application' in order to present a balanced and engaging approach to teaching (ACARA, 2011, para. 8). Science investigations answer questions posed by the children and the teacher, so it is with an emphasis on children's questions that teachers will provide the platform for doing science in the classroom.

1.3 Research into Children's Science Questions

Children's questions in science appear to have received little research attention however, the research that does exist has been reviewed by Chin and Osborne (2008). These authors nominate some main areas of research into children's questions. These are: i) the types of children's questions; ii) the effects of teaching questioning skills; iii) the relationship between children's questions and a variety of factors, such as achievement level and conceptual understanding; iv) children's perceptions of their own questions; and v) teachers' responses to children's questions. Thus, this research is concerned with two of the suggested main research areas reviewed in Chin and Osborne (2008): the types of questions children ask and the teachers' responses to these questions.

Researchers have examined the science questions that children pose in different contexts (Biddulph, Osborne, & Freyburg, 1985; Kurose, 2000; Scardamalia & Bereiter, as cited in Chin & Osborne, 2008; Spargo & Enderstein, 1997; van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001). However, further exploration of children's questions is needed, as most of these studies are ten or more years old and are not in an Australian context.

1.4 Factors that can Limit Children's Questions

Children's science questions may be important but one of the most common concerns teacher's have about teaching science is not being able to answer the questions posed by children in their classroom (Zeegers, 2002). Not having the science background knowledge to give scientifically accurate explanations has been promoted as a barrier to using children's questions in the classroom (Biddulph, Symington, & Osborne, 1986; Harlen, 1996; Kallery & Psillos, 2001; Ward, 1997). Answering the children's questions with a scientific explanation immediately puts pressure on teachers to know the 'right' answer and promotes a view of science that does not meet with the current educational viewpoint of science as 'a collaborative human endeavour and a body of rapidly changing knowledge and understanding' (ACARA, 2009). The Australian Curriculum: Science promotes questioning and investigating for which teachers would need a good grasp of science background knowledge in order to scaffold the children's learning. However, not having good background knowledge in science may be limiting for many teachers in their efforts to support learning and in their ability to give detailed scientific explanations to answer children's questions. Not knowing the answers is just one obstacle teachers perceive to using children's questions effectively in science.

Time constraints, issues of control, and teachers' lack of confidence in their answers have all been suggested as obstacles to children asking questions in the classroom (Biddulph et al., 1986; Engel & Randall, 2008; Harlen, 1996; Ward, 1997). Also, new research points to a lack of science pedagogical content knowledge as the underlying difficulty in teaching science competently (Fleer, 2009). There may be a similarity between teachers' views about children's science questions and perceived barriers to teaching science competently that are reported in the literature.

1.5 Research into Teachers' Responses to Children's Science Questions

Past research has also provided information on some ways teachers respond to children's questions in the classroom (Rop, 2002; Watts, Gould et al., 1997; Yip, as cited in Chin & Osborne, 2008). Studies about teachers' responses to children's science questions suggests their questions are not welcomed (Chin & Osborne, 2008), yet there seems to be scant research given the importance of children's questions. Children ask different types of questions in science, for example; to clarify and confirm understandings, to investigate and also to express wonder and interest (Harlen, 2006). Categorising children's questions could help the education community to understand how to utilise them and an exploration of the variety of questions they ask could benefit teachers by highlighting the use of children's science questions as a starting point for inquiry.

Therefore, this study aims to fill a gap in the research about children's science questions. It is essential to address this research gap due to the change in curriculum that creates a circumstance in which children's inquiry questions become more important in class. Thus, a problem emerges for investigation. Expectations are that the teacher does the questioning in the classroom, not the children, consequently children's questions are limited. Teacher's responses to questions may limit the children's question-asking because science questions create potential issues for teachers but, with the need to implement the new Australian Curriculum: Science, teachers may be compelled to deal with the children's questions. Investigating this problem will contribute to the research focus about the usefulness of children's science questions as a resource for teaching and learning.

1.6 The Research Purpose

This research is founded on the principle that the questions children ask during science lessons can be a valuable resource for teaching and learning in science. Initially then, this study will explore the types of questions that children ask in a science activity and aims to categorize the questions based on the teacher's responses. This investigation will be conducted in order to answer the first research question: ***What types of science questions do children ask in response to stimulus pictures of lunar phenomena?***

Current practice, supported by curriculum initiatives, supports the view that questions generated by children may be an effective way to motivate and engage them as learners and promote learning in the classroom. As such, it is important that teachers respond to children's science questions in a manner that shows they value their questions and are willing to use their questions as a means of supporting their learning. This study will explore teachers' responses to children's science questions and in doing so, will address the second research question: ***What do teachers consider to be suitable responses to children's science questions?***

In the education community emphasis in the past has been placed on teachers' abilities to answer children's questions with accurate, current scientific explanations. A good understanding of science background knowledge is certainly necessary for scaffolding children's learning but it would be unfair to expect generalist primary teachers to be able to answer *all* children's questions accurately. It is important that teachers know where their own gaps in understanding are and can identify current scientifically accurate concepts to teach their classes. The conceptual area of Space science, in particular questions about and knowledge of the Earth's Moon, were chosen as the context for the study and will be used to explore teachers' understanding of lunar concepts and to reflect on teachers' perceptions of how they respond to children's questions. In doing so, this study will address the third research question: ***What influence do science background knowledge and pedagogical content knowledge have on how teachers deal with children's questions?***

Obstacles exist for some teachers to teaching science competently and confidently. This includes utilising children's science questions and being able to answer them. Teachers may be more open to children asking science questions if they value them as a tool for learning or if they feel confident about how to deal with them. Thus, this study will explore teachers' concerns to address the fourth research question: ***What do teachers identify as issues with responding to children's science questions?***

1.7 Design of the Research

This study employs both a qualitative and a quantitative methodology through the use of teacher questionnaires, in-class observations and teacher interviews. This approach was selected in order to provide an in-depth exploration of teacher's perspectives about children's science questions and to investigate what types of questions children ask in the classroom and how teachers respond to those questions.

A questionnaire was designed, incorporating two parts. The first part explored teacher's views about children's questions and how they responded to them. The second part tested teacher's understanding of science background knowledge in the context of lunar phenomena. Qualitative data were incorporated about teacher's responses to children's science questions to provide further information about how teachers deal with children's questions. This was gathered through in-class observations and teacher interviews. Children's questions were collected and analysed after a whole class activity.

1.8 The Significance of the Study

The results of this study will provide useful information for primary school teachers, schools and system-level administrators. By identifying children's science questions about lunar phenomena, practicing teachers could gain a greater understanding of what questions to expect from their own students in this context. The issues raised about children's questions and how teachers deal with those questions may help other teachers deal with their own concerns about children's questions in the science classroom. Teachers could use the findings to create a professional learning plan by embracing the use of children's questions in science lessons.

This study will also contribute to the research discourse about children's science questions as a resource for teaching and learning science.

1.9 Limitations of the Study

The schools and teachers that participated in this study volunteered to be involved so they may not be a typical and representative sample of the general population of primary schools or teachers in an Australian state.

Another limitation of the current study is that the teachers had time to reflect on their understanding and answer questions on the questionnaire but in the classroom answers to children's questions are often brief and given without first reflecting on their own understanding of the phenomenon. They may have chosen responses to children's science questions that are not a truthful depiction of what actually occurs in their classrooms. Some of the questionnaires could have been completed outside of the staff meeting time, so teachers may have researched the answers to the questions in Part Two and thus their responses may not be an accurate representation of their understanding. However, including data from a study group of teachers who were observed and responses from individual interviews with them may amend that limitation somewhat.

Also, the teachers and children in the study group may not have demonstrated their usual behaviour because they were being recorded. Much of the data gathered was in relation to how teachers planned to respond to children's questions or brief periods of observation of teacher's actual responses in a contrived classroom activity, rather than through observation of their actual responses in an everyday classroom setting.

1.10 Delimitations of the Study

A delimitation of this study is in the boundaries attached to the participants. Only Catholic primary schools were included in the study and only Year Six classes were included in the study group. The data were all gathered in the first semester of a school year prior to a change from a state science syllabus to a national science curriculum.

1.11 Outline of the Thesis

Chapter Two provides an overview of literature in relation to the categories of questions children ask and children's science questions about the Moon, teachers' responses, teachers' confidence in their understanding of science background knowledge and their grasp of science pedagogical content knowledge and issues that arise from utilizing children's questions in the classroom. Chapter Three explores the research methodology and the process employed. It describes the collection and analysis of data from a questionnaire and from observations and interviews. Chapter Four presents an analysis of the results. Chapter Five discusses the results within the framework of the research literature. Chapter Six provides a summary and some recommendations for the teaching of science and the on-going professional learning of teachers. Chapter Six also offers suggestions for the direction of future research and concludes the study.

CHAPTER TWO: REVIEW OF THE LITERATURE

In this chapter, relevant literature will be reviewed about the classroom as a learning environment, categories of science questions asked by school children, how teachers typically respond to questions in different ways and the role of their understanding of science background knowledge in providing answers to the children's questions. Considering the types of questions children ask and how teachers respond to them can help form an appreciation of how children's questions contribute to the teaching and learning of science. It is helpful to examine children's questions in a context and for the purpose of this study the context is lunar phenomena. This chapter will include a consideration of the research into teachers and children's understanding of lunar phenomena and will conclude with factors that affect teachers' responses to questions and their use of questions in the classroom.

Despite the lack of research (Chin et al., 2002), children's questions are important because they are beneficial to the learner and to the teacher (Pedrosa de Jesus et al., 2003). The skill of posing questions is part of the Australian Curriculum: Science. Questions are utilised as a means of developing scientific explanations, as a way of understanding the world and as a starting point for investigations. Thus, an awareness of the types of questions children pose is necessary for an understanding of how best to utilize them in the classroom.

2.1 The Classroom Learning Environment

The discourse in a classroom reflects the culture of the classroom. In terms of discussion/discourse, culture can be conceptualized as an unwritten contract in which both parties have clear ideas/roles about the way in which classroom discourse is conducted. Teachers and students are well practiced in talking to one another, and often that means that the teacher asks questions he or she already knows the answers to so that students can recall and repeat others' thoughts (Cazden, 1986; Nystrand, 1997). Evolving relationships between teachers and students develops the culture of the classroom and this strongly shapes classroom activities. Children work at becoming experts in the nature of classroom activities but this is a continuous and incomplete process (Nuthall, 1999). Children's science questions have been undervalued in education research, perhaps because the teacher typically asks questions and the children are typically expected to answer (Chin & Osborne, 2008).

The role of the teacher has begun to change in classrooms where Information Communication Technologies (ICTs) are utilized. In these classrooms the children often work at their own pace and the teacher moves to a guiding role (Lim, Pek, & Chai, 2005). This corresponds with Prensky's view (2001) of how the teachers' roles need to change from being experts in the classroom, as they had to be in the past, to guiding learning in a partnership with the children. Prensky coined the phrase "digital natives" (2001) to describe today's school children that engage in digital media to learn, socialise and communicate. They have access to ICTs in their classroom and often lessons are delivered digitally. Pauling (2008) explains: "The nature of the student has now changed….They are more consumers of learning who want what they want….They know that gaining access to knowledge is no longer limited to the classroom". (p. 403)

Technological skills is one area where children sometimes surpass adults so teachers have an important role in the interface between children's learning experiences and digital information. Today's students "think of the Internet as the place to find primary and secondary source material for their reports, presentations, and projects" (Royal, 2003, p. 6). However, Carr (2008) describes how research shows that using the Internet in unprecedented amounts induces only superficial understanding of topics. The vast amount of information accessible to students on the Internet is information that teachers do not know (Green & O'Brien, 2002) and so their role becomes one of a facilitator more than an expert. It is possible that the access to information is inducing only superficial understanding of science topics and also changing the categories of questions that children ask.

2.2 Categories of Children's Science Questions

Over thirty years of research has provided some studies in which several authors have categorised children's questions (Allison & Shrigley, 1986; Chin et al., 2002; Chin & Osborne, 2008; Harlen, 2006; Harry, 2003; Rop, 2002 & 2003; Spargo & Enderstein, 1997). Categorising children's questions allows the education community to compare and contrast children's questions and provides a starting point for reflection on teaching practices. Questions have been classified in many ways: on the cognitive processes used to pose the question or answer the question; the process of conceptual change during which they occur; whether they are investigatable or not; the type of information the question is pursuing; the context that the questions were posed in and the response required by the teacher.

In a recent review of literature about children's science questions, Chin and Osborne (2008) reported several classifications of questions from a range of authors. One way of classifying children's science questions was based on the cognitive levels needed to pose or to answer a question. It focused on 'recall' of information, 'analysis', 'evaluation' and 'creation' of the question or the answer (Anderson & Krathwohl; Bloom, Engelhart, Furst, Hill, & Krathwohl, cited in Chin & Osborne, 2008) or on the 'processing' between 'input' and ‘output’ (Pizzini & Shepardson, cited in Chin & Osborne, 2008). This classification values higher order questions that can lead to a deep understanding of the concept through the thinking processes used for analysing and evaluating but it doesn’t acknowledge questions seeking basic information, which are also important in the process of learning (Chin & Osborne, 2008).

Another classification of children’s science questions reviewed in Chin and Osborne (2008) is questions that were raised at stages of learning; this includes higher and lower order questions. These categories of ‘Confirmation and Transformation’ (Pedrosa de Jesus et al., 2003) and ‘Consolidation, Exploration and Elaboration’ (Watts, Gould, & Alsop, 1997) are also aligned with thought processes as they pinpoint the stages of conceptual change and can clarify or restructure ideas. These questions may be seen on a continuum rather than a hierarchy and therefore they recognise the importance of questions seeking basic information. However, they are dependent on factors such as children’s prior knowledge and the stage of learning they are at and so are highly context dependent.

Chin and Osborne (2008) classified ‘Investigatable’ and ‘Non-Investigatable’ questions by grouping children’s ‘raw’ questions based on whether they are suitable for empirical testing or not. Although this appears to be a highly practical way to group children’s questions testable questions are not common among children’s questions in science. Children’s questions usually need teacher input and adjustment to become testable or investigatable (Roth & Roychoudhury, 1993; Symington cited in Biddulph, Symington, & Osborne, 1986; Chin & Osborne, 2008).

Two other reported classifications were from very different contexts. One was an on-line ‘ask-a-scientist’ website (Baram-Tsabari & Yarden, 2005) and the other context was questions related to class textbooks and those that arise in the natural course of teaching (Scardamalia & Bereiter, cited in Chin & Osborne, 2008). Both these groups of questions are dependent on the context in which they are asked. One of those contexts is not in a classroom and the other involves the use of student textbooks that are not usually incorporated into primary school teaching of science.

A South African study (Spargo & Enderstein, 1997) grouped children’s science questions according to the type of response required by the teacher. However, Spargo and Enderstein’s (1997) categories were based on responses that ranged from a simple scientific explanation to a more complex one, with no expectation that a teacher might encourage a hands-on investigation or search for information from a secondary source. The only responses they considered were verbal answers from the teacher. The categories of questions in Spargo and Enderstein’s work were chosen after they showed children a collection of photographs of space science stimuli, such as an astronaut in space, and then collected a list of the children's questions about the stimulus pictures. The categories that emerged were:

1. questions requiring essentially factual knowledge;
2. questions requiring a relatively simple explanation;
3. questions requiring a greater degree of insight (*into science concepts, by the teacher*);
4. questions requiring some understanding of first causes (*by the teacher*).

Harlen (1996) proposed another classification of five categories of questions, based on the responses required from the teacher. These categories were:

1. Questions that are an expression of wonder or interest;
2. Philosophical questions;
3. Requests for simple facts;
4. Complex questions;
5. Investigatable questions.

The fourth category of questions is 'Complex questions' that require scientific answers that rely on complex explanations, not just a simple statement (Harlen, 1996). She explains that complex questions are the most frequent spontaneous questions asked by children in science classrooms. Jelly (2001) describes how these questions often start with 'Why...?' or sometimes 'How…?'

The fifth category of questions, 'Investigatable questions', can be answered through hands-on investigations by the children, often fair tests in which variables are manipulated (Harlen, 1996). These investigatable questions are not common amongst children's science questions although they are widely discussed in the literature (Chin & Osborne, 2008). They are also known as: 'testable questions' (Kur & Heitzmann, 2008); 'operational questions' (Allison & Shrigley, 1986); 'researchable questions' (Primary**Connections**, 2009) and 'action questions' (Harry, 2003).

Spargo and Enderstein's (1997) and Harlen's (1996) question categories are aligned in Table 1 with three other studies reported in Chin and Osborne (2008) that also use teacher's responses or question purpose as a basis for classification (Bloom et al., 1956, Chin & Kayalvizhi, 2002; Scardamalia & Bereiter, cited in Chin & Osborne, 2008).

Table 1
Classifications of Children's Questions Based on the Teachers' Responses or the Purpose of the Question

Harlen (1996)	Spargo and Enderstein (1997)	Chin and Kayalvizhi, cited in Chin and Osborne (2008)	Scardamalia and Bereiter, cited in Chin and Osborne (2008)	Bloom, Engelhart, Furst, Hill and Krathwohl, cited in Chin and Osborne (2008)
• Philosophical questions		• Non-investigatable questions		
• Requests for simple facts	• questions requiring essentially factual knowledge • questions requiring a relatively simple explanation		• basic information questions	• knowledge; comprehension
• Questions that are an expression of wonder or interest • Complex questions	• questions requiring a greater degree of insight by the teacher • questions requiring some understanding of first causes by the teacher		• wonderment questions	• analysis; synthesis; evaluation
• Investigatable questions		• Investigatable questions		• application

Spargo and Enderstein's (1997) categories separate questions that require 'factual' answers, 'simple explanations', 'insight' by the teacher or 'understanding of first causes' by the teacher. However, other responses are valid too. Their categories do not include 'investigatable questions' as a category, which are of consequence, and widely reported in the literature. Other categories of questions should also be examined because even basic requests for simple information contribute to student learning (Chin & Osborne, 2008). The various classifications for grouping children's science questions reported in the literature employ a variety of perspectives that value question types differently. The research community agrees that children's science questions are important and that a variety of categories have value in the classroom, yet few studies have focused on children's questions. Those studies that have reported on the questions children ask about lunar phenomena are explored in section 2.3.

2.3 Children's Science Questions about lunar phenomena

Lunar phenomena can be a fascinating topic of study for the learner. In this study lunar concepts are the focus for children's questions as they are of interest to children but difficult for teachers to support with hands-on investigations. Unlike other scientific disciplines such as the Physical sciences, investigations in the Earth and space sciences can be difficult to execute and can lead to a reliance on common-sense explanations. It is also an area in the curriculum that past research has highlighted as being problematic for teachers because of their lack of background knowledge of space sciences concepts and their lack of confidence in this area. Children and teachers tend to share common alternative conceptions about the Moon and other space science topics, such as how seasons occur. Some alternative conceptions about Moon phases can even become more prevalent with age. The Moon was also chosen as the science context for the teacher questionnaire and the children's questions because it has been part of the core curriculum in the Earth and Beyond strand of the QSA Science Syllabus since 1999 (QSA, 1999) and is included in the new Australian Curriculum: Science (ACARA, 2012).

Research from the last twenty-five years has established some common children's questions about the Moon. Children living in different countries have all asked questions about the changing appearance of the Moon. In Greece, children asked: 'What do you think happens so that the Moon does not always have the same shape in the sky?' (Kallery & Psillos, 2001). This is similar to 'How does the Moon get all its different shapes?' from a South African study (Spargo & Enderstein, 1997). In the United States, Kurose (2000) was asked 'How did the Moon turn into different parts?' by a Year One child and 'How do we get the phases of the Moon?' by another Year One child in a different study (van Zee, Iwasyk, Kurose, Simpson & Wild, 2001). Thus the questions children ask transcend age groups and country of origin. Biddulph et al. (1986) established that there are "common questions across classrooms, even across countries" amongst children (p. 85).

2.3.1 Lunar Concepts in the Curriculum

Lelliott and Rollnick (2009) explain that children under the age of 10 may not be cognitively developed enough to understand the sun-earth-moon relationship that leads to understandings about the seasons, day and night, and moon phases. However, children in the upper primary years of schooling *are* capable of learning about solar system concepts (Sharp & Kuerbis, 2005). These concepts have been traditionally dealt with in the upper primary years but in the new Australian Curriculum: Science 'phases of the moon' and 'the Sun-Earth-Moon relationship' are identified in the descriptors of the Science Understanding strand of Year Seven (ACARA, 2012). Lunar phenomena also appear in the descriptors of Year Three as the 'Earth's rotation on its axis causes regular changes, including night and day' (ACARA, 2012). Children in Year Three are likely to introduce the idea that the Moon is essential to the night in discussions about day and night because of the common misconception that the Moon is only visible at night. Thus teachers need knowledge about the Moon and its relationship with the Earth to handle students' alternative conceptions. Lunar phenomena are explicit in

Year Three and Year Seven, which is currently middle and upper primary, and so teachers should be aware of questions children will have in order to be prepared for investigations, and to support their learners when planning science units.

There is a need to examine children's questions in this study given that research in this field has not been undertaken in an Australian context and much of it is many years old. Although a variety of categories of questions are used, categorising children's questions based on the response required from the teacher would have meaning for teachers currently implementing the Australian Curriculum: Science. It is also one of the more practical methods for examining them. This study is concerned with children's questions as a resource for teaching and learning, so it is important to make the results useful for teachers implementing the Australian Curriculum: Science.

Thus, a question for investigation is: What types of science questions do children ask in response to stimulus pictures of lunar phenomena?

2.4 Teachers' Responses to Children's Questions

When children ask questions of consequence 'the form and detail of the teacher's response is highly significant' (Watts, Alsop et al., 1997 p. 1028). A response to a child's question can take many forms, such as answering with a scientific explanation, investigating or testing the idea, referring to secondary sources of data (books, internet, experts), redirecting the question to other children to answer, saying "I don't know" or sometimes ignoring it because it is not contributing to the teaching topic. Several studies have focused on how teachers respond to children's science questions by using their questions as the basis for investigations (Chin & Osborne, 2008; Jelly, 2001; Zeegers, 2003), having the children find the answers (Biddulph et al., 1986), by giving brief scientific explanations in response to questions (Kallery & Psillos, 2001) or using questions as a starting point in a discussion (Chin & Osborne, 2008; Pedrosa de Jesus et al., 2003). A variety of teacher responses seem worthwhile but past research has focused mainly on how to encourage testable questions for investigation.

Chin and Osborne (2008) maintain that questions should be seen as being on a continuum, rather than a hierarchy, so although questions for investigation are important, even requests for simple facts can be of consequence to children. However, a study from the United Kingdom by Watts, Alsop, Gould, and Walsh (1997) found that three out of the five typical responses teachers gave involved a deflection of the child's question. They explored how children's questions put teachers 'on the spot' to respond. They also found some teachers tried to answer children's questions immediately with a brief scientific explanation as best as possible or turned the question into one that could be investigated.

Teachers need to be able to identify the questions that should be answered briefly or be tested in investigations by the children (Piggott, 2002). Conducting investigations based on children's questions is part of developing Science Inquiry Skills (ACARA, 2009). Unfortunately, children's questions are not usually expressed in a way that makes them suitable for investigation and even after teacher modification they are not always practical to investigate (Chin & Osborne, 2008). However, questions can become the basis for investigation in primary science if teachers draw out children's questions after a period of stimulation with the topic (Biddulph et al., 1986). Children can be taught how to ask questions that are suitable for investigations (Chin & Osborne, 2008) which is encouraging considering more than half of the questions children ask are not suitable for investigation (Symington, cited in Biddulph et al., 1986).

It is not easy to teach about lunar phenomena through investigations (Naylor & Keogh, 2000). Investigatable questions about the Moon are not as obvious as in some other science contexts, because space concepts involve huge scales of time and space, making manipulation of variables difficult. Some research has suggested ways to combat this difficulty by using models and Virtual Reality (Guimaraes & Gnecco, 2007; Plummer & Krajcik, 2010). Teachers are better able to explain concepts when manipulating models than just writing explanations (Lelliott & Rollnick, 2009) thus teaching with models could be more successful.

When questions are posed that are unsuitable for hands-on investigation or a direct answer, then teachers give other responses. As described previously, Watts, Alsop et al. (1997) found five ways that teachers traditionally respond to children's questions. The first two were giving a direct answer or investigating the answer. The three additional responses involved different means of deflecting the questions. They were: i) saying they didn't know the answer; ii) ignoring the question as an interruption; or iii) turning the question back onto the children by saying "What do you think?".

Teachers' responses are important to children and the type and manner of their response may have a great impact on learning. Teachers' initial responses to children's science questions have been reported in the literature with the main focus on teachers answering with either a scientific explanation or an alternative concept (Harlen, 2006; Rop, 2002; Spargo & Enderstein, 1997; Watts, Alsop et al., 1997; Yip, cited in Chin & Osborne, 2008). Some research has focused on children asking testable questions (Chin & Osborne, 2008) but not on how the teacher responds and if they can recognise and capitalize on opportunities to investigate some questions. Therefore, this study will examine teacher responses to children's questions to identify teachers' views of what constitutes a suitable response because teacher responses are central to an understanding of how they use children's questions in the classroom.

Thus, a question for investigation is: What do teachers consider suitable responses to be to children's science questions?

2.5 Teachers' Scientific Explanations

One response teachers can have to children's questions is a scientific explanation that provides an answer. Some questions are best dealt with by giving a direct answer. These questions that don't lend themselves to investigations, but require scientific explanations, can be the most difficult for teachers to answer (Jelly, 2001). They are also more common than investigatable questions and put teachers under pressure. Teachers have very little time to think of answers to children's questions, especially when they have to meet the needs of a classroom full of children. If those questions require complex answers that involve scientific concepts teachers may rely on simplified answers (Kallery & Psillos, 2001). Sometimes these ill-prepared answers are alternative conceptions and are perhaps reinforcing the children's own alternative conceptions (Kallery & Psillos, 2001).

From a study of teachers' scientific explanations in response to pre-school children's questions Kallery and Psillos (2001) developed five categories to classify teacher answers containing scientific explanations:

1. Answers with scientific conceptions – these contained scientific concepts that were close to, or matched current scientific understandings;
2. Answers with alternative conceptions – these were answers that relied on unchallenged 'common-sense explanations' and represented over half of the answers given in the study;
3. Incomplete answers – these were correct but did not fully explain the phenomenon or give enough information to answer the question;
4. Answers with anthropomorphic views – these were answers in which inert things were regarded as living or conscious, although there were a higher proportion of scientific answers and less anthropomorphic answers when the teachers wrote their answers on a paper test;
5. No answer - a response of 'I don't know'.

Some answers require scientific knowledge the teacher does not have and even if the teacher is able to explain the scientific concept, the answer may be conceptually beyond the child's understanding (Jelly, 2001). These questions may not be suitable for scientific explanations, but would make interesting investigations once they are 'turned' into empirical questions that can be explored with hands-on materials (Jelly, 2001). Nevertheless, turning the children's complex questions into a question to be investigated can be problematic for teachers and is sometimes unsuccessful because of teachers' lack of understanding of the concept (Kallery & Psillos, 2001).

2.5.1 Content Knowledge and How it Affects Teacher Confidence

A teacher's confidence may be an important factor in how he or she chooses to respond to children's science questions in the classroom. Many studies have examined the confidence of teachers and how this is affected by their understanding of science concepts (Biddulph et al., 1986; Harlen, 1996; Swackhamer, Koellner, Basile, & Kimbrough, 2009; Ward, 1997; Weinburgh, 2007). One reason for this lack of confidence could be that primary school teachers are required to teach from a range of science disciplines included in the curriculum. In the Australian Curriculum: Science the concepts are grouped and described as Chemical sciences, Earth and space sciences, Physical sciences and Biological sciences (ACARA, 2011). Teaching such a wide range of concepts is considered a great challenge (Weiss, Banilower, McMahon, & Smith, cited in Rice and Neureither, 2006). A national review of science teaching and learning in Australia Rennie et al. (2001) found four major issues for teachers of science: (i) a lack of science background knowledge; ii) the issue of an overloaded school curriculum, which limits the time available for teaching science; iii) a lack of resources, and; iv) inadequate time for preparing to teach science lessons. However, the enduring issue in science education is the lack of science content knowledge of primary teachers

A recent study into student and teacher alternative conceptions in the Physical sciences found that teachers had alternative conceptions about gravity, magnetism, gases, and temperature (Burgoon, Heddle, & Duran, 2010). The study claimed that it would be impossible for teachers to change the alternative conceptions of the children in their classes if they held the same alternative conceptions themselves: "Without a thorough understanding of the science concepts being taught, teachers are unlikely to provide the experiences needed to transform their students' incomplete ideas into accurate comprehensive framework". (p. 103)

2.5.2 Common Alternative Conceptions

Goodrum and Yates (1990) and Kallery and Psillos (2001) found that teachers hold alternative conceptions about the content knowledge in the physical sciences and that teacher confidence is lower with understandings about areas such as the Solar System than other areas of the science curriculum. Most research studies into astronomical understandings have been conducted with children, very few with teachers (Trumper, 2005; Trundle, Troland, & Pritchard, 2008). However, several do report on the lunar conceptions of primary school and high school children, pre-service and practicing teachers and found that they share common understandings about the Moon. For example, how the phases of the Moon occur or if the Moon rotates as it orbits Earth. These studies (Bayraktar, 2009; Lelliott & Rollnick, 2009; Plummer & Krajcik, 2010; Trumper, 2005; Trundle et al., 2008; Wilhelm, Smith, Walter, Sherrod, & Mulholland, 2007) identified alternative conceptions about a variety of phenomena, but of particular interest to this study are alternative conceptions relating to lunar concepts. Trundle et al. (2008) reported that 2,600 participants in fourteen different studies didn't have a scientific understanding of moon phases.

A project from the United Kingdom in 2000 compiled common alternative conceptions from a range of science topics and developed cartoons to test both children's and teacher's views of those concepts (Naylor & Keogh, 2000). This resource, *Concept Cartoons*, devoted five of its space science cartoons to lunar phenomena. One common alternative conception it described is that the Moon is thought of as a source of light. The Moon only reflects light from the Sun, but at times the Moon appears so iridescent our common sense may tell us that it is a light source, like the Sun. Children often believe that the Moon 'goes down', 'vanishes' or 'goes to sleep' during the day, however the Moon can sometimes be seen during the day. Another common alternative conception among children and adults described in *Concept Cartoons* is that shadows cast by the Earth cause the Moon's phases. This is the most common alternative understanding about moon phases (Trundle et al., 2008). Interestingly, this idea becomes more prevalent with age with younger children believing cloud coverage is the cause of the different phases (Baxter, 1989). The Moon phases are really created by different proportions of its lit surface being visible from the Earth. Half of the Moon's surface is lit by the Sun at any one time; the proportion of the lit surface visible from Earth determines the phases. This differs according to the relative position of the Sun, Earth and Moon. With so many alternative conceptions held by both teachers and their students it is not surprising that teachers find it difficult to recognize areas they are uncertain of in their understanding of science concepts (Naylor & Keogh, 2000).

Alternative concepts related to lunar concepts are resistant to change, despite formal schooling at many levels (Plummer & Krajcik, 2010; Trundle et al., 2008). A difficulty children and adults face when learning about lunar phenomena is, although they experience the phenomena regularly, they can only explain them with complex, non-intuitive ideas (Lelliott & Rollnick, 2009).

Primary teachers are not usually qualified in any one specific science discipline prior to graduation from their teacher-training course, but need to be competent in many. Arzi and White's longitudinal study (2008) exploring the change in secondary science teachers' knowledge of subjects they teach over a 17 year period, found that a positive change occurred in teachers' improved understanding of areas they were interested in or qualified to teach. Deficiencies occurred in the other subjects they were asked to teach but were not an area of interest or one they had previously studied. Arzi and White's research highlights the need for career-long support for teachers for improved understanding of science concepts.

A lack of teacher science background knowledge has long been blamed for teachers' low confidence and avoidance of science teaching in Australian primary schools (Appleton, 2008). Even pre-service teachers, who are still completing their own education, struggle with a lack of background knowledge in science. If they have fragmented understanding of core science concepts they have difficulty accessing their understandings when they teach and, as a result, tend to focus on teaching skills and isolated, superficial knowledge rather than developing student understanding (Gess-Newsome, 1999 cited in Loughran, Mulhall, and Berry, 2008). The dilemma for practicing teachers is that professional learning requires a big commitment and successful models of professional development are cost-prohibitive (Appleton, 2008).

There has been a consensus in the past among researchers that good science background knowledge makes better teachers (Shallcross, Spink, Stevenson, & Warrick, 2002). However, with access to Information Communication Technology in classrooms teachers have scientific information available at their fingertips and a lack of background knowledge may not be as limiting as it was in the past. Poor science content knowledge might only be part of the current problem. Fleer (2009) suggests that teacher background knowledge is not the real issue in teachers' lack of confidence and competence in teaching science but rather teachers' understanding of their craft and the way they use knowledge.

2.5.3 Teachers' Pedagogical Content Knowledge

If teachers feel they cannot give scientific explanations that are current scientific theory in response to some children's science questions then the obvious result would be a reluctance to encourage questioning in the classroom. The ability of a teacher to skillfully encourage and use children's questions in the classroom is reliant on their confidence in the applicable science topic and their pedagogical knowledge (Zeegers, 2003). Pedagogical Content Knowledge (PCK) is an amalgam of content and pedagogy that is unique to teachers. "Pedagogical content knowledge has greater input on teachers' classroom actions than other forms of knowledge", such as content knowledge, knowledge of context and general pedagogical knowledge (Gess-Newsome, 2001, p. 4).

Australian research into children's science questions explored the knowledge and skills of teachers who use children's science questions as a basis of inquiry in their classroom (Zeegers, 2003). The research found that teachers who encourage and use children's science questions effectively share a common praxis. It is based on four interrelated elements that include:

1. pedagogical knowledge
2. conceptual knowledge
3. beliefs about learning science; and
4. knowledge and understanding of the nature of questioning in science.

In addition, Fleer (2009) also examines teacher beliefs about learning, pedagogical knowledge and content knowledge and describes PCK as teacher knowledge of science concepts alongside of knowing how to teach these concepts. She also states: "teacher beliefs about how children learn science are a much more important variable to consider when examining teacher confidence and competence to teach science" (p. 1081). If this is so, then teachers would need to update their skills throughout their career, reflect on their practice, and network and observe other teachers. Teachers' concerns about their science background knowledge may undermine their confidence, which in turn could harm their ability to facilitate and support learning in the classroom and perhaps how they respond to children's science questions. However, a thorough understanding of how to teach science, how children learn and an understanding of the 'big ideas' in science may be more important for teachers. Teachers need to mediate and facilitate the children's experiences with the use of materials in order for learning to occur, thus a lack of pedagogical content knowledge is a major additional hindrance to competent science teaching (Fleer, 2009).

The education community has adapted and developed its understanding of Pedagogical Content Knowledge (PCK) since it was first proposed by Shulman in 1985 (Gess-Newsome, 2001). In 2008, Appleton explored the nature of Pedagogical Content Knowledge in science and discovered different perspectives of PCK by researchers. The commonalities were:

Knowledge of subject matter, knowledge of students and possible misconceptions, knowledge of curricula, and knowledge of general pedagogy. (p. 525).

Appleton's use of the term PCK is broader than Fleer's, as it incorporates subject matter knowledge rather than exists alongside it. The integrated manner of subject-matter knowledge and pedagogical knowledge suggests that both play a part in the self-efficacy of primary science teachers. Kind (2009) agrees. She argues that content knowledge (a Bachelor degree in science) is not enough to make a good teacher of science. She explains that if a teacher's belief systems and confidence were taken into account, and PCK became a focus, then better teaching would be the outcome.

These defining features of a 'better teacher' are highly individual and seem mostly reliant on a teacher's experience, as well as knowledge of content. Similarly, a study from the United Kingdom of pre-service teachers' confidence, competence and content knowledge in science found:

There is a clear link between confidence and competence. Trainees [pre-service teachers] feel more competent when they are confident with the subject knowledge they teach. This is not to suggest that confidence and accurate subject knowledge equate, but to recognize the importance of confidence as an emotional influence on competent classroom performance. (Shallcross et al., 2002, p. 1302)

Therefore, many elements of teacher pedagogical content knowledge impact on the quality of science teaching but teachers' confidence in their understanding of science background knowledge is an important factor in their ability to answer children's questions with a scientific explanation. Past research has shown the link between competent teaching and confidence about science background knowledge but has not explored the resulting effect on teacher's ability to deal with children's questions.

Thus, a question for investigation is: What influence do science background knowledge and pedagogical content knowledge have on how teachers deal with children's questions?

2.6 Children's Science Questions in the Classroom

Zeegers (2003) claims that even experienced teachers have difficulty teaching using students' questions. This is compounded when only a few children in typical classrooms ask questions (Rop, 2002, 2003) and when their questions are procedural in nature, which is common (Dillon, 1988). Teachers may be limiting children's opportunities to ask science questions for a variety of reasons that will be explored in this section, but it is also possible that teachers can create a culture of question-asking in the classroom.

2.6.1 Encouraging Children to ask Questions

Teachers who encourage children to ask science questions in the classroom create a set of circumstances that promote questioning. Zeegers (2003) identifies these circumstances as: a belief in the need for children to ask science questions; a sound understanding of science topics; a culture of question-asking; teaching children about the nature of questioning; flexibility; working with children at the individual; then small group and whole class levels to support them with question generation and providing appropriate experiences on which children can base their questions.

Relationships between teachers and students change as the school year progresses and often settle into a comfortable routine or pattern of behaviour. Children become adept at the nature of schooling as they progress through the primary school years, beginning in their first year with little shared understanding with the teacher and their peers about the purpose of their daily trips to school (Anna, 2002). Over several years they become experts in the nature of classroom activities (Nuthall, 1999). In this process of change and relationship building a culture develops in the classroom influencing both teaching and learning. If this culture is one of mutual respect and a partnership in learning then children's questions would possibly thrive. However, if teachers ask all the questions and don't invest in higher order questions that require the student to examine and reflect then children's interesting questions may be stifled. Carlsen (cited in Kallery & Psillos, 2001) explains that teachers who ask fewer low-level questions, and allow more opportunities for children to do so, can also encourage children's questions. He adds that motivation and student participation are also linked to questioning with higher levels of student participation observed when students ask their own questions. However, at times teachers may limit the opportunities children have for asking questions that interest them.

2.6.2 Factors that Limit Children's Question-Asking Behaviour

The teacher's need to meet curriculum goals is often a factor that limits children's question-asking behaviours in the classroom. Engel and Randall (2008) examined teacher responses to children's questions during a prescribed task and found that teachers sometimes control activities and discourage children's questions in order to meet curriculum goals and work within time constraints. They noted that some teachers would put children's questions aside during a science activity, viewing children's curiosity as an interruption rather than an opportunity. Teachers often set aside the children's questions in favour of their pre-planned activities resulting in children asking fewer questions as they progress through school (Chin et al., 2002).

Similarly, pre-service teachers also attempt to control science activities rather than use children's science questions as a focus for their learning or as the beginning point of investigations (Windschitl, 2002). Even when investigation is the focus, some pre-service teachers want to offer their own students a series of testable questions to choose from during practicum placements in schools, rather than using questions generated by the children (Windschitl, 2002). This may be a perceived need by the pre-service teachers to maintain control in a situation that is still unfamiliar.

Another reason for fewer children's questions may be that teachers do not invite them to pose science questions at all (Chin et al., 2002). This may be due to teachers' lack of confidence in their ability to respond with a scientific explanation. In contrast, Kallery and Psillos (2001) found that when teachers were confident about their scientific understanding they allowed children to ask more questions.

Often, the limited number of questions asked came from the same children every time. The observation that question-asking is limited to a small group of children in the classroom may be due to the negative response it elicits from the teacher and other children. A small minority of motivated learners set themselves apart from the rest of the class by the questions they ask. They isolate themselves socially from their peers and provoke their teacher, who often dismisses their questions (Rop, 2003).

It seems that question-asking is the domain of the teacher and a small number of children, and strategies need to be employed to encourage more wide-spread question-asking. Teachers of science may experience issues of time constraints and the pressure to meet curriculum goals, a need for control and a lack of confidence in their science background knowledge. Underdeveloped science pedagogical content knowledge is reported in the literature as a concern and perhaps the underlying difficulty for teachers of science and an influence on how they deal with children's questions. Australian research in this area has centred on factors that limit science teaching rather than issues that limit the use of children's questions in science, therefore there is a need to further explore teacher perceptions in this field.

Thus, a question for investigation is: What do teachers identify as issues with responding to children's science questions?

2.7 Deriving the Research Questions: Summary Statements

The purpose of this research is to examine children's science questions to see what types they posed and to investigate teachers' views about how they could respond to those questions and if the issues they perceived with doing so were common amongst teachers in the study and in the literature. Research that has been reported in the literature has provided an understanding of questioning, predominately questions posed by the teacher, and an awareness of the complexity of teaching science.

Researchers agree that children's science questions are important, particularly those that lead to investigation and develop understanding. Thus, it is necessary to find out to what extent children ask different categories of questions. Gathering children's science questions in response to stimuli establishes the category of questions they ask. A further comparison between the questions establishes if any of their questions are similar to, or are based on alternative conceptions. Collecting children's science questions in response to a stimulus across several classrooms and in a variety of schools provides data about the type of questions children ask. A comparison between the types of questions they ask and those reported in the literature form a picture of the questions teachers may expect to hear in their own classroom, which would be useful for teachers implementing a new curriculum. Thus, a research question asks: *What types of science questions do children ask in response to stimulus pictures of lunar phenomena?*

Question-asking appears to be the domain of the teacher rather than the children and teachers may be dissuading children from asking questions that require complex responses. Observing and discussing teacher responses to children's questions establishes the repertoire of responses they use and their perception of question-asking in the classroom. Thus, a research question asks: *What do teachers consider to be suitable responses to children's science questions?*

The education community has blamed primary school teachers' lack of understanding of science concepts for low confidence in teaching science and a subsequent lack of competence. However, a teacher's skill in dealing with children's questions may not be wholly reliant on their background knowledge of science concepts. An examination of teachers' understanding of lunar phenomena and observations of how they deal with children's questions will establish the effect of pedagogical practice, confidence and science background knowledge on how teachers respond to children's science questions. Thus, a research question asks: *What influence do science background knowledge and pedagogical content knowledge have on how teachers deal with children's questions?*

Teachers may be limiting the questions children pose in science because they are time poor and do not know how to respond to the questions asked. Prior research has identified issues that limit the teaching of science that may have an impact on responding to children's science questions. Consideration of teachers' concerns about what issues arise for them when utilising children's science questions will establish the factors that limit question-asking in Primary classrooms. Thus, a research question asks: *What do teachers identify as issues with responding to children's science questions?*

Chapter Three outlines the theoretical framework employed in this study. It also includes a description of the methods used to collect and analyse data.

CHAPTER THREE: METHODOLOGY AND METHOD

This study employs both qualitative and quantitative methods through interviews, in-class observations and teacher questionnaires. This mixed-methods approach was selected in order to provide an in-depth exploration of teachers' perspectives about children's science questions and to investigate what types of questions children ask in the classroom and how teachers respond to those questions. The conceptual area of Space science, in particular questions about and knowledge of the Earth's Moon, were chosen as the context for the study.

3.1 Theoretical Framework

3.1.1 Assumptions About Learning

Constructivism is the social construction of knowledge through interaction with other people and with materials, hence, this view of knowledge can influence a teacher's view of learning and has implications for classroom practice (Bush, 2006). For example, if children are constructing their own knowledge then they need opportunities to express their understandings of phenomena and have their existing ideas challenged. Seeking out and using children's questions to guide the development and implementation of science teaching units is a good method to find out what the children already know and support them to develop and change their ideas. This method refers to constructivism as a theory of knowledge (Plourde & Alawiye, 2003). Key elements of this study reflect the paradigm of a view of learning informed by constructivism because of the intention to explore the perceptions of teachers and their changing views about children's questions and how to respond to them. The teachers involved in all stages of the research reflected on their practice and considered how they taught science, particularly how they utilized children's questions in science lessons. This was diagnostic in nature and for the teachers in the study group it was an opportunity for them to explore and perhaps change existing ideas during an interview discussion about how to utilize children's science questions as a resource for teaching.

3.1.2 Assumptions About Teaching

The identification of children's existing ideas about scientific phenomena is a common feature of teaching when referring to a constructivist view of knowledge in science. Child-centred teaching approaches identify children's existing ideas as a basis for teaching and learning (Appleton, 2007). These teaching approaches that value children's ideas and questions are important as they result in better communication and cooperation skills in children (Ugaste & Oua, 2007). Whilst there is no one method of teaching that can claim unambiguous success, many studies in the constructivist tradition report impressive results in terms of students' conceptual outcomes (Tytler, 2002). The traditional approach of transmitting new ideas to learners who are assumed to have little or no understanding of the concept (Fleer & Hardy, 2001) is contrary to teaching approaches that have a constructivist view of knowledge as a referent. A transmission approach to teaching is considered teacher-centred rather than child-centred and a national study into the status and quality of science education found "in many classrooms across Australia there is still an emphasis on the traditional 'chalk and talk' and a textbook science approach that has changed little over the past 40 years" (Rennie et al., 2001, 4.1.2.2).

There are times when traditional teaching approaches, such as the transmission approach, are valid in today's classrooms (Fleer & Hardy, 2001). When a new concept does not lend itself to hands-on activities then teachers need to find other ways to develop understanding. This should still be with reference to a constructivist view of knowledge but often the use of the transmission approach is based on a teacher's view that the child is an 'empty vessel' to be filled with new knowledge from the teacher or that science is a body of facts to be remembered (Fleer & Hardy, 2001).

Other teaching approaches that are more child-centred include inquiry approaches. Inquiry approaches to teaching have been prominent in science curriculum materials for nearly half a century (Anderson, 2007). An inquiry approach is an active process of learning (Anderson, 2007), which values questions from the children as part of the learning sequence.

3.2 Research Design and Epistemology

A Mixed Methods Design was used in this study. Quantitative and qualitative data were connected through discussion of the results to better understand teachers' responses to children's science questions and their confidence in their science background knowledge, also to explore their views on children's science questions, typical teacher responses and the issues that questions may raise for them in their teaching. The advantage of a Mixed Method Design in this study is that it provided a combination of both quantitative and qualitative data that afforded a better understanding of the research focus, than either by itself (Creswell, 2008). In this study the researcher employed an interpretive process to the quantitative and qualitative data to allow for broader and deeper information from which to understand teachers' views and to inform suggestions and conclusions in relation to the research focus.

Objective data were collected via questionnaires and question generation sessions and analysed quantitatively using the statistical software program 'Statistical Package for the Social Sciences' (SPSS) (Pallant, 2007). Inferential statistics were used to analyse data from a sample of teachers and classes in order to understand the types of questions children asked and teachers' views on how to deal with them.

Data from teacher observations and interviews were analysed qualitatively. In keeping with mode approaches (Joyce, Weil, & Calhoun, 2009) to science knowledge and science teaching, this study used a constructivist perspective as a framework to analyse the qualitative data. Constructivist epistemology is concerned with the meaning ascribed by participants. In this study the researcher used a constructivist epistemology to develop an understanding of the significance of children's questioning for teachers. A constructivist perspective also involves the researcher making decisions and bringing questions to the study using their own values (Creswell, 2008). The researcher's previous experience as a teacher and a professional learning facilitator had highlighted the time constraints teachers work under and the prevalence of teacher questions over student questions. The researcher coded the qualitative data gathered and constructed a perspective about the views of teachers, the assumptions they made and the beliefs they had about children's science questions and how to deal with them.

3.3 Study Participants

The participants who volunteered to take part in this study were teachers and children in Catholic primary schools in an Australian capital city. One hundred and forty-five teachers of science in sixteen primary schools volunteered to participate. The sixteen schools involved in the study were located across a large geographical distance in the archdiocese of the city involved in the study. Six teachers in the group of 145 teachers also volunteered to be part of a study group as did their Year 6 students.

The teachers in these Catholic schools were accessible to the researcher and were chosen because they had recently participated in system-wide science professional learning. The professional learning undertaken by teachers in Catholic schools was part of a process of Consistency of Teacher Judgement in 2009 and 2010. Teachers had planned, taught and assessed nominated science strands (Earth and Beyond; Life and Living; Energy and Change) and the skills of working scientifically. Five hundred teachers had each attended a one-day workshop and five schools were part of a group that had lesson demonstrations and feedback sessions conducted at their schools. The objective of the professional learning was to up-skill teachers in using an inquiry approach to teaching using hands-on activities to develop the children's understandings. Consequently, the teachers were afforded opportunities to reflect on their teaching practices and develop ideas about science teaching to share in this study.

Year Six classes were the focus of this study because by the time children are in Year Six it is expected that they are able to formulate scientific questions according MYCEETA's National Scientific Literacy Progress Map (Department of Education, Science and Training, 2004). Similarly, Sharp and Kuerbis (2005) maintain that children in the upper primary years of schooling (currently Years 6 and 7) are capable of learning about solar system concepts, unlike their younger peers who may not be developmentally able to understand a complex sun-earth-moon relationship.

In 2009, when data were collected for this study, teachers used a state developed curriculum that focused on a two year band of core learning outcomes in Years Six and Seven, in which children explored changes that occurred in the solar system (QSA Year 1-10 Science Syllabus, 1999). This study focuses on that level of schooling and the concepts identified in that syllabus.

3.3.1 Consent and Process of Data Collection from Study Participants

This research study was composed of two stages. Stage One was a teacher questionnaire distributed to two hundred and ninety-one teachers. One hundred and forty-five teachers agreed to be involved in this part of the study by completing and returning the questionnaire.

3.3.1.1 Stage One Participants

Information about the purpose of the study and the requirements for participation were sent to the principals of 133 schools (Appendix I). Sixteen schools consented to be involved in the study. The questionnaire was distributed to 291 primary school teachers in those sixteen Catholic primary schools who agreed to take part in the study (Appendix A). Teachers of the Preparatory Year to teachers of Year Seven were included so a comparison of answers could be made between teachers of different year levels. The inclusion of all teachers allowed for broad background data to be collected and contrasted with the focused data from teacher interviews. Information letters for teachers were distributed by the Curriculum Support Teachers in schools (Appendix I). The Curriculum Support Teachers placed the letters in staff mail boxes. Consent forms and questionnaires were distributed at a staff meeting (Appendix I). The questionnaires were completed during a half hour scheduled staff meeting, so teachers could take time to think about their responses. Participation was anonymous and voluntary, teachers who did not wish to participate, or those who did not teach a class, left early. When completed, the questionnaires were placed into a drop box so no identification of the teachers was possible. Then the Curriculum Support Teachers returned the collected questionnaires to the researcher. The researcher was not present during the collection of these data.

Stage Two involved six volunteer Year Six teachers and their classes in three events: (i) Elicitation of children's science questions in response to stimulus pictures; (ii) Observations of the teacher's responses to the children's questions; and (iii) Individual interviews with each teacher.

3.3.1.2 Stage Two Participants

Six teachers (Teacher 1, Teacher 2, Teacher 3, Teacher 4, Teacher 5 and Teacher 6) volunteered to be further involved in Stage Two of the research project. These teachers all taught Year Six classes. Each teacher was posted an information letter and a consent form to sign. They were also emailed an information letter and consent form for parents and an information letter for the children (Appendix I). The schools copied the number of letters needed and distributed them through homework folders to parents and students. The signed consent forms were then returned to the researcher.

3.4 Stage One Method

3.4.1 Structure of the Questionnaire

The questionnaire used in Stage One was developed for this study (Appendix A). It was a paper and pen instrument containing twelve questions. Eleven questions were multiple-choice and one sought an optional comment from the respondents. The answers required on the questionnaire could be completed with ticks/checks to avoid teachers becoming uninterested or tired. The only question requiring a written answer was optional. In the concluding section of the questionnaire teachers were invited to declare if they were interested in being further involved in the study. The questionnaire was divided into two parts.

Part 1 of the questionnaire focused on teachers' planned responses to children's science questions. It included six multiple-choice questions about the science they taught, how they taught it, their initial responses to children's science questions and issues they thought could arise for them from children asking science questions. This was necessary to get the perceptions of teachers who represented a variety of levels of enthusiasm for teaching science and also competency in teaching science. The data collected contributed towards answering Research Question 2: What do teachers consider to be suitable responses to children's science questions? And Research Question 4: What do teachers identify as issues with responding to children's science questions?

Part 2 of the questionnaire consisted of five multiple-choice questions designed to examine teachers' science background knowledge of lunar phenomena. The five multiple-choice questions corresponded with Harlen's (1996) description of 'Complex questions' and were taken from a study of children's questions about the Moon (Spargo & Enderstein, 1997) (Appendix B). The five possible answer choices to the children's questions on the questionnaire (Part 2) came from a study by Kallery and Psillos (2001). Their research proposed five categories of teacher answers to children's science questions. Thus, the answers for each multiple-choice question in Part 2 were based on teacher's answers from a previous study. One of the choices was a full, correct scientific explanation and another was an alternative conception which was chosen from commonly held alternative conceptions reported in the literature (Skamp, 1998; Nuffield Primary Science, 1997). Another two were an incomplete answer that contained only part of the full correct scientific explanation and one answer with anthropomorphic views where an inert object was described as conscious or living. The final answer choice was "I don't know". "I don't know" was included so the teachers could indicate they did not have that knowledge rather than guessing from the other options. This section of the questionnaire was required to explore the science background knowledge of a wide variety of teachers with different enthusiasm levels for science teaching and varying exposure to professional learning. A lack of science background knowledge has been reported in Australian research so testing teachers' knowledge of scientific concepts was important to clarify if teachers were still struggling with this issue and if it effected their ability to deal with children's science questions. The data collected contributed towards answering Research Question 3: What influence do science background knowledge and pedagogical content knowledge have on how teachers deal with children's questions?

3.5 Stage Two Method

Stage Two of the data gathering had three events, namely: (i) Elicitation of children's science questions in response to stimulus pictures; (ii) Observations of the teacher's responses to the children's questions; and (iii) Individual interviews with each teacher .

3.5.1 Event 1: Elicitation of Children's Science Questions

In this event, the researcher observed Teachers 1, 2, 3, 4, and 6 gathering children's science questions from each of their classes in separate sessions held in their own classrooms. The children's science questions were elicited and collected using a process described by Spargo and Enderstein (1997). The process involved the class being shown a series of three large colour photographs of the Moon (Appendix C). The photographs portrayed a partially illuminated Moon, an astronaut walking on the Moon and Moon craters. These photographs had the potential to highlight a range of science concepts for children. The children could ask questions about phenomena, such as: the effects of gravity on the Moon, phases of the Moon, space travel, the relationship between the Sun, the Earth and the Moon and how craters are formed.

The photographs were shown one at a time. The children were then asked to identify features of the picture. Following this, the children were invited to pose questions inspired by the picture. The questions were recorded verbatim on a white board (Classes 1, 4, 5 & 6) or on a computer attached to a data projector (Classes 2 & 3) so that all the children could see the questions being asked. The second and third pictures were introduced at the teacher's discretion. The researcher collected the children's questions for further analysis using a photograph of the questions written on the whiteboard (Classes 1, 4, 5 & 6) or a print-out of the computer document produced by the teacher (Classes 2 & 3).

The researcher elicited the questions from Class 5. Teacher 5 was feeling unwell on the day of the researcher's visit but did not want to postpone the data gathering as she had scheduled the session into a busy week. The children's questions were the focus of this event, not how the teacher gathered them, so the researcher offered to gather the children's questions in the teacher's place allowing the teacher to sit and watch instead of pacing the room and writing on the board. The researcher had been present in the five other classrooms when Teachers 1, 2, 3, 4 and 6 elicited the questions, so the researcher used the same process with Class 5. It's possible that the children increased their efforts to ask interesting questions because the researcher was gathering them, however, in the other five classrooms the researcher was present during the question gathering and the children should have been aware that their teachers were clearly following the researcher's directions. As a consequence, they too could have increased their questioning efforts, making all six classes comparable. Eliciting the children's science questions contributed to answering Research Question 1: What types of science questions do children ask in response to stimulus pictures of lunar phenomena?

3.5.2 Event 2: Teachers' Responses to Children's Science Questions, as Observed by the Researcher

After gathering the children's science questions, four of the six teachers (Teachers 1, 2, 3 and 4) who volunteered to be part of the study group, were observed responding to the questions they had collected from their classes. Two of the teachers in the study group (Teachers 5 and 6) chose not to take part in this part of the research. Teacher 5 was feeling unwell and Teacher 6 could not spare the time to continue on with the responses to the children's questions.

In each of the four classrooms Teachers 1, 2, 3 and 4 were observed by the researcher responding to their children's questions. The teachers were encouraged by the researcher to demonstrate their normal pedagogical practice by 'doing what they would usually do'. The questions were displayed on a whiteboard or a screen for the teacher and children to see. Each teacher stood at the front of the class so the children could see the questions and the teacher could see both the questions and the children. The researcher noted how the teachers interacted with the children and dealt with the questions presented on the board (Teachers 1, 4, 5 & 6) or screen (Teachers 2 & 3).

The teacher observations contributed to answering Research Question 2: What do teachers consider to be suitable responses to children's science questions? And Research Question 3: What influence do science background knowledge and pedagogical content knowledge have on how teachers deal with children's questions?

3.5.3 Event 3: Interviews with Teachers

All of the six teachers volunteered to be further involved in the research by participating in individual interviews with the researcher. The researcher posed questions to each teacher (Appendix D) and discussed their answers with them over a period of approximately a half an hour. This semi-structured interview style was chosen to permit teachers to explore areas of interest to them. Semi-structured interviews also permitted a more informal approach to put the teachers at ease. The interview discussions focused on the topics of categorising of children's science questions, teachers' understanding of lunar concepts and issues related to responding to children's science questions.

Interview topic: categorising children's science questions

During the interviews with the researcher the six teachers were introduced to Harlen's (2001) categories of children's science questions. Harlen's categories were derived from teachers' responses to children's questions. These categories were:

1. Questions that were an expression of wonder or interest;
2. Philosophical questions;
3. Requests for simple facts;

4. Complex questions;
5. Investigable questions.

Each teacher viewed Harlen's question categories and identified questions posed by the children in their classes that corresponded with Harlen's categories. The teachers were then invited to identify which of the children's questions could be investigated with hands-on materials, for example, the use of a sand tray and a variety of balls to investigate craters. Some of the questions were identified as suitable to explore with models, such as a lamp or torch and polystyrene balls on sticks to represent the Earth and Moon in modelling the phases of the Moon. The remainder were considered questions more appropriately answered with a scientific explanation.

Interview topic: understanding of lunar concepts

The understanding of lunar concepts that were held by each of the six teachers was explored during respective discussions with the researcher. Each teacher viewed the three stimulus pictures of the Moon that had been used in the question elicitation event with the children in their classroom (Appendix C) and was invited to share his or her understanding of the science concepts represented by the picture. Then each teacher explained his or her understanding of how phases of the Moon occur and why only one face of the Moon can be viewed from Earth. If the teacher's explanation indicated that he or she held an alternative conception then the researcher explained the current scientific view to them. Each teacher was then asked to examine the list of questions their class posed and to identify alternative conceptions the children might have revealed.

Interview topic: issues with responding to children's science questions

During the interview, following the discussion about lunar concepts and alternative conceptions, each of the teachers was asked if the children's questions created issues for them in the classroom. The issues nominated by the teachers could have been as a result of formulating responses to the children's questions. The stated issues were discussed with the researcher.

Discussions between the researcher and each teacher were recorded in a digital audio recording and later transcribed by the researcher. The teacher interviews contributed to answering Research Question 2: What do teachers consider to be suitable responses to children's science questions? And Research Question 3: What influence do science background knowledge and pedagogical content knowledge have on how teachers deal with children's questions? And Research Question 4: What do teachers identify as issues with responding to children's science questions?

3.6 Data analysis

3.6.1 Teacher Questionnaire

Teacher's responses to questions in Part 1 and Part 2 of the questionnaire were analysed using non-parametric tests as data were categorical and did not meet the stringent requirements of parametric statistical analysis (Pallant, 2007). A Kruskal-Wallis Test was used to explore the frequency distribution of categories of questions between the classes. This test is used to compare more than two samples. A significant result confirms that at least one of the samples is different from the others. In the Kruskal-Wallis Test it is assumed that the classes are of unequal size.

The issues that children's questions raise for the teacher in Question 6 of part 1 of the questionnaire were compared to the factors that limit the teaching of science according to four categories suggested by Rennie et al. (2001): i) a lack of science background knowledge; ii) the issue of an overloaded school curriculum, which limits the time available for teaching science; iii) a lack of resources, and; iv) inadequate time for preparing to teach science lessons. The 2001 report was based on a nationwide survey of teachers and was used as a comparison in this study because it reported on Australian primary school teachers and nothing on it's scale has been published since. The issues reported referred to general concerns with teaching science, rather than those related to children's questions but were still relevant.

Teachers' choices of responses to children's science questions in Part 2 of the questionnaire (Appendix A) were categorized using Watts, Alsop et al., (1997) five types of 'traditional teacher options' to respond to children's science questions. The types of responses to children's questions reported in Watts, Alsop et al., (1997) have been used as a point of reference in more recent published articles reviewing the literature about teachers' responses to children's science questions (Chin & Osborne, 2008). Their inclusion in this research created an opportunity in this study to examine the changes in teachers' responses over fifteen years.

3.6.2 Children's Science Questions

The children's science questions were organized and grouped into three categories by the researcher based on the teacher's possible responses. The researcher devised categories based on the following criteria:

i. Questions that began with ‘Is, Can, Does, Are, Could, Would and Has’ were categorized as questions that could be answered with a Yes or No response and were called Yes/No Questions.
ii. If the answer to a question was a name, a number or a short statement then it was categorized as a Short Answer Question. Many of the answers to Short Answer Questions could have been about dates, sizes, times, ages, names and distances.
iii. Questions starting with “Why?” or “How come?” that needed an explanation to answer them or were suitable for hands-on investigation or further research were categorized as Complex Questions.

The three categories were based on possible teacher responses, as were categories identified by Spargo and Enderstein (1997) and Harlen (2001). Consequently, the categories of questions collected in this study were compared to those from Spargo and Enderstein (1997) and Harlen (2001). The children’s questions were also examined across the six classes to determine similarities amongst the questions and these similarities and differences were compared to the children’s questions in Spargo and Enderstein (1997) (Appendix B).

3.6.3 Teacher Interviews and observations

Information was gathered from interviews and observations of Teachers 1, 2, 3, 4, 5, and 6. These data were used in conjunction with the questionnaire results to add individual perceptions to the research. Also, coding emerged from themes in the data. These codes were used to analyse interviews and observations of Teachers 1, 3, 4 and 5. These teachers were chosen because they represented good examples of elements of the research purpose. Teacher 5 was included in the descriptions even though she didn’t participate in the follow-up lesson where teachers responded to the children’s questions. This was because her interview was different to the other teachers’ interviews and her class was unique in this study. Teacher 5 had opinions about how children learn and how science was taught and the researcher believed the interview warranted inclusion because it would add to the discussion of the research questions as an in-depth exploration of a teacher and class with a unique situation. Teachers involved in collecting and responding to children’s science questions and discussing their views about children’s questions and their responses provide insight into the focus of research of this study. The interviews in particular provide a context for understanding the teachers’ responses on the questionnaires.

The coding provided headings that were used for comparison. The headings were: the school context, the process for collecting questions, the type of questions the children asked, the teachers responses to the questions, the teachers' views of knowledge and how that influenced their view of learning, their understanding of lunar concepts, their recognition of alternative conceptions and questions that were suitable for hands-on investigations and their pedagogical content knowledge. The description of interviews and observations of Teachers 1, 3, 4 and 5 added teachers' individual perceptions to the body of quantitative data in this study (Appendix E).

Individual teacher's initial responses to children's science questions during the classroom observations were compared to corresponding teacher's ideas in Part 1 of the questionnaire. In the questionnaire teachers identified how they believed they would respond to science questions in the classroom. Like the questionnaire responses, these observed responses were compared for similarities and differences to five types of 'traditional teacher options' to respond to children's science questions suggested by Watts, Alsop et al., (1997).

In individual interviews teachers highlighted issues they had with responding to children's science questions. These were compared to the perceived issues that teachers identified in Part 1 of the questionnaire. Teachers were also asked to give 'on-the-spot' explanations of lunar concepts in the individual interviews. Their answers were compared to survey responses in Part 2 of the questionnaire.

3.7 Research Questions and Related Data Set

Data gathered in this study relate directly to the research questions and the research focus of children's science questions as a resource for teaching and learning. Two stages of data gathering consisting of teacher questionnaires and three events with a study group provided information that contributed to answering the research questions. The research questions and related data sets as described in 3.4 and 3.5 are, in summary: Questionnaires (Research Questions 2, 3 & 4); Elicitation of children's science questions (Research Question 1); Teacher observations (Research Questions 2 & 3); Teacher interviews (Research Questions 2, 3 & 4).

In addition, Teachers 1, 3, 4 and 5 were described and compared to synthesize information and views. Data were analysed about (i) teachers' knowledge of science concepts, (ii) the questions children pose, and (iii) the pedagogical practices of teachers of science. Chapter Four presents the findings from the two stages of data gathering in this study.

CHAPTER FOUR: RESULTS

Chapter Four begins with a description of the participants in both stages of this study. Data gathered from teacher questionnaires, elicitation of children's science questions, teacher interviews and observations of teachers' responses to children's questions are described in the subsequent sections. Each data set is described in relation to the research question that it assists in answering.

4.1 Study Participants

5.1.1 Respondents to Questionnaire

The Catholic Education Centre services 133 schools across a geographical area in a metropolitan and rural area of the state in which the study was conducted. Sixteen of the 133 schools participated in the questionnaire with all of their teaching staff, from the Preparatory Year to Year 7.

Two hundred and ninety one questionnaires were distributed to the 16 schools and 145 completed questionnaires were returned. Of the 145 teachers who returned questionnaires 18 were males (12%), 125 were females (86%), and two respondents did not indicate gender (2%). Thus, most of the teachers involved in the study were female.

When the teaching experience of the participants was investigated, 40% had graduated as teachers less than 10 years ago, 10% had ten to twenty years teaching experience and 31% had graduated more than 20 years ago (Table 2). Nineteen percent did not indicate length of teaching experience (Table 2). Thus, the largest group of respondents was teachers with less than 10 years teaching experience.

Table 2

Questionnaire Respondents' Years of Teaching Experience

Years since qualifying as a teacher	Number of teachers	Percentage of teachers (%)
< 10 years	58	40
10-20 years	15	10
> 20 years	45	31
not indicated	*27*	*19*
TOTAL	145	100

When the number and percentage of the 145 teachers was examined for the previous year's teaching level 16% taught Prep, Year One, Year Four and Year Six (Table 3). Eleven percent taught Year Three, 10% taught Year Two, 9% taught Year Five and 6% taught Year Seven (Table 3). Thus, teachers from all of the primary year levels were represented in this research.

Table 3

Year Levels taught the Previous Year by the Questionnaire Respondents

Year levels	Number of teachers	Percentage (%) of teachers
Prep	22	16
1	23	16
2	14	10
3	15	11
4	22	16
5	12	9
6	23	16
7	9	6
First year of teaching or missing data	*5*	
TOTAL	145	100%

In summary, the questionnaire study participants were mostly female (86%). There were two larger groups within the sample of questionnaire respondents: teachers with up to ten years experience; and very experienced teachers who had been teaching for more than 20 years. The greatest number of respondents were teachers who had less than ten years experience. The year levels taught by the 145 teachers spanned the Prep to Year 7 range of the primary school years.

5.1.2 Study Group of Six Classes and their Six Teachers

The study group was comprised of six Year 6 classes and their teachers. The combined classes consisted of 112 children. The children were all in Year Six and were based in four schools. Classes 1, 2 and 3 were from the same school, which was a large coastal college. Classes 4 and 5 were from different, small, inner city schools. Class 6 was from a small suburban school. Five of the six teachers were female and one was male. All of the teachers had less than ten years of teaching experience (Table 4).

Table 4

Characteristics of Study Group Classes and Teachers

Class	Number of children	School	Characteristics of school	Teacher study group number	Teacher gender	Number of years of teaching experience
1	21	1	coastal P-12 college	1	female	4
2	24	1	coastal P-12 college	2	male	2
3	22	1	coastal P-12 college	3	female	4
4	16	2	Inner city school, high socio economic area	4	female	>1
5	14	3	Inner city school, high numbers of special needs, high numbers of new arrival refugees	5	female	7
6	15	4	Suburban school	6	female	8

Class 1, Class 2, Class 3

Class 1, 2 and 3 represented the entire cohort of Year Six children at one school. The children were predominantly of European heritage. The classrooms in the school were laid out in a hub with grassy areas and walkways between Year levels. Each of the three classrooms had computers available for student use. All three classes had studied a unit of work earlier in the year about space science. The unit focused on the exploration of space.

Class 1 consisted of twenty-four Year Six children. The parents of twenty-one of the children consented to their participation in this study. Their teacher was female (Teacher 1) and had been teaching for four years. In the previous school year she had also taught Year Six. This teacher was undertaking further study in a Master of Teacher Librarianship.

Class 2 consisted of twenty-seven Year Six children. The parents of twenty-four of the children consented to their participation in this study. Their teacher was male (Teacher 2) and had been teaching for two years. He had also taught Year Six in the previous year. This teacher had worked with children in another career prior to becoming a teacher and was considering a further career change in the coming twelve months.

Class 3 consisted of twenty-six children. The parents of twenty-two of the children consented to their participation in this study. Their teacher was female (Teacher 3) that had four years teaching experience. She had also taught Year Six in the previous year. Teacher 3 recognized her students as being knowledgeable about science topics.

Class 4

Class 4 was situated in a middle-class inner-city school (School 2) with children of predominately European heritage. Class 4 was in a room adjoining another Year Six classroom and had ICT (Information Communication Technology) in the form of computers around the edge of the room for student use. The class had studied a unit of work earlier in the year about space science. Class 4 consisted of sixteen children and their parents consented to their participation in this study. They had a female graduate teacher (Teacher 4). Her deputy principal portrayed her as a capable new teacher who had taken easily to teaching. She presented as a serious and confident person.

Class 5

Class 5 was situated in a small inner-city school (School 3). The school had a Special Education unit for children verified with disabilities and disorders and had also catered for ‘new arrival’ refugees for many years. There were seven children in this class who came to Australia from refugee camps in Egypt as ‘new arrivals’ and had less formal schooling than their peers. Class 5 had not studied space science concepts within the past year. Class 5 consisted of seventeen children that represented the Year Six cohort at the school. The parents of fourteen of the children consented to their participation in this study. They had a mature female teacher (Teacher 5) who had seven years teaching experience and had come from another career into teaching. In the previous year she had taught Year Four. Three quarters of the class spoke English as a second language so their teacher focused on introducing unfamiliar ideas to the children in a concrete way and regularly taught science.

Class 6

Class 6 was situated in a small suburban primary school (School 4). This was an old school in a high traffic area with a multi-cultural student population. They had an adjoining ICT room with several computers and a window that provided a view to the classroom. This class had not studied space science concepts within the past year. Class 6 consisted of nineteen children. The parents of fifteen of the children consented to their participation in this study. They had a female teacher (Teacher 6) with eight years teaching experience. In the previous year she also taught Year Six. Teacher 6 described her class as a very ‘social’ group who were very interested in each other. Teacher 6 regularly taught science and had a keen interest in curriculum as the staff Curriculum Support Teacher.

Thus, the study group were representative of a range of school sizes, cultural heritage, socio-economic status and geographic locations and the teachers represented the full range of experience with graduates to teachers with several years of experience.

4.2 Research Question 1: What types of science questions do children ask in response to stimulus pictures of lunar phenomena?

4.2.1 Data Set: Children's Science Questions

The children in the six classes of the study group asked 75 similar science questions about the Moon (Appendix G). Every class asked a question about the bumpy surface of the Moon and about the astronaut's suit (Table 5). All but one of the six classes asked questions about how the phases of the Moon occur and why the Moon appears to be white at times and yellow or grey at others (Table 5). Five classes also asked about life on the Moon, how astronauts move on the Moon and how many astronauts have been to the Moon (Table 5). Four of the six classes asked questions about the shape or surface of the Moon, the depth of craters, the reflected sunlight on the Moon, and the blackness of space (Table 5).

In individual classrooms some of the children repeated other children's questions using different words. These repetitious questions occurred as children listened to each other's questions. The repetitions are not included in the class lists of questions (Appendix G). Some children asked nonsense questions, such as 'Could you paint the Moon orange?' and 'What do astronauts carry in their man-bags?'. These nonsense questions came from groups of children in Class 2 (Appendix G).

Table 5

Frequency of Moon Questions Asked in Six Classes by Year Six students

Frequency	Questions
6	Why is it so bumpy?
	What is the suit made of and how much would it cost?
5	How does the Moon get all its parts?
	Are there any living things on the Moon?
	How high can you jump on the Moon?
	How many people have been on the Moon?
	Why does the Moon look different colours?
4	How does the Moon light up?
	Why is the Moon round?
	Is there water on the Moon?
	How deep are the craters?
	What is the Moon made of?
	Why is the night sky black?
3	Why do big rocks hit the Moon?
	Is it cold on the Moon?
	How old is the Moon?
	Why do people visit the Moon?
2	What would happen if it blew up?

The researcher coded the 329 science questions asked by children in the six classes into one of three categories: 'Yes/No Questions'; 'Short Answer Questions' and; 'Complex Questions'. Each question only appeared in one category, for example, a question requiring a short but complex scientific explanation was categorized as a Complex Question. The categories were defined as:

i) Yes/No Questions: questions that required a response from teachers of a "Yes" or a "No". For example, 'Could there be life on the Moon?' or ''Is there any water on the Moon?'

ii) *Short Answer Questions*: questions that required a brief reply. For example, 'When did the first person land on the Moon?' or 'What is the [astronaut's] suit made of?'

iii) *Complex Questions:* questions that required a detailed scientific explanation, research from a secondary source, or an investigation. For example, 'What makes the different stages [phases of the Moon]?' or 'Why is the Moon round?'

When the three categories of questions were considered, 54% of the 329 questions asked by the 112 children were Short Answer Questions (Table 6). Twenty-seven percent were Yes/No Questions and 19% were Complex Questions.

Table 6

Number and Percentages of Yes/No, Short Answer and Complex Questions from each of the Six Study Group Classes

		Question categories		
Class	Total number of questions	Yes/No	Short Answer	Complex
2	95	47 (49%)	43 (45%)	6 (6%)
3	71	16 (22%)	29 (41%)	26 (37%)
6	54	13 (24%)	41 (76%)	0 (0%)
1	43	8 (19%)	23 (53%)	12 (28%)
5	38	1 (3%)	23 (60%)	14 (37%)
4	28	4 (14%)	18 (64%)	6 (22%)
Total	329	89 (27%)	177 (54%)	64 (19%)

The question categories were not asked consistently across the six classes. Class 2 and 6 asked fewer Complex Questions than the other classes (6% and 0% respectively) and more Yes/No Questions (49% and 24% respectively) (Table 6). Class 3 and Class 5 asked the highest percentage of Complex Questions (37%) (Table 6). Only one Yes/No Question was asked by Class 5. Thus, the percentage of questions in each category varied in the individual classes and Short Answer Questions were the most frequently asked by children in this study as a whole.

The distribution of categories of questions asked in all classes shows that Short Answer Questions were most frequent. When a Kruskal-Wallis Test was used to explore the frequency distribution a statistically significant difference in the number of questions in each of the three categories across the six classes was revealed (x^2 (2, $^{n=18}$) = 9.00, p = .011). The category of Short Answer Questions was found to have a higher median value (Md = 26.00) than both the category of Yes/No Questions (Md = 10.50) and the category of Complex Questions (Md = 9.00). This means that the six classes asked more Short Answer Questions than Yes/No or Complex Questions.

When a Mann-Whitney U Test was used to explore the relationship between the number of Yes/No Questions and Short Answer Questions significant differences were revealed (U = 1, z = -2.73, p = .004, r = 0.79). Significant differences between the Short Answer Questions and Complex Questions (U = 3, z = -2.41, p = .015, r = 0.70) were also revealed for the sample. These results indicate the difference between the number of Short Answer Questions and other types of questions was statistically significant.

The most common category of questions, Short Answer Questions, required many answers that were numerical. Forty-one percent of the total 177 Short Answer Questions required a numerical answer, such as a date, a time or a distance (Table 7).

Table 7
Frequency of Short Answer Questions Requiring a Numerical Answer

CLASS	Number of Questions	Number of Questions requiring a numerical answer
2	43	25 (58%)
6	41	22 (54%)
4	18	9 (50%)
3	29	12 (41%)
1	23	3 (13%)
5	23	2 (9%)
Total	177	73 (41%)

Class 2 and Class 6 asked more Short Answer Questions than the other study group classes and more than half of those questions (58% and 54% respectively) could be answered with a number (Table 7). The remaining study group classes asked between 2 and 12 (9% and 41%) Short Answer Questions that could be answered with a number (Table 7).

In summary, in this study it was found that more than half of the questions posed by the six classes were Short Answer Questions, that is, questions requiring a short and often numerical answer. Also, the children asked the same type of questions in the six classes but the number of times they were asked differed.

4.3 Research Question 2: What do teachers consider to be suitable responses to children's science questions?

Two sources of data were analysed to address this research question. The first data source was three questions from Part 1 of the questionnaire that investigated teachers' views about how they respond to children's questions in their own classroom and their perceptions of children's question-asking behaviours. The second data source was based on an analysis of qualitative data from the interviews with the six study group teachers.

4.3.1 Data Set: Questionnaire, Part 1

4.3.1.1 Initial Responses to Children's Questions – Respond or Ignore

Most of the 145 teachers (93%) who completed the questionnaire indicated that they would always respond to the children's questions rather than ignore them (Table 8). Responses, in this instance, were giving a brief explanation. They indicated this by choosing category E at Question 3 on Part 1 of the questionnaire for 'Respond' or category F at Question 3 on Part 1 of the questionnaire for 'Ignore' (Appendix A). Only 4% of the 145 teachers stated they would ignore the question at that time for the sake of keeping the lesson moving and not allow a question to be a distraction to a lesson.

Table 8

Categories of Responses from 145 Teachers to Ten Children's Moon Questions

Categories of responses	Teachers' responses	Valid percent (%)
RESPOND	"Give a brief explanation"	93
IGNORE	"Keep the lesson moving and don't answer the question at that time"	4
Question not responded to		3

4.3.1.2 Typical Teacher Responses – Investigation or Re-direction

When typical teacher responses to children's questions were considered both investigation and re-direction were identified. Investigation includes both hands-on investigation with materials, exploring the concept through models and researching information from sources such as the Internet and books. Most teachers (60%) indicated that they would respond both ways at different times (Table 9). They did this by choosing categories A and D from Question 3 in Part 1 of the questionnaire for 'Investigation' or categories B, C, F for 'Re-direction'. The choices for re-direction included doing further research, asking the class to answer the question and keeping the lesson moving and not answering the question at that time.

Table 9

Percentage and Types of Typical Responses from 145 Teachers

Types of responses	Percentage (%)
Investigation	22
Re-direction	12
Either	60
missing	*6*

4.3.1.3 Investigations with Hands-on Materials

The 145 teachers who responded to the questionnaire identified questions from a list of ten that could be suitable for investigation with children. The ten questions were adapted from children's questions in Spargo and Enderstein's study (1997) (Appendix B). Questions 1 to 6 were the most frequently chosen by teachers and Questions 7, 8, 9 and 10 were chosen less frequently (Figure 1).

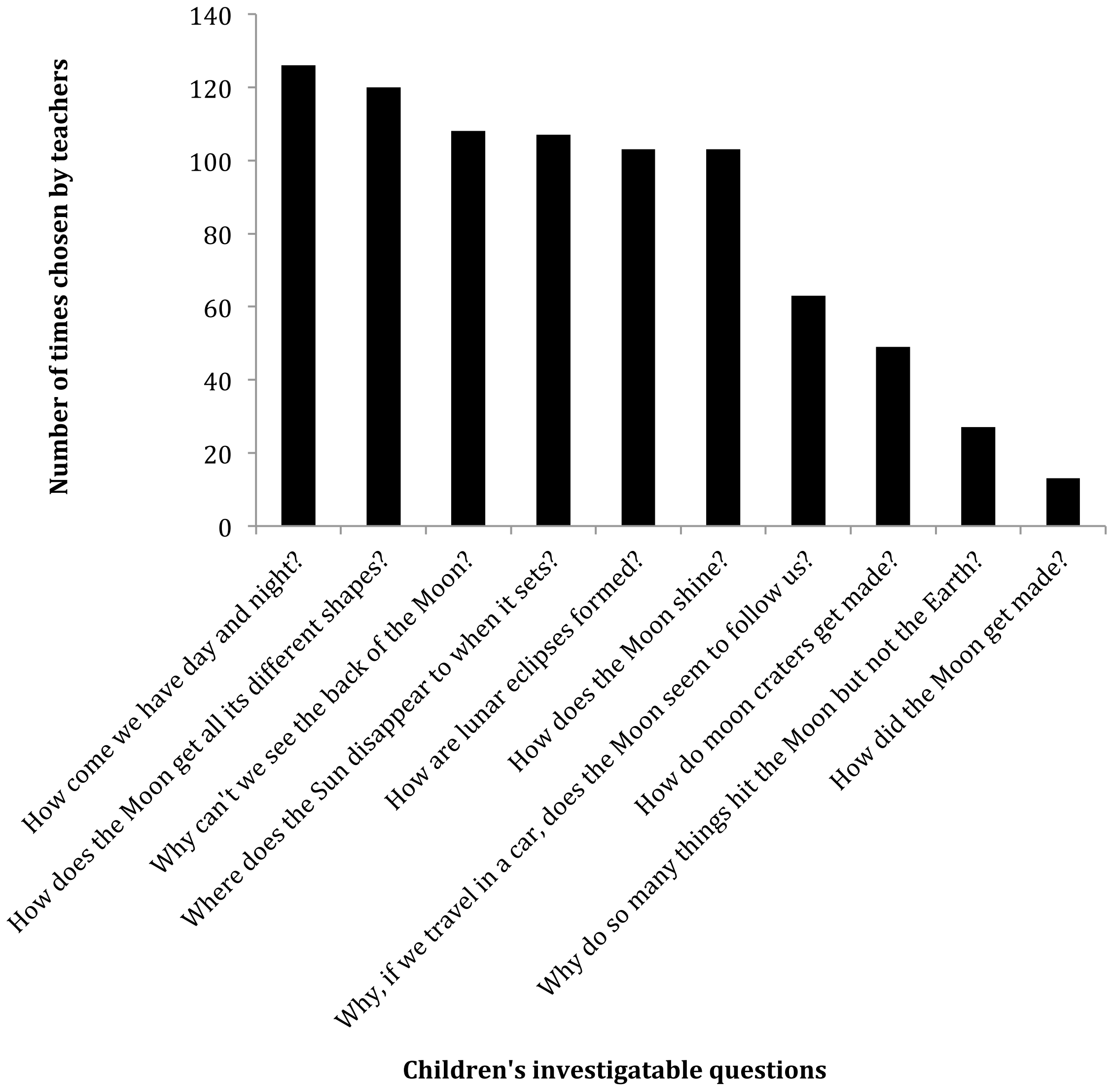


Figure 2. The number of times each of ten children's questions about lunar phenomena was identified as investigatable by the 145 teachers who responded to the questionnaire.

The six most frequently chosen questions are evident in the frequency distribution (Figure 2). Thus, teachers could clearly identify a method for investigating six of the questions but they were unsure about how to investigate a further four questions with the children.

In summary, 93% of 145 teachers identified 'giving a brief explanation' as a response they intended using for the children's questions. Sixty percent of 145 teachers indicated they would use both investigations and re-direction of the children's questions as a response. Teachers identified 6 of 10 questions as suitable to investigate with materials. These six questions were about light in relation to the Sun, Earth and Moon and the other four were not. Perhaps the teachers' choices were related to the concepts they felt comfortable with, such as, investigating light-related concepts rather than forces or perception.

4.3.2 Data Set: (Qualitative) Interviews with Teachers

4.3.2.1 Investigation with Materials or Exploration with Models

During individual interviews with the researcher all six study group teachers identified questions that would be best responded to with a hands-on investigation from the list of questions posed by each of their classes. The teachers explained that they would also use models to investigate space science concepts with the children. All six of the study group teachers explained that craters on the Moon could be investigated with objects varying in size and shape dropped from a height into a shallow tub of granules (such as cat litter) or by using online interactive digital resources, such as *Learning Objects* from the Learning Federation which are available for each education system through portals such as Education Services Australia or Scootle. Four of the six teachers described how they would use models to explore the phases of the Moon with their classes and two of the teachers were interested in investigating the astronaut's suit.

Teacher 1

Teacher 1 named several concepts arising from the children's questions that would be best answered through investigation with materials or exploration with models in her classroom. They were: how craters are formed; where is the moon in space (using a model); the size of the Moon in relation to the Earth and the Sun; the phases of the Moon (using a torch and ball, as a model) and why we always see the same side of the Moon (Appendix F, Teacher 1).

Teacher 2

Teacher 2 indicated he would help the children investigate questions about the phases of the Moon and the surface of the Moon with materials and models. He also identified 'Why does the Moon light up at night?' as a question that could be explored with a model to help the children to understand the phases of the Moon and how they occur (Appendix F, Teacher 2).

Teacher 3

Teacher 3 named four concepts from the children's questions as suitable for hands-on investigations. They were: phases of the Moon; meteors (sic) with a tub of a dust-like substance and several different sized and shaped objects; the difference between decomposing on Earth and on the Moon; past and present day astronaut's suits – a comparison (Appendix

F, Teacher 3). The final two ideas appear to be more suited to research from secondary sources than a hands-on investigation with the children.

Teacher 4

Teacher 4 explained that she would help the children to do investigations with hands-on materials to answer questions about craters, dark spots on the Moon, shadows and the astronaut's suit (Appendix F, Teacher 4). It would be difficult to do investigations to answer questions about the space suit if the teacher does not have access to one, so this would be a concept for research rather than an investigation with materials. Teacher 4 also stated that she would not spend a lot of class time on some of the questions but would just give a brief answer to them, such as: Who was the second person to go to the moon? (Appendix F, Teacher 4).

Teacher 5

The researcher asked Teacher 5 how she would answer one of the children's Complex Questions from her class. Despite asking directly for an answer (which to most would imply a scientific explanation) Teacher 5's immediate reply was to give a brief explanation and then design an investigation.

> R: Let's look at why the craters have a circular shape. If you got that one [question] in class and it put you on the spot, if you felt compelled to answer, what sort of answer would you give to that?
>
> T: I would talk to them about the impact of something heavy going into something else and I would probably very quickly generate a quick experiment and they could test that. We could do it using sugar, dirt, rice or a lot of things. If you dropped something into any of those depending on the shape you would be able to test it very quickly and be able to get a visual of the impact of the site and I think once the kids see it they would know it. (Appendix E, Teacher 5).

She describes a teacher demonstration rather than an investigation, but does clarify that 'they could test that' (Appendix F, Teacher 5).

Teacher 6

Teacher 6 indicated that she would help the children to investigate questions about craters with hands-on materials. She stated she would use models of the Moon to teach the phases of the Moon with paper-mache or digital online models (Appendix F, Teacher 6). She described how she would put the children into working pairs, have them research the answer to some questions and then share five things they found out about the concept with the whole class (Appendix F, Teacher 6). She also said she would give a brief explanation to some of the children's Short Answer Questions (Appendix F, Teacher 6).

All of the study group teachers chose questions about the formation of moon craters as suitable to investigate with hands-on materials and yet this was an unpopular choice among the 145 questionnaire respondents. Questions about the interactions between the Sun, Earth and Moon were chosen twice as frequently on the questionnaire. Perhaps the teachers who chose from a list of ten questions on the questionnaire became focused on questions that could be explored using a light source and balls, as the six most frequently chosen questions were suitable for this type of investigation with models and the least frequently chosen questions were not. Balls and a light source are a very popular way to model the phases of the Moon and interactions between the Sun, Earth and Moon. They are also featured as a resource in learning activities in the Primary**Connections** program in the upper primary stage curriculum unit 'Earth's Place in Space' and as such, would be familiar to many teachers.

In summary, teachers indicated that investigating with hands-on materials was important to do in the classroom and they could also identify some questions suitable for investigation with the children. Six children's questions stood out to teachers as suitable for hands-on investigation. Ninety-three percent of teachers responding to the questionnaire indicated that they would respond to the children's questions by giving a brief explanation, rather than ignore them. Although the 145 teachers indicated that they appreciated the importance and suitability of hands-on investigations they overwhelmingly intended to give brief explanations in response to the children's science questions in their classroom. However, 60% of teachers considered both investigations and de-flection strategies suitable responses when questions were posed in science lessons, depending on the question.

4.4 Research Question 3: How do science background knowledge and pedagogical content knowledge influence how teachers deal with children's questions?

Teachers in this study clearly knew the importance of children doing hands-on investigations with materials to answer their own questions and they also claimed they could give brief explanations in answer to the children's questions. However, the type of response they choose to give may be based on confidence in their own science background knowledge or on their abilities and skills as a teacher of science. This section explores the 145 teachers' answers to children's questions in multiple-choice format to ascertain if they have an appropriate science background knowledge to answer correctly. The researcher's observations of teachers in the study group responding to questions from their classes are also examined.

4.4.1 Data Set: Questionnaire, Part 2

The 145 teachers who responded to the questionnaire answered multiple-choice questions about their understanding of lunar phenomena (Appendix A). Forty-five percent of all the answers were a full scientific explanation, 19% of all the answers were incomplete explanations, 24% were alternative conceptions, 2% contained anthropomorphic views and 9% of all the answers were "I don't know" (Table 10). Missing answers only represented 1% of all the answers.

Table 10

Answer choices for the Multiple-choice Questions by 145 Teachers

Question	full scientific explanations (%)	incomplete scientific explanations (%)	alternative conceptions (%)	anthropomorphic views (%)	I don't know (%)	missing (%)
1	46	4	34	2	12	2
2	40	17	36	1	5	1
3	30	50	12	1	6	1
4	59	21	1	7	10	2
5	50	3	35	0	10	2

Shading indicates the most frequently chosen answer choices.

The most frequent answer to four out of the five multiple-choice questions was the full scientific explanation. Question 1, 46% (Why can't we see the back of the Moon? Because the Moon spins slowly on it's axis each time it orbits the Earth), Question 2, 40% (How does the Moon get all its different shapes? Because different portions of the illuminated surface of the Moon are visible), Question 4, 59% (What keeps the Moon there in space? The Moon is like a satellite; the Earth's pull of gravity keeps it in orbit) and Question 5, 50% (Why do objects NOT float off or away from the Moon? Because the Moon's gravity pulls objects to its surface). In contrast, the most frequent answer for Question 3 (Where does the Moon disappear to when we can't see it? Sometimes the Moon is only visible from the other side of the Earth) was the incomplete scientific explanation (50%, The Moon is always in the sky) (Table 10).

Four of the five questions were answered most frequently with a full scientific explanation (40% to 59%) with a mean response of 48.75%. Thus, based on the mean response more than half of the teachers answered with other choices that were incorrect or incomplete (Table 10). On Question 3, half the teachers (50%) answered with an incomplete scientific explanation (Table 10), repeating the same results from the other four questions of half the teachers answering with an incomplete or incorrect choice.

When the relationship between length of teaching experience and the number of correct scientific answers was investigated it was found that teachers with less than ten years teaching experience answered Questions 1, 2, 3 and 5 with full scientific explanations more frequently than teachers with twenty years or more teaching experience (Table 11). Question 4 (What keeps the Moon there in space?) was answered correctly, with full scientific explanations by 35% of both groups of teachers (Table 11).

Table 11

Teacher's Correct Answers to the Five Multiple Choice Questions in Comparison to Length of Teaching Experience

Questions	Percentage of correct answers for each question (%)	
	<10 years experience	>20 years experience
1: Why can't we see the back of the Moon?	27	16
2: How does the Moon get all its different shapes?	26	23
3: Where does the Moon disappear to when we can't see it?	35	34
4: What keeps the Moon there in space?	35	35
5: Why do objects NOT fall off or away from the Moon?	27	21

In summary, participating teachers answered four of the five multiple-choice questions correctly with a full scientific explanation. However, even though a full scientific explanation was most frequently chosen, based on the mean response, it was only chosen as an answer by 48.75% of teachers on the questionnaire. This may reveal a possible lack of scientific background knowledge for more than half of the teachers. Also, teachers' science background knowledge does not appear to increase with experience, as teachers with less than ten years experience chose 21% more correct answers than very experienced teachers.

4.4.2 Data Set: Study Group

4.4.2.1 Teachers' Pedagogical Content Knowledge in Science

Teacher 5 and Teacher 6 did not participate in the responses to the children's questions data gathering event, thus data about teacher responses is included for only Teachers 1, 2, 3 and 4. All six teachers in the study group were interviewed, thus data about their answers (as scientific explanations) are included here. This section reports on findings related to teachers' pedagogical content knowledge in their identification of science concepts to teach, their recognition of children's alternative concepts, their range of demonstrated responses to children's science questions and their understanding of science concepts.

Identification of science concepts

All six teachers in the study group could identify three major concepts to teach from the photographs during their interview: i) phases of the Moon; ii) how craters are formed or the surface of the Moon; and iii) space travel. Teacher 3 and Teacher 4 also identified the force of gravity as a science concept presented in the stimulus pictures. The pictures showed gravity in relation to craters being formed due to impacts, astronauts walking with weighted boots and the Moon on its elliptical path of orbit.

Recognition of alternative concepts

Only classes of Teachers 1, 3 and 5 asked questions that contained easily identifiable alternative concepts. These were:

Class 1 - How does the moon create light? How come you can't see it in the daytime but you can see it brightly at night?

Class 3 - Why does the moon disappear during the day? If there is no gravity how does space stay up? How long can you survive on the moon without a suit?

Class 5 - Why is there no gravity on the moon?

The Moon *can* be seen during the day, depending on where it is positioned in the sky and the Moon's gravity is one sixth of the Earth's gravitational pull (Nuffield Primary Science, 1997). Teacher 1, Teacher 3 and Teacher 5 could identify the children's alternative concepts from the questions they asked. Teacher 1 recognised "Why can't we see the Moon during the day?" as an alternative concept to the current scientific view and Teacher 3 recognised "How long can you survive on the moon without a suit?" She said that showed her "they had no idea about the atmosphere if they asked that" (Appendix F, Teacher 3). Teacher 5 also recognised "Why is there no gravity on the Moon?" as an alternative concept (Appendix F, Teacher 1 and Teacher 5).

Teacher 2 identified questions he felt showed that the children didn't understand the concept because of the question they posed. He chose:

i. What would people find when they get on the Moon?
ii. So what are they actually going to the Moon for?
iii. Why are we [people] travelling into space?

Teacher 4 identified "If there are so many asteroids hitting the Moon how come only a small portion hit the Earth?" from her classes' questions as an alternative conception. Teacher 6 identified "What are the names of the craters?" And "Is there another Moon?" These questions from Teacher 2, Teacher 4 and Teacher 6 are not typical alternative conceptions but rather genuine questions about something the children don't know. Thus, the only teachers in a position to recognize alternative conceptions were Teachers 1, 3 and 5 because their classes actually posed questions with identifiable alternative conceptions. These teachers could identify alternative conceptions when they engaged with the questions posed by the children in their classes.

Demonstrated responses to children's science questions and teachers' understanding of science concepts

Teacher 1

Teacher 1, one of the three teachers from the large coastal college, examined the children's science questions before she took action with a variety of responses, such as: changing the questions, turning them back to the children to answer, putting them aside to be researched and answering them briefly on the spot. One of her responses was to turn the questions back to the children saying, "Can *you* answer any of these questions?" Teacher 1 answered the more straightforward requests for simple information and asked further questions to deepen the children's understanding. The children's questions were rephrased to include scientific terminology. For example, when a child said 'stages of the Moon' in a question, she clarified when she responded that it was 'phases of the Moon'. She also introduced 'waxing' to describe a lunar phase in response to the question "What stage is it at?"

Teacher 1 grouped similar questions together to answer them, such as questions about the related ideas of asteroids and craters. Teacher 1 also broke a Complex Question down into a Yes/No Question to answer it. She focused on the question "How does the Moon create light?" and asked the children "*Does* the Moon create light?" after a discussion she gave an accurate scientific explanation of how people can see the illuminated portion of the Moon from Earth as the Sun's light is reflected off it (Appendix F, Teacher 1).

In her interview with the researcher Teacher 1 said that sometimes she didn't know the answers to children's science questions and would ask her sister to explain concepts as her sister is a High School science teacher with good science background knowledge (Appendix E, Teacher 1). She also said that she might not know the answer straight away but she would know where to find it (Appendix E, Teacher 1).

When Teacher 1 gave scientific explanations as answers, they were appropriate but perhaps needed further explanation, such as her response about how the phases of the Moon occur when we on Earth see different portions of the illuminated surface of the Moon, depending on our relative position to the Sun and Moon.

> Why we can see them [the phases] is because the Moon is rotating around the Earth and at its different stages the Sun's light is in shadow as it rotates around the Earth. (Appendix F, Teacher 1)

Half of the Moon is bathed in sunlight the other half is not (perhaps her description of 'the Sun's light is in shadow') and we can see parts of the illuminated surface of the Moon at different times of the month. She admitted that she didn't have all the answers in her responses to the children's questions but suggested they could find the answers together (Appendix F, Teacher 1).

Teacher 2

Teacher 2, the male teacher in the coastal college, demonstrated four different responses to the children's science questions. He asked the children to name some ways they could find information that would answer their questions. The class named sources such as the Internet, books in the library and going on an excursion and he then reminded them to be skeptical of what they read. He also asked the children if they knew answers to any of the questions that had been posed and referred them to specific lessons they had participated in that may have addressed concepts of interest. Teacher 2 answered some Short Answer Questions with brief, simple responses and used his understanding of science background knowledge to give an explanation of why the Moon lights up at night. Like Teacher 1, he explained the phenomenon but could have described it in clearer terms. The researcher's additions are in brackets in the following quote:

R: Can you explain to me how the phases happen?

T: What we see from Earth? *The researcher nodded.* What we see from the Earth, it's reflected from the sun [off the Moon] in regards to [depending on] the position of the Earth, the Moon and the Sun (Appendix F, Teacher 2).

Teacher 2, who had a strong rapport with the children, said he felt more confident with Mathematics but that he researched concepts before teaching them, so he would understand and be able to answer the children's science questions when they asked them (Appendix F, Teacher 2). He also said that he would ask the children to research the questions that he couldn't answer for homework (Appendix F, Teacher 2).

Teacher 2 used his understanding of the relationship between the Sun, Earth and Moon to accurately explain how the Moon's gravity is lower than the Earth's but that space suits include heavy boots to help keep the astronauts from floating away, in answer to the question 'Why don't people float up in the air?'

Teacher 3

When it was time to respond to the children's questions Teacher 3, one of the three teachers from the large coastal college, approached them one at a time. As she worked through the children's questions listed on the screen she said: "Well, *I* think…."; "I really don't know"…followed by her best guess; "I wasn't sure if it was….." and "That's something we'd have to look up". She did say that some answers could be found in secondary sources but predominately she attempted to give scientific explanations in answer to their questions. As the session progressed the children answered a lot of their own questions and she facilitated this well, nodding to individuals to have a go at an explanation, asking if anyone could answer the question and allowing conversation between two or more children to occur so they could argue a point. The children seemed empowered by her lack of conviction in her responses.

Teacher 3 tried to find answers to each question even though she was not directed to do so by the researcher. Her own motivation led her to this. She was not able to satisfactorily answer all the questions with scientific explanations, indeed it would be unfair to expect any generalist teacher to accurately answer, on the spot, questions like: 'Why does the Moon light up at night?'; Why is it round?' and 'How was it formed?' These questions require answers that are not brief and simple but rather explanations of complex ideas that need to be thought about and reflected on. They are also questions that could be best responded to with visuals, like a model or a digital resource that can represent large dimensions.

Teacher 3, who seemed to lack confidence in teaching science, identified gravity as another concept she could teach from the photographs, although it was 'no gravity' she was referring to (Appendix F, Teacher 3). She discussed her understanding of gravity on the Moon in her interview:

T: And the fact that because there is no gravity everything is there forever or for an awful long time.

R: Now, there *is* gravity on the moon. (Appendix F, Teacher 3)

Perhaps she confused the ideas of 'gravity' and 'atmosphere'. In her questionnaire responses the only question she answered correctly was the question about gravity on the Moon. So, her questionnaire response shows that she understood that there was a little gravity on the Moon but in the interview she didn't appear to be able to explain that. The multiple-choice questions she answered with alternative conceptions were those about the phases of the Moon and why we sometimes can't see the Moon. She responded with 'I don't know' to questions about the spinning Moon and the satellite characteristics of the Moon. Clearly, Teacher 3 struggled with some of the more complex lunar concepts. The fact that she used the 'I don't know' response rather than attempting an answer seems to point to her having concerns about what she knows.

Teacher 3 was asked to give a scientific explanation for phases of the Moon:

R: …….are you able to explain to me how phases of the Moon occur?

T: It's the reflection of the Sun on the Earth that flicks off to the Moon rather than the Earth actually on the Moon. (Appendix F, Teacher 3)

This answer was not correct and her explanation was confusing, particularly the phrase "rather than the Earth actually on the Moon". The researcher believed she meant 'rather than the shadow of the Earth cast onto the Moon' which is a common alternative conception. The questioning was extended to allow the teacher to share what she did know about what she thought she would see of the Moon, if the Earth, Moon and Sun were in different positions relative to each other. Teacher 3 used her hands to show correctly how the three bodies moved in relation to each other, however, she did not fix the incorrect notion of the light travelling to the Moon via the Earth's reflection (Appendix F, Teacher 3).

She was also asked about why we see one side of the Moon from Earth:

T: And there is only the one face of the moon all the time.

R: There is, and why do you think that is?

T: Because it doesn't spin.

R: It does actually.

T: Does it?

R: Yes, but it spins *so* slowly. (Appendix F, Teacher 3)

Teacher 4

Teacher 4, a novice teacher, redirected the children's questions to the whole class, saying "You should know this" and "Who can tell us about…". She appeared confident about her ability to handle the children's questions and didn't behave as if she needed to give accurate explanations to all of them. She jumped from one question to another on the web of questions recorded on the board and made links between them, saying "These questions are similar, they are both about…….what do we know about that?" and invited the class to construct the answer with her. When she gave scientific explanations as answers they were accurate and given with conviction.

Like Teacher 3, Teacher 4 also identified gravity as a concept she could teach from the photographs. Teacher 4, a graduate teacher, seemed nervous about being observed by the researcher but demonstrated a very confident approach to dealing with the children's science questions and was happy to answer questions in her interview with the researcher. Teacher 4 answered the children's questions correctly in class, however, in her interview she did not answer them accurately.

R: I just want to ask you two of the questions that the children came up with. One of them was "Why aren't there stars in the background of the Moon picture?". Do you remember the Moon picture where the background was completely black? Have you got any ideas?

T: Well, it has an atmosphere just like the Earth has an atmosphere, obviously it is not as strong as that but also it could be dependent on things like that.

R: The other one was "Why is the moon a gold colour and at night it's a white colour when we see it up in the sky"?

T: What they are seeing when they look up at the sky is they see the Moon, they see the light reflecting off the Moon and what they see is the white light reflecting off the Moon so therefore it doesn't matter what colour the surface is necessarily, it still has a white light bouncing off the moon. (Appendix F, Teacher 4)

The stars are not visible in photographs of the Moon because the sunlight reflected off the Moon 'washes out' the background. They are visible to the astronauts though. Teacher 4 thought that it might be because of the Moon's atmosphere. The Moon appears do be different colours because of the angle it is viewed at and when it appears low in the sky. At these times the light reflected off the Moon passes through dust and vapour particles and thus, distorting the way it looks. Teacher 4 thought the Moon always reflected a white light but didn't explain why it sometimes appeared to be a different colour from Earth.

Teacher 5

In her interview with the researcher Teacher 5, who didn't participate in the responding to the children's questions, spoke confidently about lunar phenomena and was able to identify valid concepts to teach from the children's questions and from the photographs as a starting point. Teacher 5 felt confident about her science understandings. She had considered how children learn and could express her view of learning in the interview. She also had an opinion of the place of investigations in science and how children's questions aid investigations.

Teacher 5 answered all of the science concept questions accurately on the questionnaire. In fact, she reworded some of the conceptual questions to better reflect her understanding of the phenomena. In answer to the question "How does the Moon get all its different shapes?" she chose both of these answers:

- 'Because of the position of the Earth at different times of the month'
- 'Because different portions of the illuminated surface of the Moon are visible'

She also wrote on her questionnaire "relative positioning of the Earth, Moon and Sun" which is a more thorough answer than just choosing one of the multiple-choice answers (Appendix F, Teacher 5).

Teacher 6

In her interview with the researcher Teacher 6, who had an interest in curriculum, said she would get the children to find answers to their questions on the Internet (Appendix F, Teacher 6). When she was asked 'Does the Moon spin?' she gave a confusing answer about the Earth and the Sun without including the Moon.

T: I don't know what I'd say. The Earth stays still and the Sun moves around it.

R: Other way. The Earth moves around the Sun.

T: That's right, you're right, yes. (Appendix F, Teacher 6)

The Moon does rotate but it does so at a slow rate that matches its orbit of the Earth, therefore only one side of it is seen from Earth. Teacher 6 appeared concerned about answering the children's questions with scientific explanations and relied on secondary information sources to refer to.

Teacher background knowledge varied amongst the study group of teachers. Three of the four teachers involved in responding to their classes' questions answered them accurately and seemed to have good science background knowledge. During interviews four of the teachers answered a question about how phases of the Moon occur and three of those were correct, although two could have been clearer. It appeared that teachers who were unsure of their answers were finding ways to avoid the problem questions. In particular, Teacher 3 and Teacher 6 used deflection or avoidance to manage gaps in their science background knowledge and Teacher 4 worked around questions that were difficult for her by grouping them as questions that would need to be 'looked up'.

All of the study group teachers involved in the question response sessions invited their classes to contribute their own ideas to answer the questions. Teacher 1 and Teacher 4 grouped similar questions together. Teacher 2 asked his class to name some sources of information that could provide answers to their questions. Teacher 1 also broke a Complex Question down into a Yes/No Question to answer it, put some questions aside to research later and rephrased questions to help the children clarify their ideas and learn scientific terminology.

In summary, the 145 teachers in this study could answer some of the children's questions accurately, however, nearly half the teachers that completed the questionnaire could not answer questions about the rotation of the Moon, the Moon's gravity and phases of the Moon. It was apparent during interviews with the study group teachers that they too had gaps in their knowledge but they showed during classroom observations that they could handle the children's questions in class without relying on their science background knowledge when they were unsure of an answer. Thus, tentatively, it seems they had a good general pedagogical content knowledge.

Primary teachers' science background knowledge doesn't seem to develop with age as teachers with more than ten years teaching experience answered marginally less accurately on the questionnaire than teachers with less than ten years experience. The study group teachers represented teachers with less than a year to eight years teaching experience and based on the accuracy of their answers they too had varying science background knowledge.

It appears that teachers with both strong and weak understanding of science background knowledge involve the whole class in answering questions, which is good pedagogical practice. So is grouping questions together, identifying trustworthy sources of information and breaking down, rephrasing questions for the children and planning hands-on investigations. All of the study group teachers who responded to the children's questions with their classes had techniques to create a successful lesson despite varying levels of science background knowledge. However, the teachers' responses to the children's questions appeared to vary in number and complexity, perhaps depending on their pedagogical content knowledge in science.

4.5 Research Question 4: What do teachers identify as issues with responding to children's science questions?

Many obstacles to teaching science are reported in the literature, however, children's science questions can cause difficulties of their own for the teacher. In this section the most frequent issues for teachers completing the questionnaire will be presented and comments from teachers about what is important about children's science questions. Many of the comments highlighted difficulties for the teachers. Also, Teacher 1, Teacher 2, Teacher 3 and Teacher 6 shared the issues they face in the classroom due to children's science questions.

4.5.1 Data Set: Questionnaire, Part 1

The 145 questionnaire respondents identified issues that occurred when utilizing children's science questions. When these issues were investigated for frequency, four issues were chosen more frequently than the other five: i) 23%, 'deviation from the lesson plan'; ii) 18%, 'I don't always know the answer'; iii) 16%, 'It's always the same small number of children who ask questions'; and iv) 15% 'There is not enough time to deal with their questions' (Table 12).

Table 12

Teachers Issues about Responding to Children's Science Questions

Common issues	Percentage (%)
Deviation from the lesson plan	23
I don't always know the answer	18
It's always the same small number of children who ask questions	16
There is not enough time to deal with their questions	15
Their questions get us off topic	7
Aims or goals are not met	5
My class don't ask questions	2
I don't know what to do with the children's questions	2
other	*2*
missing	*10*

Further to the issues identified by teachers (Table 12), 33 of the 145 teachers responded to an optional question. They commented about what they thought was important about children's science questions and how teachers would respond to them. Some of the comments were related to issues the teachers face when responding to children's science questions such as: a lack of science background knowledge; time constraints; and the need to investigate children's science questions (Table 13). Of the 33 comments, 12 (36%) were related to teachers' background knowledge in science and 'doing the best they can' given that they don't always know the answers to the children's questions (Table 13). Twenty-one percent of the comments addressed constraints in the classroom, such as a lack of time and resources, and 43% clarified the need for investigating children's questions as a way of creating interest and motivation in class (Table 13). Given that 43% were mostly positive comments about how useful children's questions are, it appears that the 33 teachers saw benefits to utilizing the children's questions despite the issues that can occur.

Table 13

Questionnaire Comments about what is Important about Children's Science Questions

Teacher science background knowledge (12 comments, 36%)

- Admit your own knowledge gaps – find out together.
- Important to acknowledge that the 'knowledge' doubles every 10 years (approx.). Teachers of science must keep up with the changes.
- There is a shortage/lack of scientifically trained personnel in our primary schools and resultantly a lack of confidence in teaching some science topics.
- It is vital that teachers are provided with the adequate knowledge. It is a speciality like music etc. Therefore we need background knowledge.
- It's important to answer and answer correctly as questions show what students want to know.
- Be honest – if you don't know – look it up/investigate.
- Teacher knowledge and/or interest in the subject.
- I am very happy to admit I don't know but I am also very quick to seek the answer together – library, internet, brainstorm
- Science is a very specific subject – we need specialist teachers in primary school. We do the best that we can.
- Latest scientific knowledge is conflicting which leads to more discussion.
- I am often reluctant to deal with science questions, as I am not confident of the answers.
- That they are answered scientifically and correctly.

Constraints in the classroom (7 comments, 21%)

- Be flexible with time. Allow specific question time, if there are many questions then move on. Question box for out of class time. Question lesson to focus on answering questions.
- Trying to balance meeting requirements for units/reporting and encouraging active investigating and questioning.
- The children ask great questions but time doesn't always allow for research as a class.
- Investigation and hands on is important however WPH&S issues limit activities, time constraints
- Often it is not having the necessary equipment and resources and space on hand to involve children in investigations.
- The need to refer to other authorities.
- That a lot of learning objects/visual representations on the Internet show the American/Northern hemisphere perspective. This often confuses the children.

The place of investigations (14 comments, 43%)

- Sometimes the questions are the important thing because students are motivated to learn when they can seek answers.
- Being aware of children's need to know. Opening up a wide option for children to explore for answers.
- I think it is important for children to realise that at times teachers don't have the answers so they (the students) can go and explore other avenues to get an answer to their query.
- Answering science questions provides teachers with great opportunities to provide negotiable inquiry based learning experiences.
- If questions are not answered children become discouraged.
- Keep them interested by investigating.
- Children's experiences are to be told information. They need to be taught/encouraged to ask questions.
- It is important to shape the unit on what the children are interested in and want to know.
- Their questions mirror their thinking processes and show their interest and understanding of a topic.
- Encouraging questions of a scientific nature.
- By encouraging the children to learn through investigations, children gain a larger interest in their topic and are therefore more likely to present a well-informed assessment item.
- They are not usually enquiry based.
- Science in Prep is based on children's needs/interests – will vary from year to year, focus in covering the ELAs not a topic as such.
- Focus in Prep is on covering ELAs and not specific topics – "science and related investigations is based on needs and interests of children" and will change/vary from year to year.

In summary, the four most frequent issues reported on the questionnaire that children's questions raise for teachers are a lack of time to deal with the questions, curriculum pressures making deviations from the lesson a problem, a small group of children taking on the role of questioning in the classroom to the exclusion of others and teachers' lack of confidence in their science background knowledge to answer children's questions with scientific explanations.

4.5.2 Data Set: Interviews with Teachers

Teacher 1, Teacher 2, Teacher 3 and Teacher 6 identified issues in their interviews with responding to children's science questions in their classrooms. Teachers 4 and 5 did not, so only issues from Teachers 1, 2, 3 and 6 are reported in this section.

Teacher 1

Teacher 1 explained in her interview with the researcher that not knowing the answers to children's questions was a difficulty for her but that she would feel comfortable finding the answers and would include the children in that research. Teacher 1 also explained that she would support the children to find their answers on the Internet and referred to accessing high quality, accurate information from secondary sources to answer the children's questions (Appendix F, Teacher 1).

Teacher 2

Teacher 2 said that the children's questions sometimes turn silly in a long discussion (Appendix F, Teacher 2).

Teacher 3

Teacher 3 had similar concerns to Teacher 1 about not knowing the answers:

The kids are so well read, information is so readily available to them, they sit on the computer and find lots of information and sometimes it's not always the right information but they're using that as their basis so I have to make sure that what I'm giving them is correct, as much as I know of. (Appendix F, Teacher 3).

Teacher 3 explained that she would support the children to find their answers on the Internet and, like Teacher 1, she referred to accessing quality, accurate information from secondary sources to answer the children's questions.

Teacher 6

Teacher 6 said that her class asked a lot of questions. She explained that they do a lot of group work, so questioning happens in small group work rather than as a whole class. She also said the children were more confident with questioning in that situation (Appendix F, Teacher 6).

In summary, Teacher 1 and Teacher 3 agreed with 18% of the questionnaire respondents that not knowing the answers to children's questions created an issue for them. However, the study group teachers did not express concerns about the other three issues that were frequently highlighted by the respondents to the questionnaire: questions deviating from set work, a lack of time to deal with the questions, or only a small number of children asking all the questions.

4.6 Summary of results

One hundred and twelve children in 6 Year Six classes, based in 4 schools, posed three hundred and twenty nine questions. Despite the large amount of questions gathered in this study (329) there were still many common questions found amongst the six classes. Questions about the surface of the Moon and astronauts were very common as were questions about phases of the Moon, travelling to the Moon, the colour of the Moon, life on the Moon and gravity on the Moon. Short Answer Questions were found to be the most frequent questions asked by children (54%).

One hundred and forty-five teachers completed a questionnaire and indicated that they appreciated the importance and suitability of hands-on investigations and they could also identify some questions suitable for investigation with the children. However, they overwhelmingly intended to give brief explanations in response to the children's science questions in their classrooms. Most teachers (60%) indicated that they would respond with both investigation (through research and hands-on investigation) and with re-direction (dismissing the question, turning it back to the class to answer and saying "I don't know").

Teachers in this study could answer some of the children's questions accurately, however, nearly half the teachers that completed the questionnaire could not answer questions about the rotation of the Moon, the Moon's gravity and phases of the Moon. More experienced teachers did not have greater science background knowledge than teachers with less than ten years experience in the role, consequently, understanding of science background knowledge does not appear to develop with teaching experience. The 6 study group teachers represented graduates to experienced teachers and it was apparent during interviews with the study group teachers that they too had gaps in their knowledge. However, they showed during classroom observations that they could handle the children's questions in class without relying on their science background knowledge when they were unsure of an answer. It appears that teachers with both strong and weak understanding of science background knowledge involve the whole class in answering Complex Questions. Thus, it seems they had good general pedagogical content knowledge, as defined by Appleton (2008).

Four major issues about dealing with children's science questions were identified by teachers in this study. They were: questions creating deviation from set work; not knowing the answers to children's questions; a lack of time to deal with the questions; or only a small number of children asking all the questions. Two of the study group teachers agreed with the questionnaire respondents that not knowing the answers to children's questions created a problem for them but they did not have concerns about the other identified issues. These results will be discussed in Chapter 5 in light of the research literature.

CHAPTER FIVE: DISCUSSION

5.1 Overview

The key focus of this study was to explore children's science questions as a resource for teaching and learning. The types of science questions children ask and how teachers deal with them were investigated to provide information for teachers engaged in implementing a new science curriculum and to add to the discourse about children's science questions in educational research. This chapter examines the results of the study using the research questions as organisers and draws on findings from previous research to analyse and discuss results for each research question. Finally, implications of the research for teachers and schools are discussed.

5.2 Discussion Of Results

5.2.1 Research Question 1 - What types of science questions do children ask in response to stimulus pictures of lunar phenomena?

Children ask different types of questions about lunar phenomena, however, there are similarities between classes in the same school and those in different schools. Past research has found that children's questions are comparable even when children are living in different countries (Biddulph et al., 1986). Results from this study support that finding and also that children in this study asked similar questions to those asked by children fifteen years ago.

Amongst the six classes in the study group there was a repetition of questions about how the phases of the Moon occur, how gravity works on the Moon, the history of space travel, life on the Moon, asteroids and craters, and questions about the physical characteristics of the Moon (Table 4.5). Three of the classes were from the same school but the other three were in different suburbs, had different socio-economic status and cultural backgrounds (Table 4.4). Thus, the types of questions children ask are very similar and are probably not influenced by location, culture or society.

Not only were the questions asked in this study comparable to each other between schools but they were also like the questions from Spargo and Enderstein's research (1997) (Appendix B). The questions in both studies were gathered the same way using similar photographs, which may account for why some of the questions were the same. However, the Spargo and Enderstein study was conducted in Western Cape Town middle class schools in South Africa. The schools involved were comparable to Australian schools in middle class suburbs (P. Spargo, personal communication, June 26, 2009). Thus, in a different country more than fifteen years later children are asking the same types of questions about lunar phenomena. If children's questions about a topic were the same in different classrooms around the world and likely to remain similar over time then teachers would benefit from knowing what questions children are interested in and likely to ask about. It would allow teachers to better prepare investigations to challenge children's thinking and hence, provide answers to satisfy their curiosity that in turn could help support scientific inquiry in the classroom.

Other researchers have flagged the idea of providing children's common science questions for teachers. As a result of the Learning in Science Project, Biddulph, Osborne and Freyburg (1985) created support booklets for teachers. One of these booklets detailed the questions the children might ask about a range of science concepts and was based on their findings that there were common questions across classrooms and countries. The list was designed to support teachers and to reduce obstacles to using children's questions in the classroom.

Common alternative conceptions and teacher background knowledge have been included in curriculum resource documents, such as the Primary**Connections** – *Linking Science with Literacy* program, to support quality teaching of primary science. These inclusions were a research-based decision and as such, including possible children's questions in resource materials may provide further benefits for teachers.

A key component of this study was the collection and analysis of the types of questions asked by 112 students across six classes. The children's science questions in this study were gathered in each of the six classrooms in the study group using the same process, and were divided into number and percentages of Yes/No, Short Answer and Complex Questions (Table 4.6).

The three categories of Yes/No Questions, Short Answer Questions and Complex Questions identified in this study are comparable to those identified by other researchers (Bloom, et al., 1956; Chin & Kayalvizhi, 2002; Scardamalia & Bereiter, cited in Chin & Osborne, 2008) (see Table 5.14). The researchers used the teachers' responses or expected responses as a way to categorise the children's questions (Chin & Osborne, 2008). Two further studies also identified question categories based on the teachers' responses (Harlen, 2001; Spargo & Enderstein, 1997) (Table 5.14). Thus, the methods used in this study to categorise children's science questions are validated by five previous studies.

Table 14

Comparison of Classifications of Children's Questions

Harlen (2001)	Spargo and Enderstein (1997)	Chin and Kayalvizhi, cited in Chin and Osborne (2008)	Scardamalia and Bereiter, cited in Chin and Osborne (2008)	Bloom, Engelhart, Furst, Hill and Krathwohl, cited in Chin and Osborne (2008)	Question categories in this study
• Philosophical		• Non-investigatable			
• Requests for simple facts	• Requiring essentially factual knowledge		• Basic information	• Knowledge; comprehension	• Yes/No
	• Requiring a relatively simple explanation				• Short Answer
• Expression of wonder or interest • Complex	• Requiring a greater degree of insight by the teacher • Requiring some understanding of first causes by the teacher		• Wonderment		• Complex
				• Analysis; synthesis; evaluation	
• Investigatable		• Investigatable		• Application	

Children's questions, similar to those in this study, were collected in South African research conducted by Spargo & Enderstein (1997). The researchers gathered children's questions about space science concepts to examine the ability of primary teachers to provide complex explanations in answer to the children's questions. Their view of teacher responses was limited to scientific explanations and did not encompass the idea of hands-on investigations resulting from questions (Table 5.14). Concern for adequate teacher background knowledge may have been an important education issue at that time. A developing understanding of the importance of child-centred approaches to teaching in the last fifteen years shifts education concerns from the actions of the teachers to those of the children. Thus, there would now be a possible range of suitable responses to children's questions that would be considered more appropriate than giving direct answers and relying on teachers' science background knowledge.

The three categories of questions in this study were asked inconsistently across the six classes, as shown in Table 4.6. A comparison between classes illuminates some differences that may have had a bearing on the questions the children posed.

5.2.1.1 A Comparison of Question Categories of the Six Study Group Classes

Yes/No Questions

Students in four of the six study group classes (Class 1, Class 3, Class 4, Class 6) asked a similar percentage of Yes/No Questions (14% to 24%) (Table 4.6). Yes/No Questions were not the dominant category of questions, as they represented less than a quarter of the questions asked in those classes (Table 4.6). Class 2 and Class 5 were exceptions. Class 5 will be discussed in section 5.2.1.2. Class 2 asked more Yes/No Questions than any other class and it was their most frequent category of questions, unlike the other five classes that had more Short Answer Questions than Yes/No or Complex Questions. Nearly half of the questions posed by Class 2 were Yes/No Questions and nearly half were Short Answer Questions (Table 4.6). The question-asking session with Class 2 was animated and the class appeared to be fun loving (section 4.1.2, p. 42). There were many nonsense questions in this class as well (Appendix G), which could be a sign that the children were being playful and were not committed to asking genuine questions. Zeegers (2003) explains that the children need to be committed to posing genuine questions in order for the teacher to be able to utilize those questions in lessons.

Short Answer Questions

Class 6 asked more Short Answer Questions than the other study group classes (Table 4.6). Short Answer Questions were the most frequent category of questions posed by five of the classes. When this category of questions was examined, 41% of the Short Answer Questions required merely a numerical answer, such as a date or a quantity. At least half of the Short Answer Questions posed by three classes (Class 2, Class 4 and Class 6) required a numerical answer, which was more frequent than for the other classes (Table 4.7).

Class 2 asked an almost equal number of Short Answer Questions and Yes/No Questions (Table 4.6) and this set them apart from the other classes whose Short Answer Questions dominated the sessions. Class 4 was similar to Class 6 in many ways. They were both in small, inner-city schools with similar socio-economic and cultural demographics. They both had young, female teachers and both teachers regularly taught science and had taught a space unit in a previous term. Fifty percent of Class 4’s Short Answer Questions and 54% of Class 6’s questions required a numerical answer, higher than all the other classes in the study group (Table 4.7). Short Answer Questions requiring a numerical answer are a basic form of Short Answer Question because a single word or number may be the only answer necessary. The Short Answer Questions from Class 6 were similar to those asked by other classes, for example: “How much gravity is on the Moon?” In order to ask that question the child needs an understanding that there is *some* gravity on the Moon. A common alternative conception held by many children and some adults is that there is *no* gravity on the Moon (Nuffield Primary Science, 1997). This indicates that the children had some background knowledge and were interested enough to ask relevant questions even if they were not Complex Questions. Perhaps they were expressing wonder in their questions. ‘Questions that are an expression of wonder or interest’ (Harlen, 2001) and ‘Wonderment Questions’ (Scadamalia & Bereiter, cited in Chin & Osborne, 2008) are in the Complex Questions category in this study (Table 5.14).

Complex Questions

There was a greater range of percentages of Complex Questions asked by the six classes (Table 4.6), unlike the other question categories (Yes/No and Short Answer Questions) where percentages were similar. Thirty-five percent of the questions posed by Class 3 and Class 5 were Complex Questions but Class 2 and Class 6 posed few Complex Questions, or no such questions (Table 4.6).

Although Class 6 asked more Short Answer Questions than any other class, they did not ask any Complex Questions (Table 4.6). The researcher noted that there were many comments and interested looks from students about the technological equipment being used to record the research event in their classroom. The microphone was particularly attention-grabbing. Teacher 6 stated in her interview “They’re very into computers, this class” (Appendix F, Teacher 6). Perhaps the distractions had an effect on the category of questions they asked, particularly the lack of Complex Questions. Another possible explanation for the relatively large number of Short Answer Questions is that Class 6 usually posed questions in a small group rather than as a whole class (Appendix F, Teacher 6). Small groups may allow more opportunities for children to share ideas without the censure of the rest of the class. So, perhaps the whole class exercise was uncomfortable for them and discouraged them from thinking of Complex Questions.

Only 6% of the questions generated by Class 2 were Complex Questions (Table 4.6). Classes 1, 2 and 3 were from the same school. The children were the same age (Year Six: approximately 11 years old) and were in classrooms next to each other. Class 1 and 3 asked a similar number of Complex Questions to each other (28% and 37%). The much lower percentage of Complex Questions in Class 2 seems unusual given the relationship between the three classes and their teachers. The teachers of the three classes plan units of work each term together (Teacher 2, Appendix F). All three teachers had taught Year Six the year prior to this study, all were recent graduates who had moved from other careers and all three teachers worked closely together, particularly when planning.

The only observable difference between the three classes was that Class 2 had a male teacher who had a strong rapport with the children, particularly the boys. The question-asking activity was more light-hearted in this class than the other two classes. There was more laughter and talking during the session and less serious contemplation than in the other two classes. It is possible that the teacher of Class 2 was influencing the classroom culture in a way that meant the students were potentially less likely to ask Complex Questions. The links between classroom culture and questioning will be explored later in this discussion in section 5.2.1.5.

5.2.1.2 The Effect of Teacher Responses on Question Categories

The number of Complex Questions the children ask appears to be linked to a particular response teachers have of *not* providing a definitive answer. Class 3 and Class 5 had the highest percentage of Complex Questions of the six classes (Table 4.6), however, their teachers (Teacher 3 and Teacher 5) identified very different ways to respond to the children's questions. Teacher 3 tried to answer the children's questions with scientific explanations but she found that her background knowledge had gaps (Appendix E, Teacher 3). This 'open space' from the teacher's failure to provide definitive answers created freedom in questioning for the children (Bowker, 2010). The term 'open space' describes the freedom to ask questions that interest the student because the teacher is not promoting their own expertise. This freedom from the teacher's quick answer means that students can try out and revise their own questions and answers. Teacher 5 was enthusiastic about hands-on investigations for her class to help them experience the concept and develop the language to be able to answer their own questions (Appendix E, Teacher 5). Again, she didn't believe in providing quick answers and thus the children are provided with Bowker's (2010) 'open space' to develop their own Complex Questions and subsequent answers. It appears that a higher percentage of Complex Questions from the children in this study is linked to teachers *not* providing definitive answers in an immediate response to the children's questions. Teacher responses will be discussed further in the discussion in section 5.2.2.

During observations of the question gathering in the other five classrooms the researcher noted that at times the children seemed to be trying to think of a question to ask, just for the sake of asking a question. They also phrased questions to show that they knew things, for example: "Why isn't there oxygen on the Moon?" This question indicates that the child knows that astronauts cannot breathe air on the Moon but they are looking for more information about that phenomenon. Another explanation for the children in Class 5 asking more Complex Questions and fewer Yes/No Questions could be because they had less interest in sharing what they already knew, or maybe didn't have a broad experience about Moon phenomena to draw on and so were genuinely curious.

Class 5 could have had less experience with the teaching of lunar phenomena than the other classes because most of the children had been refugees from Africa. Four of the children in Class 5 had less formal schooling in Australia than their peers and no schooling before their arrival in Australia. Three quarters of the class spoke English as a second language. African children who are refugees face many challenges in the Australian schooling system, not just gaining literacy and numeracy skills, but also learning time management and organisational skills as well as recognising and understanding Western cultural concepts in the curriculum (Oliver, Haig, & Groate, 2009). This could mean that the higher frequency of Complex Questions and lower frequency of Yes/No Questions was due to their curiosity and their lack of formal schooling. If curiosity and a lack of formal schooling were responsible then the other five classes may have a higher incidence of Yes/No Questions because their curiosity had faded over the years. Schooling is sometimes blamed for receding curiosity when in reality "mounting practical concerns that accompany maturation may take the larger toll on curiosity" (Schmitt & Lahroodi, 2008, para. 48) or, in other words, trials of the teenage years and puberty are enveloping them and their interest in asking questions in class is less of a priority than when they were younger. Unfortunately, that means that children in Year Six may be less curious than younger children, which is problematic, as curiosity is needed in science.

Perhaps Class 5, new to so many of the concepts presented in school, had the interests and curiosity of younger children because of the gaps in their prior experiences. Teachers in a study of educational challenges faced by African refugee background children (Oliver et al., 2009) expressed concerns about 'gaps' in knowledge and experiences. Many of the children in Class 5 experienced some schooling in refugee camps prior to their present situation. Schooling in refugee camps is often just copying from the board (Miller, Mitchell, & Brown, 2005) and is not comparable with formal Australian schooling. These children may be asking Complex Questions because they want to understand and don't necessarily have the language to describe these new ideas and experiences. The teacher of Class 5 understood how difficult it was for some of the children in her class to converse (personal communication, March 28, 2011). She explained that for six hours every school day the children communicated in English and for the rest of the week they communicated in other languages. It takes refugee children four to seven years to develop academic English proficiency and up to 10 years if they have interrupted schooling (Miller et al., 2005).

Teacher 5 appears to have had success in Class 5 with modeling question-asking. Her class was one of two classes who asked the most Complex Questions and she had explicitly taught them how to pose questions. She also promoted oral language proficiency in the classroom and was generous with her praise of students when they asked questions or shared ideas. Allison and Shrigley (1986) explain that modeling how to ask desired questions is more successful when another factor is added, such as praise, parent modeling or active manipulation of materials. In the case of Teacher 5, praise was added.

5.2.1.3 The Emphasis on Question Categories in the Science Curriculum

Children in Year Six are at the end of their primary schooling years and are expected to ask a range of questions differing in purpose and complexity during science activities (ACARA, 2010). While all categories of children's science questions should be valued for teaching and learning, even questions seeking basic information are important in the process of learning (Chin & Osborne, 2008), the Australian Curriculum: Science has a focus on questions that develop clarity and understanding and that contribute to investigations.

In the upper primary years children can pose scientific, testable questions, rather than those that arise purely out of their own interests (ACARA, 2010). Their questioning skills should have developed during exposure to science education every year and from a focus on questioning as an everyday literacy. Curriculum documents describe these upper primary years as "a period during which children ask questions to clarify practical problems or inform a scientific investigation" (Year Six Australian Curriculum: Science content description - ACSIS232). Thus, according to this curriculum, children's science questions should be those that require responses that include hands-on investigations, research from secondary sources or scientific explanations to clarify understanding. The most frequently asked questions from children in this study were those that required a brief, often simple answer (Table 4.6). Although these are important in the process of learning they are not those that are a focus of the Australian Curriculum: Science.

Complex Questions include questions that can often be investigated after some assistance from the teacher to rephrase them. Many children's questions are not expressed in a way that is applicable to a hands-on investigation without teacher help (Kur & Heitzmann, 2008; Roth & Roychoudhury, 1993; Swatton 1992; Symington, cited in Biddulph et al., 1986; Watts & Alsop, cited in Chin & Osborne, 2008). 'Investigatable questions' was not an independent category chosen for analysis in this study because they do not often occur naturally from the children's questions. However, they have value as a type of Complex Question and without them teachers may not have material to promote children's investigations in the classroom.

Finally, the Australian Curriculum: Science has a focus on questions that develop clarity and understanding and that contribute to investigations. The category of Complex Questions in the present study would include those questions given prominence in the Australian Curriculum: Science. Thus, the low percentage of Complex Questions in this study is of concern given the importance in the curriculum of Investigatable Questions and questions seeking a deeper understanding of science concepts.

5.2.1.4 The Effect of Access to the Internet on the Proportion of Questions Asked in each Category

A higher percentage of Complex Questions in this study would be desirable. Harlen (2001) explained that the most frequent type of questions asked by primary school aged children are "Why?" questions or questions requiring complex explanations. Thus, perhaps in the ten years since Harlen's work, children and teachers have become used to getting large amounts of information and answers quickly from the Internet and the teacher is no longer seen as the expert in the classroom by the children. Royal (2003) explains that today's students "think of the Internet as the place to find primary and secondary source material for their reports, presentations, and projects" (p. 6). Thus, there has been a shift in the role of teachers and in classroom culture due to the vast amount of information easily accessible to children at school and often at home.

The sources and types of information available to children in school may be influencing them to ask fewer Complex Questions and more questions requiring a brief answer or a Yes/No response. Carr (2011) describes how research shows that using the Internet in unprecedented amounts induces only superficial understanding of topics. Not only does the Internet offer access to large amounts of information but it also holds a great attraction for children (Kuiper, Volman, & Terwel, 2005). Information from digital media sources such as Wikipedia, is factual and easy to view, however, it is not always accurate. The headings, videos and images encourage skimming and links urge the young reader to continue searching and jumping from one idea to the next.

Finally, the teachers and classes in the study group used the computer access they had in their classrooms to research ideas and answers to questions however, information presented in this manner on the Internet lends itself to providing answers to requests for brief empirical data rather than promote more complex questions and searching for understanding. Thus, it is possible that easy access to the Internet in Australian classrooms is increasing the number of questions children ask that would not be considered Complex Questions.

5.2.1.5 The Effect of Classroom Culture on the Proportion of Questions Asked in each Category

The prominence of questions in this study requiring a short answer, or even just a Yes or No, could also be due to the nature of the classroom. A teacher sometimes asks questions he or she already knows the answers to so that students can recall and repeat others' thoughts (Cazden, 1986; Nystrand, 1997). If this is the culture established in the classroom then it follows that children's questions may reflect the teacher's questioning style. They may be influenced to ask knowledge-based questions to which there are expected and known answers. This could account for frequent questions from the children in this study that only needed brief answers. A question-centred culture needs a teacher-student relationship that is caring, equitable and responsive (Bowker, 2010) in order to develop risk-taking and enabling the posing of questions that are complex and challenging.

Teacher 2 may have influenced his class by encouraging fun and banter. If that were the established way to discuss ideas then the classroom culture of Class 2 may not support much genuine question-asking from the students. This idea is supported by Zeegers (2002) who researched teachers' practices in generating children's questions in science and found that the children need to commit to asking genuine questions or their questions are not useful for teaching. Real discussion between children occurs on average for less than one minute a day and the quality of learning in classrooms is closely linked to the quality of classroom talk (Nystrand, 1997). Thus, if children are asked to voice their own thoughts in response to a teacher question, rather than trying to guess the teacher's answer, then perhaps the questions they ask would better reflect their ideas and interests.

Classroom culture may be one influence on the categories of children's questions. It is possible the physical layout of the classroom can hinder or enhance discussion too. The six study group teachers had their classrooms laid out in different ways. Teacher 1 had desks arranged in a winding U shape with additional rows jutting into the centre of the room, so that children were close to each other or facing each other. Teacher 2 had desks in large groups of six where children were facing each other but not close to anyone, except the one child immediately beside them. Teachers 3, 4 and 6 had their desks in rows facing the front of the room and Teacher 5 had her desks in a U shape. It is almost impossible for children to engage with anyone but their teacher when they are seated in rows and the opposite is also the case, sitting in a circle encourages engagement with each other (Fivush, cited in Cazden, 1986). The seating arrangements in the six classrooms somewhat reflects the types of questions they posed. Class 1 and Class 5 were the only classes to pose almost no questions (13% and 9% respectively) that required merely a numerical answer (Table 4.7) and they had desks arranged in a U shape or a U shape modified with some extra desks jutting out from the U. All of the other classes who did not have this desk arrangement but rather had desks arranged in rows and large groups of six desks joined together, asked a high percentage of Numerical Short Answer Questions (41% to 58%) (Table 4.7).

Finally, the physical layout of the classroom and the culture of question-asking appeared to impact on the categories of questions children pose. Thus, further research in this area may be useful for teachers wanting to encourage more Complex Questions in their classrooms.

5.2.1.6 Encouraging more Complex Questions in Science Lessons

That only 19% of the questions required a complex answer or explanation in response from the teacher is of concern (Table 4.6). Questions requiring complex answers include higher order questions and Testable or Investigatable Questions and are desirable in science lessons, so it is problematic that they occurred infrequently in the questions the children posed in this study. This is not consistent with other studies in which Complex questions (Harlen, 2001) or questions requiring teacher insight or understanding of first causes (Spargo & Enderstein, 1997) were found to be very common children's science questions.

The low percentage of questions requiring a complex explanation from the teacher may have been influenced by the stimulus material, and the artificial way of gathering questions. The pictures were showing static images - the Moon surrounded by black space, craters in the Moon's surface and an astronaut standing on the Moon. The pictures did not capture any movement or relationships between elements. If they had shown images such as an astronaut drifting near a space shuttle or a view of the Moon from Earth with the Sun also visible in the sky then perhaps the children's questions might have inspired more complex answers because they could have explored concepts of cause and effect, gravity, momentum, velocity and spatial relationships. Contrary to the findings of this study Harlen (2001) reported that Complex questions were the most common of children's science questions from observations of classrooms in natural teaching situations. The questions were gathered in this study in the children's classrooms using a simple process of 'hands up to ask a question', so the event was life-like. However, it was not an everyday lesson with their teacher and so the questions were called for rather than occurring spontaneously. As a result, the children asked many questions and participated with enthusiasm, but that may not occur in a science lesson on another day with their teacher. Thus, the category of questions posed in this research study may differ from those questions occurring spontaneously in classes because of the presence of the researcher and the process that was used to generate questions.

Bowker (2010) explains that it would be naïve to expect all children to spontaneously ask great questions and that in reality it requires sustained practice and guidance. He describes how questions need to be nurtured and taught, not merely demanded and some answers need to be offered to help children move from asking one question to asking another. The questions also need to be appropriate to the ability of the learner. In addition, he stresses that the classroom environment needs to be a reassuring one where children will not feel abandoned, forgotten or embarrassed by the teacher or other students so that they can ask questions with security. The best methods for encouraging more Complex Questions have been found to be the use of an inquiry approach to teaching and by explicit teaching and modeling of how to ask the preferred types of questions (Allison & Shrigley, 1986; Bardeen, 2000; Cuccio-Schirripa, & Steiner, 2000; Haefner & Zembal-Saul, 2001; Rennie et al., 2001).

A teacher who responded to the questionnaire with additional comments had insightful ideas for the promotion of questioning in the classroom to share: "Be flexible with time. Allow specific question time, if there are many questions then move on. Have a question box for out of class time. Have a question lesson to focus on answering the children's questions". (Table 4.13)

Finally, despite the importance of all question categories in the process of learning, Complex Questions are important and are considered in the literature to be the most frequent of children's science questions. The low percentage of Complex Questions in the present study, contrary to past studies, may indicate the difference between asking questions spontaneously and being invited to pose questions as part of a questioning session.

5.2.1.7 Summary of Research Question 1- What types of science questions do children ask in response to stimulus pictures of lunar phenomena?

Children's questions about lunar concepts are very similar between classes in the same school, classes in different schools, and between children from different countries. Their questions also appear to be similar over time. As a consequence it could be beneficial to teachers to have access to compiled lists of likely questions on a range of science topics from the Australian Curriculum: Science.

More than half of the total questions asked represented Short Answer Questions and less than a quarter of the children's questions were Yes/No Questions. Although all categories of questions can be important for learning, Complex Questions are desirable because they encompass questions for investigations, research, exploration with models, and represent higher order thinking. They did not occur as frequently as desired in classrooms in this study, the children asked more questions requiring a short answer. If teachers want to encourage more Complex Questions then they should be aware that classroom culture and the physical environment could have an effect on the categories of questions children pose. Children are required to pose questions to clarify meaning, develop understanding and to test through investigation as they progress through the curriculum in their primary years (ACARA, 2012). So, teachers need to model asking the preferred questions and explicitly teach children how to ask questions for investigations. Findings from this study suggest that not providing definitive answers gives children space to develop their questions more fully and explore their own answers. The type of response a teacher gives to a child's question can have implications for learning, so it is advantageous for teachers to have an understanding of responses that are suitable to use. Teachers' views on suitable responses are discussed in section 5.2.2.

5.2.2 Research Question 2 - What do teachers consider to be suitable responses to children's science questions?

There are a number of possible responses to a child's science question in the classroom and they are linked to the category of question asked. One way of responding to children's science questions is to answer with a scientific explanation (Kallery & Psillos, 2001). In this study, 'teacher answers' refer only to the scientific explanations teachers provide when answering children's questions and 'teacher responses' is a wider term referring to a variety of teachers' initial reactions to children's questions, such as turning the question back to the children to answer, using the question for an investigation with materials or looking up the answer in a secondary source, for example, the internet or a book. In this study teacher responses were observed in classrooms and were also described by the teachers. These data were collected through classroom observations, questionnaire answers and interview discussions. In this section these responses will be compared to teachers' typical responses reported in the literature. Two responses will be discussed in some detail here: (i) research from the Internet; because of the regard shown by teachers in this study; particularly evident in the responses by the 145 teachers to the questionnaire; and (ii) hands-on investigations, because of the focus on it in the literature and in the Australian Curriculum: Science. Many of the other responses from teachers in this study might be a result of good pedagogical practices and understanding of science background knowledge, which will be discussed in section 5.2.3.

Teachers in the study group demonstrated and described a variety of responses to children's science questions. They were:

i. turning the questions back to the children to answer;
ii. giving accurate scientific explanations as answers;
iii. asking further questions to deepen the children's understanding;
iv. breaking questions down into simpler versions that could be answered immediately by the children;
v. saying "I don't know" and "Where can we find an answer to that?" or "Who can answer that?";
vi. researching answers using information sources such as the Internet;
vii. investigating using hands-on materials.

These are similar to teachers' typical responses in Watts, Alsop et al. (1997) study that found that teachers did one of four things: they said "What do you think?"; gave a brief explanation; said "I don't know"; or planned an investigation. However, there were three additional responses by teachers in this study, namely: i) research the answers (this will be discussed further in section 5.2.2.2); ii) ask further questions to deepen the children's understanding; and iii) break questions down into simpler versions that could be answered immediately by the children. The last two additional responses from teachers in this study will be discussed in 5.2.3.

5.2.2.1 Ignoring Children's Questions as Interruptions

One response from past research (Watts, Alsop et al., 1997) that wasn't observed in the classroom observations in this study, was 'ignoring the question as an interruption'. Three of the teachers used in the case studies (Appendix E) appeared surprised at the suggestion that teachers would ignore a child's question. They said:

"I don't ignore a question……I always try and follow with an answer or a task to try and find the answer" (Appendix E, Teacher 1).

"Ignoring the question surprises me. Generally there might be 'we'll get back to that later or I'm not sure'. Just to completely ignore it suggests that you don't even respond to it, which is a bit ordinary" (Appendix E, Teacher 3).

"I try not to ignore the question ever" (Appendix E, Teacher 5).

Perhaps the teachers were influenced in what they said about never ignoring a child's question because they were being observed in the classroom and were trying to display their best work or maybe they don't think they ignore questions because they don't consciously decide to do it. Some of the questions the children asked in this study were irrelevant questions clearly designed for humour, hence, it is doubtful that teachers would take those questions seriously in the classroom and would ignore them or treat them as a disruption. For example, Teacher 2 smiled and held the gaze of a child who asked " Can a cow jump over the Moon?" and "If there is [was] grass on the Moon, can [could] there be space cows?" (Appendix G, Class 2). He added them to the list of questions because the researcher directed him to accept all questions and record them verbatim. However, it is doubtful he would accept them during regular teaching times. He confirmed during his interview that "getting silly….can be a problem with this group" (Appendix F, Teacher 2). Observations of teachers by Watts, Alsop et al. (1997) contradicts the study group teachers' assertations that they don't ignore children's science questions as they observed teachers in science lessons ignoring questions as if they were an unwanted interruption.

Only 11 teachers (3%), of the 145 who completed the questionnaire, indicated that they 'sometimes keep the lesson moving and don't answer the question at that time' (Table 4.9). This is a very low percentage response, but it does correspond with the findings from Watts, Alsop et al. (1997). Perhaps the way the response was expressed was an issue for the study group teachers. 'Ignore as an interruption' may be seen as a callous treatment of a child's question, where as 'keep the lesson moving and don't answer the question at that time' on the questionnaire, is less harsh. Watts, Alsop et al. used the term 'ignore as an interruption' to describe the actions of the teachers they observed.

5.2.2.2 The Effect of Increased Access to the Internet on Teachers' Responses

Finding the answers to children's questions by researching on the Internet was a response highly valued by teachers in this study but it was not identified as one of the typical responses available to teachers in Watts, Alsop et al. (1997). Presumably that is because access to computers in classrooms has increased enormously in the last fifteen years and today's children are often skillful practitioners, in contrast to 1997 when Watts, Alsop et al. conducted their research and computers were predominately used only in business. When the teachers' questionnaire answers identified 'research from the Internet' as a common response they clarified that they would work with the children to research the answers (Table 4.8 and Table 4.13). This was also a popular method of the study group teachers. This is not surprising given the good access to Information Communication Technology that the schools in the study group had and the limited floor and workspace available in those classrooms for hands-on investigations. Researching answers on the Internet could be still described as inquiry but it could not be identified as working scientifically. In the Australian Curriculum:

Science the working scientifically strand is called ‘Science Inquiry Skills’. This strand stresses the importance of prediction and gathering evidence for children and cannot be completed without doing investigations with hands-on materials, thus, no matter how much classrooms operate digitally the children do need to manipulate materials to answer scientific questions.

Pauling (2008) supports the view that in schools the Internet “is used as a major, sometimes primary, source of information” (p. 389). If the teachers are collaborating with the children to answer their questions they could be engaging in a valuable form of inquiry, in contrast, if the research on the Internet is very teacher-directed and focused on retrieving information requested by the teacher then it would be arguably a more traditional approach to teaching, with ICT replacing books. Hence, generating a problem to solve or researching answers to a question might be useful.

The Internet may be very attractive for children (Kuiper, Volman, & Terwel, 2005), but finding answers to questions using it is fraught with potential problems. Alternative conceptions, inaccurate explanations, advertising and biased articles can be found but perhaps are not always recognised as such by children. This means the teacher must play a role in sourcing appropriate digital resources and teaching children to be critical users and thus, learning the pathways to knowledge (Frechette, cited in Kuiper et al., 2005) by helping students to analyse the relevant material. Digital resources using models of space science concepts, such as phases of the Moon, are available to teachers in repositories like the Learning Federation. Research has shown that teachers are better at explaining concepts when they use models (Lelliott & Rollnick, 2009), and space science is on such a huge scale that models can be a necessity.

5.2.2.3 Hands-On Investigations as a way to Respond to Children’s Science Questions

The teachers involved in this study recognized the importance of investigations as a valid response to children’s science questions (Table 4.13). They could also identify questions suitable for investigations with hands-on materials (Figure 1). Although the 145 teachers indicated on the questionnaire that they appreciated the importance and suitability of hands-on investigations they overwhelmingly intended to give brief explanations in response to the children’s science questions in their classroom (Table 4.8). Three questions that were not popular amongst the teachers as possible investigations were:

1. How did the moon get made?
2. Why do so many things hit the Moon but not the Earth?
3. Why, if we travel in a car, does the Moon seem to follow us?

These three questions are more difficult than the other seven to deal with, either with a scientific explanation or another response. Possibly the first two wouldn't be well suited to investigations with materials. The first and second are best answered with concepts from the Physical sciences. The third is a question of perspective that can be taught during the primary school years and perhaps, if using a shorter distance in an investigation, it could be viewed as an investigatable question. Teachers who responded to the questionnaire highlighted the need for scientific investigations in response to children's questions. One teacher commented that "Sometimes the questions are the important thing because students are motivated to learn when they can seek answers to their own questions" (Table 4.13). Another commented that "Answering science questions provides teachers with great opportunities to provide negotiable inquiry based learning experiences" (Table 4.13). These questionnaire answers matched the information shared by the teachers in the study group.

The six teachers in the study group agreed with the teachers who responded to the questionnaire about the importance of investigations with hand-on materials. They believed that their classes' questions about craters could be investigated this way. The teachers also identified questions about the phases of the Moon as being suitable for hands-on investigations using models. Some of the teachers thought they could investigate questions about the space suits through investigations. This perhaps suggests that they are thinking of investigation as research from a secondary source, rather than the gathering of primary data through hands-on experiences. The term 'investigation' could refer to either activity. None of the teachers would have access to specialized astronomical equipment in the classroom but would be able to get information from other sources, such as the Internet. Teachers advocated 'investigation' as a response to children's questions on the questionnaire but 'research from secondary sources' was actually detected in the classroom observations (Appendix E). Research from secondary sources is certainly a valid form of investigation, however, if it was the only method used to gather data the children would not be engaging fully in using inquiry skills. Perhaps their inclination to refer to the Internet, or books, to gather data was due to the time constraints of the session or because of the need for resources and preparation to do investigations with materials. Lack of resources in primary science has been proposed as a hindrance to dealing with children's questions (Biddulph, Symington, & Osborne, 1986) thus, with good access to information on the Internet and poor access to equipment and other resources it is likely that teachers would be quick to use computers to answer the children's questions rather than encourage investigations with materials to gather primary data.

5.2.2.4 Summary of Research Question 2 - What do teachers consider to be suitable responses to children's science questions?

Teachers in this study thought that suitable responses to the children's questions included those found in previous research, namely: saying "What do you think?"; giving a brief explanation; saying "I don't know"; and planning an investigation. They agreed that 'ignoring the child's question as an interruption' was not suitable. The study group teachers also displayed further techniques that helped them and their classes deal with the questions that were posed, they were: breaking the question down into a simpler form to answer it; and asking further questions to deepen the children's understanding. Researching answers from the Internet was a preferred response, especially working with the children to research their own answers.

Teachers' responses to children's questions can be critical for promoting learning. A variety of responses to the different types of questions children ask would help to create a culture of question-asking in classrooms and allow for different ways to learn, such as hands-on investigations. Investigations using models have been found to be very useful for concepts such as day/night and phases of the Moon (Plummer & Krajcik, 2010; Guimaraes & Gnecco, 2007). A range of factors can promote or hinder question-asking in science. One factor shown in this study that is of concern, is teachers' lack of confidence in their science background knowledge (Table 4.12) preventing them from responding in a way they think is suitable - with a scientific explanation. However, teachers' pedagogical content knowledge can help them to deal with children's science questions when they don't know the answer themselves. Science background knowledge and pedagogical content knowledge will be discussed in the next section.

5.2.3 Research Question 3 - What influence do science background knowledge and pedagogical content knowledge have on how teachers deal with children's questions?

Australian research has nominated gaps in science background knowledge as the cause of low confidence in Primary teachers of science (Rennie et al., 2001). However, that may not be the whole reason. For example, an underdeveloped pedagogical content knowledge could also be a factor. Teachers who have limited understanding of science concepts or who hold alternative conceptions cannot teach those concepts accurately (Burgoon et al., 2010) and so would find it difficult to respond to children's science questions with an answer or guide the children to an accurate scientific explanation. Thus, science background knowledge can have an influence on how teachers respond to children's questions. This section will explore teachers' science background knowledge and their associated lack of confidence, and teachers' pedagogical content knowledge.

5.2.3.1 Answering Children's Complex Science Questions using Science Background Knowledge

Part 2 of the teacher questionnaire (Appendix A) investigated teachers' science background knowledge of lunar concepts. The 145 teachers that responded to the questionnaire taught a range of year levels and had varied teaching and professional development experiences. Of these teachers, less than 50% used a full scientific explanation to answer three out of five questions about space science concepts (Table 4.10). Moreover, the remaining multiple-choice questions were answered with a full scientific explanation by only half of the teachers and the highest percentage of full scientific explanations used to answer a question (Question 4 – What keeps the Moon there in space) was 59% (Table 4.10). Thus, full scientific explanations were not common answers to the children's questions. This supports past research (Appleton, 2008; Rennie et al., 2001) that clearly highlights teachers' lack of science background knowledge as an issue in science education.

The six teachers who participated in the study group were asked the same complex science questions as the 145 teachers who responded to the questionnaire. During interviews four of the six teachers could answer questions correctly showing that they had some understanding of lunar phenomena. Three of the six teachers were asked to explain why people only see one side of the Moon from Earth (Teacher 1, 3, & 6, Appendix F) but they did not know the current scientific explanation that the Moon spins slowly in synchronization with it's orbit of the Earth, so that one orbit of the Moon is the same length of time as one rotation on its axis and that is why only one side of the Moon is seen from Earth (Naylor & Keogh, 2000). Moreover, on the questionnaire only 45% of teachers answered the question about the Moon rotating on its axis with a full scientific explanation (Table 4.10). Thus, some concepts are more difficult for teachers to grasp than others. Another concept that is often held as an alternative concept is how the phases of the Moon occur. Thirty-six percent of teachers responding to the questionnaire did not know the current scientific explanation for this in Question 2 (How does the Moon get all of its shapes?) (Table 4.10). Four of the study group teachers answered this question in their interviews. Three teachers answered correctly with varying degrees of complexity, and one answered incorrectly (Appendix F). Similar findings showing teachers have gaps in their understanding of lunar concepts have been reported in the literature (Bayraktar, 2009; Lelliott & Rollnick, 2009; Plummer & Krajcik, 2010; Trumper, 2005; Trundle et al., 2008; Wilhelm et al., 2007). This is a concern because lunar concepts are part of the Australian Curriculum: Science as noted in the Elaborations and Science Understandings in Year 1 (ELBS706, ACSSU019), Year 3 (ELBS779, ACSSU048) and Year 7 (ELBS969, ELBS970, ELBS968, ACSSU165) (ACARA, 2012).

Teachers in this study appear to understand enough space science concepts to answer less than half of the questions children pose, however, the questions in Part 2 of the questionnaire were all Complex Questions. The answers they could choose on the questionnaire were based on direct answers teachers use, not a variety of responses such as, investigation, turning it back to the class to answer, and research from a secondary source. Thus, they had no choice but to provide a scientific explanation or an incorrect, incomplete or no answer. Perhaps if teachers are concerned about their understanding of science background knowledge they could respond in other ways to the children's Complex Questions and not try to formulate a scientific explanation. Then they would only have to rely on their science background knowledge for the other categories of questions (Yes/No Questions and Short Answer Questions). They may be more likely to have correct answers for Yes/No Questions and Short Answer Questions with their understanding of current scientific concepts.

5.2.3.2 The Development of Teachers' Science Background Knowledge from Research of Concepts Prior to Teaching a Science Unit

Teachers plan and prepare prior to teaching a unit of work and this should include confirming their understanding of relevant science concepts. It could be assumed that they would have a good understanding on that particular topic of science background knowledge. Teacher 2 described how he worked with the other two Year Six teachers at his school and would always research the science topic before teaching it, so he felt he wouldn't be ignorant of the topic if the children asked complex questions. "I wouldn't say I'd admit ignorance more than the others [responses] though. …If it was a mathematical question I'd be more confident, I'd know it most of the time anyway because of what we are studying - we always do the research before we teach it" (Appendix F, Teacher 2).

Teacher 1 (at the same school) agreed that she needed to do some reading before she taught a topic and that often if she didn't understand a concept she would ask her sister who is a High school science teacher (Appendix F, Teacher 1). Teachers 1, 2 and 3 described their teaching preparation in a way that showed they were developing skills and understandings through their teaching preparation rather than avoiding challenges by remaining rigidly with previously used activities and resources.

If this prior research and preparation to teach a concept is enhancing teachers' science background knowledge then it could be assumed that more experienced teachers would have a better understanding than teachers that are new to the role. However, in this study there was no significant difference between the science background knowledge of very experienced teachers and teachers with less than ten years experience (Table 4.11). This may mean that pre-service teachers are being well-prepared for teaching science and retain those understandings throughout their career. On the other hand, it may mean that practicing teachers are not progressing in their understanding of science concepts, such as those in space science, even though they are exposed to them in their teaching year after year. The required curriculum has been found to be the single most powerful determinant of teacher knowledge (Arzi & White, 2008) but perhaps they are teaching the same content each time and not further developing their own ideas. The introduction of a new science curriculum over the coming years might create a learning opportunity for teachers who have to change what they are teaching to meet the needs of the Australian Curriculum: Science. However, development of science background knowledge is facilitated by teachers' knowledge and interest in a subject (Arzi & White, 2008) and so planning and prior research alone may not be sufficient to enhance teachers' understanding of science content knowledge throughout their career, hence, a systematic, regular approach to professional learning is essential.

5.2.3.3 Science Background Knowledge and Teacher Confidence

The results from this study imply that teachers can answer some Complex Questions posed by children as four of the five Complex Questions on the questionnaire were answered with a full scientific explanation. However, the percentage of teachers choosing that answer was 50% or less. Thus, the assertion that teachers' lack confidence in their science background knowledge is justified. Many researchers explain that a teacher's lack of confidence in their science background knowledge limits their teaching of science (Goodrum, Cousins, & Kinnear, 1992; Goodrum & Yates, 1990; Rennie et al., 2001; Ward, 1997). A lack of confidence in their science background knowledge in turn limits their ability to answer children's questions with accurate scientific explanations. A reflection on Australian research of the last two decades by Appleton (2008) agreed that a lack of teacher science background knowledge has been blamed for teachers' low confidence and avoidance of science teaching in Australian primary schools. If background knowledge is a concern for teachers who want to answer children's questions with a scientific explanation, then that can be addressed with good quality resources that highlight both background knowledge and common alternative conceptions (Dawson, 2009). However, poor science background knowledge may not be the only cause of teachers' low confidence in teaching science and difficulties dealing with children's questions.

Teachers in the study group who were observed by the researcher responding to children's science questions had varying levels of understanding of science background knowledge. Four of the six teachers (Teacher 1, Teacher 2, Teacher 3 and Teacher 4) responded to the children's questions (Appendix E). Two of the teachers (Teachers 1 and 2) both from the large coastal college, seemed to have good science background knowledge and confidence in their ability to teach science and handle the children's questions. Teachers 3 and 4 had less developed understanding of science background knowledge. They answered the Complex Questions in their interviews incorrectly. Teacher 4, the novice teacher, answered interview questions incorrectly but was confident in her abilities in the classroom and responded to the children's questions in a range of ways that showed she valued their questions but didn't feel that she had to have all the answers. In contrast, Teacher 3, one of the three teachers from the large coastal college, attempted to answer the children's questions with scientific explanations or by saying "I don't know" or deflecting the question back to the class to answer. She seemed to lack confidence. If low confidence was purely a result of poor science background knowledge then both Teachers 3 and 4 should have struggled when dealing with the children's questions. Teacher 4 had strategies to handle the difficult questions that she could not answer, including grouping questions together for later research. So, perhaps Teacher 3's low confidence was not just from a lack of science background knowledge but may be linked to low self-esteem or perhaps poor science pedagogical content knowledge.

5.2.3.4 Science Pedagogical Content Knowledge and Teacher Confidence

Teachers may be able to use their general pedagogical knowledge across other subject areas but in every learning area some subject-specific pedagogical content knowledge is also necessary. Pedagogical content knowledge in science incorporates subject knowledge, an understanding of students and their possible misconceptions, knowledge of the curriculum and general pedagogical practices. Science is understood to be a subject that primary teachers have low confidence in and is in fact often avoided by primary teachers (Rennie et al., 2001). This is an issue that is not easily dealt with because mentoring experienced teachers in their reflective practice would be a costly and logistical problem for educational systems (Appleton, 2008).

Low confidence may not be purely a result of gaps in science background knowledge but rather from a combination of underdeveloped pedagogical content knowledge and poor science background knowledge. Good science teaching should be seen as continuing professional growth and development (Shallcross, Spink, Stevenson & Warrick, 2002). Thus, science pedagogical content knowledge (PCK) should develop over a teacher's career. Sixty of the teachers in this study had been teaching for more than ten years and should have developed sound pedagogical knowledge in science, but given that primary school teachers often don't have a background in the sciences (Rennie et al., 2001) it's possible that some of those teachers had the same science teaching experience every year and didn't learn any new science or ways to teach science throughout their career. All of the teachers in the study group had less than ten years experience (Table 4.4), which is not a long time as several years of teaching must pass before PCK is fully developed (Kind, 2009). Nevertheless, they were also volunteers so they possibly had a personal interest in teaching science and therefore may have been more confident than other teachers.

Pedagogical content knowledge may be the key to confident, competent teaching of science, as Fleer (2009) suggests, but there is still a need for teachers to have a good background understanding of science concepts. They need to be able to recognise opportunities to investigate with the children and they need to recognise their own, and the children's, alternative conceptions so the alternative conceptions are challenged and not perpetuated (Kallery & Psillos, 2001; Piggott, 2002). It is important that teachers can identify the children's alternative conceptions when they are presented, however, if they share alternative concepts with the children they may not be aware of them. A teacher's response that uses the children's questions as a basis for research is likely to make alternative conceptions less fruitful and therefore open to change.

In some of the questions from different classes it was difficult to identify alternative concepts, as the children asked mainly Yes/No Questions that were short and often simple. Teacher 2, 4 and 6 identified mistakes in the children's questions or understandings they did not have but these were not alternative views of scientific explanations, but rather genuine questions about something the children did not understand. Teacher 6 was asked to identify alternative conceptions that would need to be dealt with but she chose questions that presented teaching opportunities instead. She said: "That is probably something that you would have to deal with…. They wanted to know about him [the astronaut] and stuff so that would be quite an easy lesson" (Appendix F, Teacher 6).

Perhaps teachers 2, 4 and 6 spend so much of their time identifying teaching opportunities that switching to alternative conceptions in the interview was difficult for them. Teacher 3 may have shared her class' alternative concepts of the Moon 'disappearing' during the day or of gravity not existing on the Moon (Appendix E). Teacher 3, who was unsure of her science background knowledge, was able to identify some children's alternative conceptions but not her own or those she shared with the children (Appendix F, Teacher 3). For example, she didn't identify the alternative conception in the question – 'If there is no gravity how does space stay up?' Presumably this was because she believed there was no gravity on the Moon. She said in her interview with the researcher: … "the fact that because there is no gravity [on the Moon] everything is there forever or for an awful long time" (Appendix F, Teacher 3). She didn't reinforce the children's alternative conception because during the responses she did not use this question, however, she did not deal with it either. This is of concern because if a teacher does not recognize the alternative concept he or she cannot challenge the concept and help the class develop their understanding through research and investigation. This lack of pedagogical content knowledge may lead to reinforcing their alternative conceptions (Kallery & Psillos, 2001).

Appleton describes pedagogical content knowledge as "knowledge of subject matter, knowledge of students and possible misconceptions, knowledge of curricula, and knowledge of general pedagogy" (2008, p. 525). The first element of pedagogical content knowledge was discussed in 5.2.3.1 and the second in this section. The third, knowledge of curricula, is something that is addressed through school-based professional learning, especially when there is a change in curriculum like the present. However, as Arzi and White (2008) explained, the required curriculum has been found to be the single most powerful determinant of teacher knowledge. Perhaps that is because teachers are concerned with accountability or maybe deeper learning occurs for them when they are teaching others. Knowledge of curricula was not a focus of this study because the study took place during a period of transition to a new national science curriculum. The fourth element, teachers' pedagogical practices, was examined through observations and interviews of the study group of teachers and is discussed in section 5.2.3.5.

5.2.3.5 Pedagogical Content Knowledge – Pedagogy and Teachers' Views of Learning

All of the study group teachers involved in the question response events invited their classes to contribute their own ideas to answer the questions that were posed. For some, that may have been a way to avoid giving scientific explanations, especially if they had concerns about their science background knowledge. Nevertheless, the teachers appeared to be genuinely encouraging learning by stimulating discussion and by organizing how they would be responded to, so the children could deal with the questions themselves. A review of research in this field (Kind, 2009) summarized some key points about pedagogical content knowledge (PCK). Firstly, that willingness to improve and reflect were significant factors in making progress with becoming a good teacher of science. Secondly, there is little difference in the content knowledge of new teachers and expert teachers, which is consistent with results from this study. However, expert teachers made more extensive connections between knowledge in different contexts and exhibited a rich set of pedagogical skills, while beginners focused on transmitting content. This suggests that teachers who focus primarily on the transmission of knowledge have less developed PCK than teachers who display a variety of skills or strategies in the classroom.

An analysis of classroom observations from the four study group teachers used in the case studies (Appendix E) reflected their understanding of the way children learn through their responses to, or discussion of, the children's questions and gave an indication of the level of development of their pedagogical content knowledge. Teacher 1 appeared to view learning as a discovery that she needed to guide the children in because she responded to the questions her class asked in a range of comprehensive ways, often prompting them to rethink questions or answer simpler questions to help them with complex ones (Appendix E, Teacher 1). Teacher 3 appeared to view learning as listening to new ideas and accepting or assimilating them because she tried to answer all of the questions the children asked with scientific explanations (Appendix E, Teacher 3). She deflected the questions back to the children or said "I don't know" but it seemed to be often said with an air of concern rather than a specific strategy to help the children think for themselves. Teacher 4 asked the children 'What do we know about that?' to invite them to contribute to answering a question. She also grouped questions together to research later by circling questions about the same concept (Appendix E, Teacher 4). This would imply that she promoted herself as a facilitator and on a learning journey with the children. Teacher 5 seemed to view learning as a construction of understanding based on experiences and interactions because she believed the children's questions should be investigated with hands-on materials or modeled with suitable equipment with her questions and statements as a scaffold (Appendix E, Teacher 5). Thus, teachers' views of learning appear to be reflected in the responses they give to children's science questions.

The teacher responses also indicated different levels of PCK. Although all the teachers had less than ten years teaching experience Teacher 4 was the most recent in the profession. Her knowledge of space science concepts was adequate in the classroom environment and her pedagogy appeared to be sound, as she had good strategies to deal with the children's questions, but with less than a year of experience she is unlikely to have developed a high level of pedagogical content knowledge. Teacher 1 had a reasonable understanding of science concepts but struggled to explain some clearly. She also displayed many strategies to enhance learning for the children and in doing so exhibited a good level of pedagogical content knowledge (Appendix E). Likewise, Teacher 5 had a robust understanding of space science concepts and strong views about how her class learnt science that suggests she had a high level of pedagogical content knowledge (Appendix E). Teacher 3 had poor science background knowledge and tried her best to give answers and in doing so exhibited a lower level of pedagogical content knowledge (Appendix E).

5.2.3.6 Summary of Research Question 3 - What influence do science background knowledge and pedagogical content knowledge have on how teachers deal with children's questions?

This study confirms that teachers' lack of science background knowledge is still an issue in science education as it was found that approximately half of the teachers had inadequate science background knowledge to answer all the children's questions accurately. Thus, teachers' lack of confidence in their science background knowledge is influencing them to avoid giving immediate answers to the children's Complex Questions. Teachers in the study group who were aware of their gaps in science background knowledge used other means to respond to the children's questions.

Some concepts appear to be more difficult for teachers to grasp than others, particularly why we only see one side of the Moon from Earth and how phases of the Moon occur. Very experienced teachers with twenty or more years in the profession had marginally fewer correct answers on the questionnaire than teachers new to the role. This implies that teachers are not developing their understanding of science concepts throughout their career. Enhancement of science background knowledge is facilitated by teachers' knowledge and interest in a subject, and so the planning and prior research done by teachers each year may not be sufficient to enhance understanding throughout their career.

Two of the six study group teachers could answer questions with scientific explanations showing that they had a good understanding of lunar phenomena but the other two teachers that were observed responding to the children's questions in class, did not. Study group teachers who were confident of their science background knowledge were able to diagnose the children's alternative conceptions by identifying them in the children's questions, and teachers who held the same alternative conceptions as their class, were not.

Each of the study group teachers responded to the children's questions or discussed suitable responses that reflected their understanding of the way children learn. Their views of learning appear to influence the responses they have to children's science questions. The way they handled the children's questions was also an indicator of their level of pedagogical content knowledge, which varied amongst individual teachers. Teachers need to have both a grasp of the big concepts in the science curriculum and good pedagogical content knowledge to be competent, confident teachers of science. This is linked to how they utilize children's science questions, but so are other factors. These factors that impact the use of children's science questions will be discussed in section 5.2.4.

5.2.4 Research Question 4 - What do teachers identify as issues with responding to children's science questions?

The 145 teachers who responded to the questionnaire recognized the importance of children's science questions, particularly as a way to keep children motivated in class and provide a starting point for implementing interesting science units (Table 4.13). However, they agreed that there were factors that limit children's question-asking behaviours in science. Four issues were more prevalent than the others (Table 4.12). The first issue they were concerned about was the children's questions often deviating from curriculum goals of the lesson (Table 4.12). The second issue they highlighted was that they didn't know the answers to some of the more complex science questions the children were asking and felt that they should. The third most pressing issue for teachers was that they reported many of the children in their classes allowed a small number of their peers to ask all the questions. Finally, they were concerned about time pressures, as they believed there was not enough time to adequately deal with children's science questions in lessons.

Rennie et al. (2001) described four factors that limit general science teaching. These were concerns about a lack of: science background knowledge; resources; preparation time and concerns about an overloaded school curriculum. Teachers in this study considered issues in relation to children's science questions. Two issues they identified matched factors that limit the teaching of science described by Rennie et al.:

1. the issue of an overloaded school curriculum, which limits the time available for teaching science;
2. a lack of science background knowledge.

However, findings from this study identified two issues related to children's science questions that were not one of the limitations to teaching science reported by Rennie et al. (2001). Teachers in this study were concerned that only a small number of children in their classes were asking questions. They were also concerned about the children's questions deviating from the curriculum goals of the lesson, or unit of work.

5.2.4.1 Questions that can Trigger a Deviation from the Curriculum

The most concerning issue for teachers in this study was a pressure to meet curriculum goals while addressing children's science questions. This was supported by the research of Rennie et al. (2001). Twenty-three percent of the 145 teachers that completed the questionnaire indicated their concern about possible deviations from the curriculum when responding to children's questions (Table 4.12). This was also an issue for Teacher 2 in the study group. He felt that when the children's questions became 'silly' during a long discussion, the lesson would no longer be on task (Appendix F, Teacher 2).

A possible explanation for this could be that each new curriculum reform seems to restructure and refocus content but rarely appears to reduce it. In the last decade there have also been new challenges for teachers in the form of cross-curriculum priorities and general capabilities – elements of learning that don't 'belong' in the content of a subject but are part of many subjects and need particular attention, such as: literacy; numeracy; Education for Sustainability; and ICTs (ACARA, 2010). These are not timetabled events but may help to crowd the school day and put pressure on teachers to be selective about the use of class time. Engel and Randall (2008) examined teacher responses to children's questions during a prescribed task and found that teachers sometimes control activities and discourage children's questions in order to meet curriculum goals. The authors found teachers were redirecting children to the prescribed task to discourage them from asking questions that would deviate from the task the teachers needed to achieve. This present study supports that result as teachers in this study who responded to the questionnaire identified 'deviation from the lesson plan' as their primary issue when dealing with children's science questions (Table 4.12).

5.2.4.2 Questions that are Difficult to Answer

A dominating issue for primary teachers in the last decade is not having the background knowledge to teach science well (Biddulph et al., 1986; Harlen, 1996; Kallery & Psillos, 2001; Ward, 1997). It was also one of the four major concerns of teachers in this study. Twenty-eight percent of teachers that responded to the questionnaire were concerned about not knowing all the answers to children's science questions (Table 4.12). A further 36% of additional comments from teachers related to teachers' background knowledge in science and "doing the best they can" given that they don't always know the answers to the children's questions (Table 4.13). Teacher 1 and Teacher 3 were also concerned about not knowing the answers to the children's questions (Teacher 1 and 3, Appendix F). This is a concern given that teachers may 'shut down' questioning in favour of greater security when they dread being unable to answer the children's questions (Bowker, 2010). Perhaps this could account for the apparent lack of children's questions in science as children progress through primary school (Chin et al., 2002). However, with access to digital information, which is continually increasing, answers to questions are easily found from secondary sources. So not being able to answer a question could be seen as a good sign that the children are asking interesting questions that need further investigation and cannot be answered with a brief explanation. Perhaps a concern here is that teachers feel a lack of confidence in what they know, as discussed in the previous section.

5.2.4.3 Questions that are Asked by Only a Select Number of Children

Another issue teachers identified with using children's questions in the classroom was only a small number of children ask all the questions (Table 4.12). Some children in the class become the only children who ask questions and the other children let them develop that role. In this study, questions were not spontaneous and part of a daily lesson, so there was no data to explore this issue further. Questions were posed by most of the children in each class, following a 'hands up' approach from the teacher. However, Rop's study (2003) of spontaneous inquiry questions in High school chemistry classrooms found that in High School when the motivated learners ask questions, the others stop. The students who ask questions become social pariahs because the other students isolate or tease them and the teacher dismisses the children's questions. He explains that only a small number of children will persist with this behaviour. If this is occurring in classes of younger children then it could also explain the apparent decrease in questions as the children progress through school and why teachers are concerned by only a small number of children – the same children all the time – asking all the questions. Teachers can encourage all the children in the class to ask questions by using strategies such as the 'Post Box Technique' (Bell, 1993) where questions are asked or answered on a slip of paper and posted for the teacher or other children to review. This makes the process anonymous and eliminates the concern of children that they will be isolated as one of the few 'question-askers' in the class.

Teacher 6 in the study group explained that her class asked questions but they usually worked in small groups. She believed they were more confident with questioning in that situation (Appendix F, Teacher 6). This could be a useful strategy to deal with the issue of a small number of children asking all the questions. It would reduce the apparent isolation of children who ask the questions in class and allow more children to pose questions with the limited audience of a small group. Teacher resources support small group work in science, such as the Australian Academy of Science's Primary**Connections** – *linking science with* *literacy* program. That program provides teachers with the support they need to teach their classes how to work collaboratively in pairs or groups of three (Primary**Connections**, 2009, Appendix 1 'How to organise collaborative learning teams').

5.2.4.4 Questions and the Constraint of Time

Teachers in this study also reported that they had concerns about time pressures that discouraged them from utilizing children's questions. Fifteen percent of the 145 questionnaire respondents stated that not having enough time to deal with children's questions was an issue for them (Table 4.12). Teacher comments on the questionnaire also addressed time constraints in the classroom, a lack of resources and space as a problem when dealing with children's science questions (Table 4.13). The six study group teachers did not identify time constraints as an issue for them but a finding from a study by Engel and Randall (2008) supports the view of the questionnaire respondents, that teachers sometimes discourage children's questions in order to work within time constraints. Hence, if teachers are genuinely concerned about time pressures when dealing with children's science questions then there could be an argument for ignoring some of the posed questions. Watts, Alsop et al. (1997) found that teachers did ignore some questions however teachers in the present study didn't believe that ignoring children's questions was a suitable response. Only 11 teachers (3%), of the 145 who completed the questionnaire, indicated that they 'sometimes keep the lesson moving and don't answer the question at that time' (Table 4.8). However, if teachers are struggling for time then it is possible they are ignoring or dismissing some questions; perhaps those they consider to be 'silly' or not relevant to the content of the lesson.

5.2.4.5 Summary of Research Question 4 - What do teachers identify as issues responding to children's science questions?

The most concerning issue for teachers in this study was the pressure to meet curriculum goals while addressing children's science questions. The curriculum has developed in scope and detail crowding the school day and putting pressure on teachers to be selective about how they spend their time. Teachers also lacked confidence in their ability to answer children's questions with a scientific explanation, which was an issue for them and may lead to reverting to a more secure teacher-directed approach. Opportunities to research answers on the Internet and using an inquiry approach, where children's questions are investigated, may mean that *not* answering the questions could be a suitable response from teachers. By not providing a definitive answer to the children's questions the children would need to find the answers from other sources, perhaps with the teacher's guidance. Moreover, teachers who completed the questionnaire were concerned about only a small number of children asking all the questions, but that was not observed in the study group of teachers. In addition, teachers in this research didn't believe they were ignoring children's science questions, but other research challenges this assumption (Watts, Alsop et al., 1997). Perhaps they are dismissing those questions that they believe are not a good use of valuable class time, as a lack of time to deal with the children's questions was a further issue for the teachers in this research. Essentially, they could be filtering the questions and judging the questions that would be a good fit to the context at the time.

5.3 Contributions of the Research

The specific contribution of this research to the literature about children's science questions and teacher's responses is stated briefly as:

- Children in different classes and in different schools ask similar questions about scientific phenomena. This appears to also be true of classes that have asked similar questions up to fifteen years ago;
- Questions requiring an answer of a brief scientific explanation were the most frequently asked by children in this study. Half of these questions could be answered with just a number;
- Classes that asked a higher percentage of Complex Questions had teachers who did not give definitive answers;
- Researching answers on the Internet was a valued response to children's science questions from teachers but they favoured working with the children to do that;
- Teachers have gaps in their science background knowledge and lack confidence in their ability to answer children's questions with current scientific theory;
- Observations of teachers in the study group highlight the impact of good pedagogical knowledge;
- Issues that arose for teachers with handling children's science questions confirmed those nominated in past studies.

Chapter Six will provide a summary of the research findings and recommendations for each of the four research questions.

CHAPTER SIX: SUMMARY, RECOMMENDATIONS, FUTURE RESEARCH AND CONCLUSION

This section will review the findings of each of the four research questions and provide recommendations in light of those findings. Questions and ideas that arise from the discussion of results in this study will be identified as possible directions for future research. Finally, a summary of the highlights from each chapter will conclude the research.

6.1 Summary of Findings

6.1.1 Research Question 1 - What types of science questions do children ask in response to stimulus pictures of lunar phenomena?

The types of questions children ask about lunar phenomena in different classes and in different schools are very similar and are probably not influenced by location, culture or society. This study found that questions collected in Australia were similar to those from a South African study (Spargo & Enderstein, 1997). There was, approximately, a fifteen year gap between the South African study and the present study thus, the passing of time does not seem to greatly change the type of questions children ask about lunar concepts in Year 6.

More than half the questions the children asked were Short Answer Questions. Yes/No Questions and Complex Questions were posed less frequently. The vast amount of information presented appealingly on the Internet and available to children in school may be influencing the children to ask fewer Complex Questions and more questions requiring a brief answer or a Yes/No response. Classroom culture may also have an affect on questioning. If teachers are asking questions that only require a brief response that is just recall of information, and this is the established culture in the classroom, then it follows that children's questions may reflect the teacher's questioning style.

Yes/No Questions represented less than a quarter of the questions in five of the study group classes and nearly half of the questions in one class. They do not appear to be a dominant category of science questions. Short Answer Questions were the most frequent category of questions posed by five of the study group classes. As many as half of these Short Answer Questions required merely a numerical answer, such as: a date, or a quantity. The classes that were seated in a U shape or in a modified U shape asked almost no Short Answer Questions requiring a numerical answer, fewer than the other classes, so consideration should be given to the physical environment in classrooms, such as the placement of desks and displays of children's questions, as a way of encouraging more problem-solving questions.

It appears that the classes that asked the highest percentage of Complex Questions had teachers who did not give direct or definitive answers to the children's questions, which is encouraging because it means there is less need to rely on teachers' science background knowledge. Supporting the children's discussions and empowering them to be active participants in the responses to questions was a successful way to encourage Complex Questions. Thus, teachers need to be aware of the role they play in supporting student inquiry by using question techniques and showing respect to the children's questions as a starting point for study in the classroom. Explicitly teaching questioning skills and praising the children's efforts is also a successful way to encourage Complex Questions. Complex Questions are promoted in the Australian Curriculum: Science and include questions that can be investigated. As a consequence, Complex Questions are desirable in science lessons in order to better attend to the Science Inquiry Skills strand of the Australian Curriculum: Science.

6.1.2 Research Question 2 - What do teachers believe are suitable responses to children's science questions?

Teachers involved in the study group displayed different methods of responding to the children's questions, some of which were observed and reported in past studies (Watts, Alsop et al., 1997). The strategies they used, that had not been identified previously, all implied good general pedagogical knowledge. These included: breaking the questions down into simpler ones, asking further questions to deepen understanding, and researching the answer. The study group teachers and teachers who responded to the questionnaire both relied upon information sources like the Internet to find answers to the questions children asked in class but they favoured working with the children to find information. Although this was a response highly valued by teachers in this study it was not recognised in older research, possibly because of the increase in ICT availability in the last few years. 'Ignoring the question as an interruption' was a teacher response neither observed in this study nor supported by the teachers. However, it seems unlikely that every single question the children ask is dealt with to the children's satisfaction in class. Teachers valued hands-on investigations as a way to deal with children's Complex Science Questions and they could identify questions that would be suitable to use. However, questionnaire respondents stated their intention to give brief scientific explanations to answer the children's questions whereas the study group teachers were enthusiastic about the use of hands-on investigations.

6.1.3 Research Question 3 – What influence do science background knowledge and pedagogical content knowledge have on how teachers deal with children's questions?

Teachers in the present study had gaps in their understanding of lunar concepts. Questions about the Moon's gravity, the Moon's rotation and the phases of the Moon were answered incorrectly by half of the teachers. This is an issue because these concepts are part of the Australian Curriculum: Science. Teachers who responded to the questionnaire appear to understand enough space science concepts to answer less than half of the questions children pose. A lack of confidence in their science background knowledge, in turn, limits their ability to answer children's questions and develop current scientific explanations. In this study there was no significant difference between the science background knowledge of very experienced teachers and teachers with less than ten years experience, suggesting that teachers are not deepening their understanding of science content throughout their career.

The study group teachers' responses to children's science questions appear to be influenced by their pedagogical knowledge. Their responses reflect their views of learning, their recognition of alternative conceptions and their confidence to handle all the children's questions. Findings from this study show that teachers with good general pedagogical knowledge can deal with children's Complex Questions, even when they cannot answer with a scientific explanation. However, teachers need to have both a grasp of the big concepts in the science curriculum and good pedagogical content knowledge to be competent, confident teachers of science.

6.1.4 Research Question 4 - What do teachers identify as issues with responding to children's science questions?

The most dominant issue reported by teachers in this study was a pressure to meet curriculum goals while addressing children's science questions. If teachers have a focus on tasks and curriculum then they may discourage children's questions in class. If teachers are discouraging questions, this could explain why children seem to ask fewer questions as they progress through primary school (Chin et al., 2002).

The second major issue for teachers was not being able to answer all the children's science questions but this could be seen as a good sign that the children are asking interesting questions that need further investigation and that cannot be answered immediately with a brief explanation. Perhaps the concern here is that if teachers lack confidence in what they know and if they dread the children's Complex Questions, they may discourage the children's questions for this reason too.

Past research shows that only a small group of children in each class ask all the questions and these are the motivated learners (Rop, 2003). In this study, teachers were concerned about this issue but it was not observed in the question-gathering sessions because of the format the sessions followed. Strategies can be used to make question-asking anonymous in the classroom which eliminates the concern for children that they will be isolated as one of the few ‘question-askers’ in the class. Also, having expectations that everyone in the class will pose questions and pausing longer to give children time to formulate questions could help some children to become question-askers in the classroom.

The fourth major issue that concerned teachers in this study was the lack of time to utilise the children’s Complex Questions. This might be difficult for them to resolve. If teachers value children’s questions in science they will prioritize them and make time to deal with them instead of viewing them as an ‘extra’. Perhaps their own curriculum goals could be met through a focus on what the children are interested in investigating.

6.2 Recommendations

The following recommendations reflect the findings and discussion of the four research questions. Overall, the recommendations emphasize the professional development needs of teachers and possible enhancements or additions to teacher resources in science.

Recommendation 1, from Research Question 1

It could be beneficial to teachers to have access to compiled lists of likely questions on a range of science topics from the Australian Curriculum: Science. Syllabus support materials or teacher resource materials would be a suitable format to incorporate children’s potential science questions. This would give teachers a starting point for units of work or investigations with their own class and would support an inquiry approach to teaching in their classrooms.

Recommendation 2, from Research Question 2

Teacher professional learning should maintain an emphasis on how to support children to answer their own questions through hands-on investigations and how to source useful and reliable information on the Internet. If children are asking a higher percentage of Short Answer Questions than Complex Questions and are using the Internet to look for answers then it would be desirable for teachers to continue to show children how to be critical of sources of information for bias. Teachers also need to be able to recognize alternative conceptions and hold a view of science that is compatible with the Australian Curriculum: Science, of science as a human endeavour.

Recommendation 3, from Research Question 3

A combination of science background knowledge and pedagogical content knowledge in teacher training, and professional learning for practicing teachers, would be desirable. In doing so teachers would learn the concepts to be taught in the curriculum as well as common alternative conceptions of those concepts and an understanding of how children learn in science. They would then be able to challenge the children's ideas, facilitate collaborative inquiry and discussion and be confident when dealing with children's Complex Questions. Professional learning for practicing teachers should appeal to their interests and be long-term so that teachers' science content knowledge develops throughout their career.

Recommendation 4, from Research Question 4

Professional learning should focus on the role of the teacher in an inquiry approach and how to explicitly teach the desired question types. To encourage Complex Questions teachers would need to promote a culture of question asking in their classrooms so children's curiosity and questions are valued. Teachers would also benefit from resources that suggest and explain strategies, such as question starters on cards, to encourage questions from all students and show teachers how to utilize them in inquiries so that curriculum goals are also met.

6.3 Suggestions for Future Research

To further understand how teachers deal with children's science questions, there are several areas that could be further investigated including:

- children's motivation for asking complex questions;
- the categories of science questions asked in a natural classroom setting;
- ways in which teachers scaffold the children's learning when teaching them to pose scientific questions, as this is a skill of the profession and would benefit all teachers;
- teachers' use of diagrams and role-play to aid scientific explanations;
- curiosity in science, an examination of contexts that children are curious about;
- teachers' perceptions about changing their teaching approach to a more collaborative inquiry approach in science.

6.4 Conclusion

Children's questions can be the impetus for hands-on investigations and a portal to their understanding and interests in science. Thus, discussion about, and focus on children's science questions is important in light of schools' implementation of the Australian Curriculum: Science in the coming years. This study investigated the types of science questions children ask in response to visual stimuli of lunar phenomena. It also examined teachers' responses to children's questions about lunar phenomena through observations, and interviews with a study group, and through questionnaires. A review of the literature highlighted the importance of children's questions, however there has been proportionally little research done in this area.

Significant findings from this research were that there was consistency in the children's questions. Common questions were found in all six of the study group classes and these were similar, in turn, to children's questions identified from the literature, including those posed by 9 to 11 year olds in South Africa more than 15 years ago. It seems that questions between classes and schools are alike and can remain constant over time, which makes them useful as a teaching resource.

Other significant findings were that children's Short Answer Questions requiring brief, often simple, answers were the most common of their questions. However, Complex Questions have been reported in the literature as the most common. It appears that teachers who do not give quick or definitive answers to the children's questions encourage them to ask more detailed questions and explore their own answers. Classroom culture and the physical environment can influence children's question-asking in science, as well.

Teachers identified being unable to answer all the children's questions as an issue in science teaching. This is clearly a concern for them although interestingly, Complex Questions in science lessons could be seen as a positive occurrence. Teachers appear to have gaps in their understanding of lunar phenomena and consequently, some of the children's Complex Questions were more difficult to answer than others. Teachers' lack of confidence in their science background knowledge may be justified given that only 48.75% of 145 teachers could answer the children's Complex Questions with a full, current scientific explanation. Only the study group teachers that appeared confident of their understanding of science concepts were able to identify the children's alternative conceptions present in their questions. Primary teachers in this research did not develop their science background knowledge through their teaching experience, even though other research (Arzi & White, 2008) would suggest that curriculum requirements determine knowledge development.

Teachers in the study group had a range of suitable responses to the children's questions. They grouped questions together to answer them, they involved the children in answering their own questions, they broke Complex Questions down into simpler versions, they asked further questions to clarify understanding, and they gave brief scientific explanations. These findings show that teachers with good pedagogical knowledge can deal with children's Complex Questions, even when they cannot answer with a scientific explanation. Consequently, perhaps primary teachers could rely more on their pedagogical content knowledge in science, than their science background knowledge, to respond to children's science questions. Despite the importance of having a good understanding of science concepts in teaching, if their pedagogical content knowledge were stronger perhaps teachers would feel more confident and competent and be less concerned about having all the answers.

Teachers in this research agreed with some typical responses to children's science questions described in the literature, namely: Saying "What do you think?", "I don't know", doing a hands-on investigation and researching the question, or giving a scientific explanation. However, they did not believe that ignoring the children's question as an interruption was a viable response to give. Nevertheless, they identified issues of 'curriculum pressures' and 'a lack of time' as a hindrance to utilizing children's science questions in the classroom hence, it would be unusual if they did not ignore some of the children's questions as a distraction to the aims of their lesson. Past research into observing teachers in a natural classroom science lesson verifies their apparent dismissal of some questions.

Recommendations for teachers and schools were made based on the analysis of the data gathered in this study. These were: i) a professional learning focus on Pedagogical Content Knowledge and Science Background Knowledge together; ii) clarification of the role of the teacher in inquiry; iii) workshops to explicitly teach the desired question types; iv) exploration of ways to promote a culture of question-asking in the classroom; v) workshops on turning children's questions into questions that can be investigated with hands-on materials or researched on the Internet (with attention to useful and reliable sources of information); and, vi) the development of teacher resources that identify children's potential questions in relation to science concepts in the curriculum and that provide strategies to utilize the questions in student-led inquiries.

REFERENCES

Allison, A.W., & Shrigley, R.L. (1986). Teaching children to ask operational questions in science [Electronic version]. *Science Education*, *70* (1), 73-80.

Anderson, R.D. (2007). Inquiry as an organising theme for science curricula. In S.K. Abell & N.G. Lederman (Eds) *Handbook of research on science education* (pp. 807-830) [Electronic version]. Mahwah, NJ: Lawerence Erlbaum Associates, Inc.

Anderson, R.D. & Krathwohl, D.R. (2001). A taxonomy for learning, teaching and assessing: A revision of Bloom's taxonomy of educational objectives (complete edition). New York: Longman. In Chin, C., & Osborne, J. (2008). Children's questions: a potential resource for teaching and learning in science [Electronic version]. *Studies in Science Education, 44* (1), 1-39.

Anna, B. (2002). "Who will I choose and who will choose me?" Using warm up and sociometry to facilitate a progressive classroom culture [Electronic version]. *ANZPA Journal, 11,* 5-14.

Appleton, K. (2007). Elementary science teaching. In S.K. Abell & N.G. Lederman (Eds) *Handbook of research on science education* (pp. 493-453) [Electronic version]. Mahwah, NJ: Lawerence Erlbaum Associates, Inc.

Appleton, K. (2008). Developing Science Pedagogical Content Knowledge Through Mentoring Elementary Teachers [Electronic version]. *Journal of Science Teacher Education*, *19*, 523–545.

Arzi, H.J. & White R.T. (2008). Change in teachers' knowledge of subject matter: a 17-year longitudinal study [Electronic version]. *Science Education, 92* (2), 221-251.

Australian Curriculum, Assessment and Reporting Authority (ACARA). (2009). *Shape of the Australian curriculum: science*. Retrieved June 20, 2009, from ACARA website: http://www.acara.edu.au

Australian Curriculum, Assessment and Reporting Authority (ACARA). (2010). *Implementation.* Retrieved July 23, 2011, from ACARA website: http://www.acara.edu.au/acara_update_30032010.html#towards

Australian Curriculum, Assessment and Reporting Authority (ACARA). (2011). Retrieved May 26, 2011, from Australian Curriculum website: http://www.australiancurriculum.edu.au/Science/Implications-for-teaching-assessment-and-reporting

Australian Curriculum, Assessment and Reporting Authority (ACARA). (2012). Retrieved November 12, 2012, from Australian Curriculum website: http://www.australiancurriculum.edu.au/Science/ Search?q=moon

Baram-Tsabari, A., & Yarden, A. (2005). Characterising children's spontaneous interests in science and technology. International journal of Science Education, 27 (7), 803-826. In Chin, C., & Osborne, J. (2008). Children's questions: a potential resource for teaching and learning in science [Electronic version]. *Studies in Science Education, 44* (1), 1-39.

Bardeen, K. (2000) *Improving student science literacy through an inquiry-based, integrated science curriculum and review of science media* [Electronic Version]. Unpublished Masters Thesis, Saint Xavier University, Illinois, United States of America.

Bayraktar, S. (2009). Pre-service Primary teachers' ideas about lunar parts [Electronic Version]. *Journal of Turkish Science Education, 6 (2), 12-23.*

Baxter, J. (1989). Children's understanding of familiar astronomical events [Electronic version]. *International Journal of Science Education, 11* (5), 502-513.

Bell, B. (1993). *Taking into account students' thinking: A teacher developmental guide.* Hamilton, New Zealand: Centre for SMER, University of Waikato.

Biddulph, F., Osborne, R. & Freyburg, P. (1985). Investigating learning in science at the Primary school level [Electronic version]. *Research in Science Education, 13,* 223-232.

Biddulph, F., Symington, D. & Osborne, R. (1986). The place of children's questions in primary science education [Electronic version]. *Research in Science and Technological Education, 4* (1), 77-88.

Bloom, B.S., Engelhart, M.B., Furst, E.J., Hill, W.H., & Krathwohl, D.R. (1956). Taxonomy of educational directives: The classification of educational goals (Handbook 1: Cognitive domain). New York: Longmans Green. In Chin, C., & Osborne, J. (2008). Children's questions: a potential resource for teaching and learning in science [Electronic version]. *Studies in Science Education, 44* (1), 1-39.

Bowker, M. (2010). Teaching students to ask questions instead of answering them [Electronic version]. *The NEA Higher Education Journal, Fall*, 127-134.

Burgoon, J.N., Heddle, M.L., & Duran, E. (2010). Re-examining the similarities between teacher and student conceptions about physical science [Electronic version]. *Journal of Science Teacher Education, 22*, 101-114.

Bush, G. (2006). Learning about learning: from theories to trends [Electronic version]. *Teacher Librarian*, *34* (2), 14-18.

Carr, N. (2008). Is Google making us stupid? [Electronic version]. *Yearbook of the National Society for the Study of Education, 107*: 89–94.

Cazden, C.B. (1986). *Classroom discourse*. New Haven: Heinemann.

Chin, C., Brown, D., & Bruce, B. (2002). Children-generated questions: a meaningful aspect of learning in science [Electronic version]. *International Journal of Science Education, 24* (5), 521-549.

Chin, C. & Kayalvizhi, G. (2002). Posing problems for open investigations: What questions do pupils ask? Research in Science and Technological Education, 20 (2), 269-287. In Chin, C., & Osborne, J. (2008). Children's questions: a potential resource for teaching and learning in science [Electronic version]. *Studies in Science Education, 44* (1), 1-39.

Chin, C., & Osborne, J. (2008). Children's questions: a potential resource for teaching and learning in science [Electronic version]. *Studies in Science Education, 44* (1), 1-39.

Creswell, J.W. (2008). *Educational Research*. 3rd edn. New Jersey: Pearson Education.

Cuccio-Schirripa, S., & Steiner, H.E. (2000). Enhancement and analysis of science question level for middle school children [Electronic Version]. *Journal of Research in Science Teaching, 37,* (2), 210–224.

Dawson, V. (2009). *Science is Primary, executive summary*. Canberra: Australian Academy of Science.

Department of Education, Science and Training (DEST). (2004). *Scientific literacy progress map.* Retrieved on October 26, 2009, from http://cms.curriculum.edu.au/sear/

Dillon, J.T. (1988). *Questioning and teaching: a manual of practice* [Electronic version]. New York: Teachers College Press.

Engel, S., & Randall, K. (2008). How teachers respond to children's inquiry [Electronic version]. *American Educational Research Journal, 46 (1),* 183-202.

Fleer, M. (2009). Supporting scientific conceptual consciousness or 'Learning in a roundabout way' in play-based contexts [Electronic version]. *International Journal of Science Education, 31* (8), 1069-1089.

Fleer, M. & Hardy, T. (2001). *Science for children: developing a personal approach to teaching* [Electronic version]. 3rd edn. Frenchs Forest: Pearson Education Australia.

Gess-Newsome, J. (2001). Introduction. In J. Gess-Newsome, N. Lederman (Eds.). *Examining pedagogical content knowledge*, 4. Dordrecht, The Netherlands: Kluwer.

Goodrum, D., Cousins, J. & Kinnear, A. (1992). The reluctant Primary school teacher [Electronic version]. *Research in Science Education, 22*, 163-169.

Goodrum, D. & Yates, S. (1990). How confident are Primary school teachers in teaching science? [Electronic version]. *Research in Science Education, 20*, 300-305.

Green, D. W. & O'Brien, T. (2002). The Internet's impact on teacher practice and classroom culture. [Electronic version]. *Technological Horizons in Education, 29* (11), *44-51.*

Guimaraes, M.P. & Gnecco, B.B. (2007). Teaching astronomy and celestial mechanics through Virtual reality [Electronic version]. *Computer Application in Engineering Education, 17,* 196-205.

Haefner, L.B. & Zembal-Saul, C. (2001). *Engaging in science as inquiry: Prospective elementary teachers' learning in the context of an innovative life science course* [Electronic Version]. Paper presented at the annual meeting of the American Educational Research Association, Seattle. Retrieved on August 8, 2008 from ERIC.

Harlen, W. (1996). *The teaching of science in primary schools* (2nd edn.). London: David Fulton Publishers.

Harlen, W. (2001). *Primary science: taking the plunge.* Portsmouth, NH: Heinemann.

Harlen, W. (2006). *Teaching, learning & assessing science 5-12* (4th edn.). London: Sage Publications.

Harry, V. (2003). *Productive questions* [Electronic Version]. Retrieved on February 17, 2009 from http://www.maisk-6scienceinquiry.org

Jelly, S. (2001). Helping children raise questions – and answering them. In W. Harlen (Ed.), *Primary science: taking the plunge* (pp. 36-47). Portsmouth, NH: Heinmann.

Joyce, B., Weil, M., & Calhoun, E. (2009). *Models of teaching* (8th edn.). Boston/London: Pearson.

Kallery, M., & Psillos, D. (2001). Pre-school teachers' content knowledge in science: their understanding of elementary science concepts and of issues raised by children's questions [Electronic version]. *International Journal of Early years Education, 9* (3), 165-179.

Kind, V. (2009). Pedagogical content knowledge in science education: perspectives and potential for progress [Electronic version]. *Studies in Science Education, 45* (2), 169-204.

Kuiper, E., Volman, M. & Terwel, J. (2005). The Web as an information resource in K-12 education: Strategies for supporting students in searching and processing information [Electronic version]. *Review of Educational Research, 75* (3), 285-328.

Kur, J., & Heitzmann, M., (2008). Attracting children's wonderings [Electronic version]. *Science and children, 45* (5), 28-32.

Kurose, A. (2000). Eyes on science: asking questions about the Moon on the playground, in class, and at home. In J. Minstrell & E.H. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp. 139-147). Washington, DC: American Association for the Advancement of Science.

Lelliott, A. & Rollnick, M. (2009). Big ideas: A review of astronomy education research 1974-2008 [Electronic Version]. *International Journal of Science Education, 32* (13), 1771-1799.

Lim, C. P., Pek, M. S. & Chai, C. S. (2005). Classroom management issues in Information and Communication Technology (ICT) – Mediated learning environments: Back to the basics [Electronic version]. *Journal of Educational Multimedia and Hypermedia, 14 (4),* 391-414.

Loughran, J., Mulhall, P. & Berry, A. (2008). Exploring pedagogical content knowledge in science teacher education [Electronic version]. *International Journal of Science education, 30* (10), 1301-1320.

Miller, J., Mitchell, J., & Brown, J. (2005). African refugees with interrupted schooling in the high school mainstream: Dilemmas for teachers [Electronic version]. *Prospect, 20* (2), 19-33.

Naylor, S. & Keogh, B. (2000). *Concept Cartoons in science education.* Cheshire: Millgate House.

Nuffield Primary Science. (1997). *Understanding science ideas, a guide for primary teachers*. London: Collins Educational.

Nuthall, G. (1999). Introduction and background, Monograph [Electronic version]. *Journal of Educational Research, 31* (3), 141-256.

Nystrand, M. (1997). *Opening dialogue*. New York: Teachers College Press.

Oliver, R., Haig, Y. & Groate, E. (2009). Addressing the educational challenges faced by African refugee background students: Perceptions of West Australian stakeholder [Electronic version]. *ESOL in Context, 19* (1), 23-38

Pallant, J. (2007). *SPSS survival manual* (3rd edn.). Crows Nest: Allen & Unwin.

Pauling, B. (2008). Engaging the digital natives. In T. Evans, M. Haughey, D. Murphy (Eds.), *International Handbook of Distance Education* (385-417) [Electronic version]. Bingley, United Kingdom: Howard House.

Pedrosa de Jesus, H., Teixeira-Dias, J., & Watts, M. (2003). Questions of chemistry [Electronic version]. *International Journal of Science Education, 25* (8), 1015-1034.

Piggott, N. (2002). CPC-7 Science, a question-driven science curriculum [Electronic version]. *Investigating, 18* (2), 30-31.

Pizzini, E.L. & Shepardson, D.P. (1991). Student questioning in the presence of the teacher during problem solving in science. School Science and Mathematics, 91, 348-352. In C. Chin & J. Osborne (2008). Children's questions: a potential resource for teaching and learning in science [Electronic version]. *Studies in Science Education, 44* (1), 1-39.

Plourde, L.A., & Alawiye, O. (2003). Constructivism and elementary preservice science teacher preparation: knowledge to application [Electronic version]. *College Student Journal, 37,* (3), 334- 341.

Plummer, J.D., & Krajcik, J. (2010). Building a learning progression for celestial motion:

Elementary levels from an Earth-based perspective [Electronic version]. *Journal of Research in Science Education, 47* (7), 768-787.

Prensky, M. (2001). Digital natives, digital immigrants [Electronic version]. *On the Horizon*, *9,* (5).

Primary Connections. (2008). *Marvellous micro-organisms*. Canberra: Australian Academy of Science.

Primary Connections. (2009). *Light fantastic*. Canberra: Australian Academy of Science.

Queensland Studies Authority. (1999) *Years 1 to 10 Science Syllabus*. Retrieved on August 27, 2010 from http://www.qsa.qld.edu.au/downloads/early_middle/kla_science_syll.pdf

Rennie, L., Goodrum, D., & Hackling, M. (2001). Science teaching and learning in Australian schools: results of a national study. *Research in Science Education, 31,* 455-498.

Rice, J. & Neureither, B. (2006). An Integrated Physical, Earth, and Life Science Course for Pre-Service K-8 Teachers [Electronic version]. *Journal of Geoscience Education, 54* (3), 255.

Rop, C. (2002). The meaning of children's inquiry questions: a teacher's beliefs and responses [Electronic version]. *International Journal of Science Education, 24* (7), 717-736.

Rop, C. (2003). Spontaneous inquiry questions in high school chemistry classrooms: perceptions of a group of motivated learners [Electronic version]. *International Journal of Science Education, 25* (1), 13-33.

Roth, W-M. & Roychoudhury, A. (1993). The development of science process skills in authentic contexts. Journal of Research in Science Teaching, 30 (2), 127-152. In C. Chin & J. Osborne (2008). Children's questions: a potential resource for teaching and learning in science [Electronic version]. *Studies in Science Education, 44* (1), 1-39.

Royal, V. H. (2003). Internet savvy students [Electronic version]. *Phi Delta Kappan, 84* (5), 343-407.

Schmitt, F.F. & Lahroodi, R. (2008). The epistemic value of curiosity [Electronic version]. *Educational Theory, 58*, 125–148.

Shallcross, T., Spink, E., Stevenson, P. & Warrick, P. (2002). How Primary trainee teachers perceive the development of their own scientific knowledge: links between confidence, content and competence? [Electronic version]. *International Journal of Science Education, 24* (12), 1293-1312.

Sharp, J. & Kuerbis, P. (2005). Children's ideas about the solar system and the chaos in learning science. *Inc. Science Education, 90*, 124 – 147.

Symington, D.J. (1980). Scientific problems seen by primary school pupils. Unpublished Ph.D. Thesis*,* Monash University. In F. Biddulph, D. Symington & R. Osborne (1986). The place of children's questions in primary science education [Electronic version]. *Research in Science and Technological Education, 4* (1), 77-88.

Skamp, K. (1998). *Teaching primary science constructively*. Sydney: Harcourt.

Spargo, P., & Enderstein, L.G. (1997). What questions do they ask? Ausubel rephrased [Electronic Version]. *Science and Children, 34* (6), 43-45.

Swackhamer, L.E., Koellner, K., Basile, C. & Kimbrough, D. (2009). Increasing the self-efficacy of inservice teachers through content knowledge [Electronic Version]. *Teacher Education Quarterly,* Spring 2009.

Swatton, P. (1992). Children's language and assessing their skill in formulating testable hypotheses. British Education Research Journal, 18 (10), 73–85. In C. Chin & J. Osborne (2008). Children's questions: a potential resource for teaching and learning in science [Electronic version]. *Studies in Science Education, 44* (1), 1-39.

Trumper, R. (2005). Teaching future teachers basic astronomy concepts—seasonal changes—at a time of reform in science education [Electronic Version]. *Journal of Research in Science Teaching, 43* (9), 879-906.

Trundle, K.C., Troland, T.H. & Pritchard, T.G. (2008). Representations of the Moon in children's literature: An analysis of written and visual text [Electronic Version]. *Journal of Elementary Science Education, 20* (1), 17-28.

Tytler, R. (2002). Teaching for understanding in science: constructivist/conceptual change teaching approaches [Electronic Version]. *Australian Science Teachers Journal, 48* (4), 30-35.

Ugaste, A., & Oua, T. (2007). Teachers' experiences in child-centered education in Estonia. *YC Young Children* [Electronic Version]. *62* (6), 54-56.

van Zee, E.H., Iwasyk, M., Kurose, A., Simpson, D., & Wild, J. (2001). Student and teacher questioning during conversations about science [Electronic version]. *Journal of Research in Science Teaching, 38* (2), 159-190.

Wandersee, J.H., Mintzes, J.J., and Novak, J.D. (1994) Research on alternative conceptions in science. In D.L. Gabel (Ed) *Handbook of research in science teaching and learning* (pp. 177-210) [Electronic Version]. New York: Macmillan.

Ward, C. (1997). Never give 'em a straight answer [Electronic version]. *Science and Children, 35* (3), 46-49.

Watts, M., Alsop, S., Gould, G., & Walsh, A. (1997). Prompting teacher's constructive reflection: pupils' questions as critical incidents [Electronic version]. *International Journal of Science Education, 19* (9), 1025-1037.

Watts, M., Gould, G. & Alsop, S. (1997). Questions of understanding: Categorising pupils' questions in science. School Science Review, 79 (286), 57-63. In C. Chin & J. Osborne (2008). Children's questions: a potential resource for teaching and learning in science [Electronic version]. *Studies in Science Education, 44* (1), 1-39.

Weinburgh, M. (2007). The effect of *Tenebrio obscurus* on elementary preservice teachers' content knowledge, attitudes and self-efficacy [Electronic Version]. *Journal of Science Teacher Education, 18*, 801-815.

Wilhelm, J., Smith, W., Walters, K., Sherrod, S., & Mulholland, J. (2007). Engaging pre-service teachers in multinational, multi-campus scientific and mathematical inquiry [Electronic Version]. *International Journal of Science and Mathematics Education, 6,* 131–162.

Windschitl, M. (2002). *The reproduction of cultural modes of "inquiry" by pre-service science teachers: an examination of thought and action* [Electronic version]. Paper presented at the annual meeting of the American Educational Research Association, New Orleans. Retrieved from ProQuest Science Journals on August 30th, 2008.

Zeegers, Y. (2002). Is a rock the same thing as a stone? *Investigating, 18* (2), 14-16.

Zeegers, Y. (2003). *Pedagogical reasoning about science teaching and learning: Insights into teacher practice that encourages students' questions.* Paper presented at the biannual conference of European Science Education Research Association, Netherlands. Retrieved on May 8, 2011 from http://www1.phys.uu.nl/esera2003/programme/pdf%5C037S.pdf.

APPENDIXES

APPENDIX A: QUESTIONNAIRE

Survey of teachers' responses to children's science questions (primary)

This questionnaire has been designed to investigate how teachers respond to children's science questions and what answers they give to those questions. Please take a few minutes to circle or write your answers to the following questions.

There are no right or wrong answers but your view would be appreciated. All information is confidential.

Completion of this questionnaire indicates your consent to participate in the study.

Kathy Harris ACU kharris@bne.catholic.edu.au

Please proceed to the next page

PART 1

The following questions are about the teaching of science in primary schools, children's science questions and how teachers respond.

1. *a. Did you teach space science topics last year?*

   ☐ Yes ☐ No

   b. If YES, please tick the topics you taught

   - ☐ The Moon
   - ☐ The planets
   - ☐ Day/Night
   - ☐ The seasons
   - ☐ Stars; Meteors; Comets
   - ☐ Orbits
   - ☐ Other: ________________________________

2. *If you answered YES to Question 1a, please tick which strategies or teaching tools you use most often to teach space science topics*

☐ Report writing	☐ Guest speakers	☐ Excursions
☐ Diaries	☐ Photographs/Posters	☐ Models
☐ Experiments	☐ Visualisation	☐ Role play
☐ Video footage	☐ Digital learning objects	
☐ Investigations	☐ Other: ___________________________	

3. *How do you respond to children when they ask questions about the Moon? Please tick your response to each of the following questions. You can choose more than one response for each question, if you wish.*

A "I don't know - you can research the answer from a book or the Internet"

B "What do you think?"

C "Does anyone else know the answer?'

D "That's a good question, let's investigate"

E Give a brief explanation

F Keep the lesson moving and don't answer the question at that time

CHILDREN'S QUESTIONS		**TEACHER RESPONSES**					
		"I don't know - you can research the answer from a book or the internet"	"What do you think?"	"Does anyone else know the answer?'	"That's a good question, let's investigate"	Give a brief explanation	Keep the lesson moving and don't answer the question at that time
		A	**B**	**C**	**D**	**E**	**F**
i	How do moon craters get made?						
ii	Why, if we travel in a car, does the Moon follow us?						
iii	How does the Moon get all its different shapes?						
iv	How are lunar eclipses formed?						
v	How did the Moon get made?						
vi	Why do so many things hit the Moon but not the Earth?						
vii	How does the Moon shine?						
vii i	How come we have day and night?						
ix	Where does the Sun disappear to when it sets?						
x	Why can't we see the back of the Moon?						

4. *Please tick the questions that you think could be answered through investigations involving models and/or collecting data through observations*

- ▢ How do moon craters get made?
- ▢ Why, if we travel in a car, does the Moon seem to follow us?
- ▢ How does the Moon get all its different shapes?
- ▢ How are lunar eclipses formed?
- ▢ How did the Moon get made?
- ▢ Why do so many things hit the Moon but not the Earth?
- ▢ How does the Moon shine?
- ▢ How come we have day and night?
- ▢ Where does the Sun disappear to when it sets?
- ▢ Why can't we see the back of the Moon?

5. *Please tick which three (3) strategies you think are most effective <u>in encouraging your class to ask a range of questions</u> about a science topic*

▢ Concept maps	▢ Playing/tinkering	▢ Think, Pair, Share
▢ Placemat	▢ KWL charts	▢ Discrepant event
▢ Y charts	▢ Round Robin	▢ Hot Potato
▢ Interviews	▢ Brainstorming	▢ Whole class discussion
▢ Examining a collection of objects	▢ Other: ________________________	

6. *Please tick three (3) of the following issues that arise during your teaching of science because children ask science questions*

- ▢ Deviation from the lesson plan or unit plan
- ▢ Aims or goals are not met
- ▢ My class don't ask questions
- ▢ I don't always know the answers
- ▢ It's always the same small number of children who ask questions
- ▢ I don't know what to do with the children's questions
- ▢ Their questions get us off the topic
- ▢ There is not enough time to deal with their questions
- ▢ Other: ____________________________________

7. *Please comment on anything that you think is important about children's science questions and how teachers respond that has not been included here in this questionnaire.*

____

____

____

<u>PART 2</u>

The following five (5) multiple-choice questions have five (5) possible answer choices. Please tick the answer that you think is a FULL and ACCURATE scientific explanation.

1. Why can't we see the back of the Moon?
   - ☐ Because the Moon does not spin, so we never see the dark side of the Moon.
   - ☐ Because the Moon spins slowly.
   - ☐ Because the Moon tries to keep it's back hidden and keeps presenting its front to the Earth instead.
   - ☐ Because the Moon spins slowly once on its axis each time it orbits the Earth.
   - ☐ I don't know

2. How does the Moon get all its different shapes?
   - ☐ Because of the position of the Earth at different times of the month.
   - ☐ Because the Earth's shadow is cast onto the surface of the Moon.
   - ☐ Because different portions of the illuminated surface of the Moon are visible.
   - ☐ The Moon makes parts of itself shine during different phases.
   - ☐ I don't know

3. Where does the Moon disappear to when we can't see it?
   - ☐ The Moon hides behind the Sun during the day.
   - ☐ Sometimes the Moon is only visible from the other side of the Earth.
   - ☐ The Moon is always in the sky.
   - ☐ The Earth turns and faces the Sun, and then it turns and faces the Moon.
   - ☐ I don't know

4. What keeps the Moon there in space?
   - ☐ The Moon is like a satellite; the Earth's pull of gravity keeps it in orbit.
   - ☐ The Moon wants to spin in a straight line past the Earth but the Earth pulls it towards itself.
   - ☐ The force of gravity.
   - ☐ The Earth orbits the stationary moon keeping it in position.
   - ☐ I don't know

5. Why do objects NOT float off or away from the Moon?

☐ Because the Moon has no air and no gravity.

☐ Because the Moon's gravity pulls objects to its surface.

☐ Because they are heavy objects.

☐ Because the objects want to stay close to the surface.

☐ I don't know

ANSWERS: iv, iii, ii, i, ii

Please circle your personal details

Gender: Male Female

Year level/s taught in 2009 Prep Yr1 Yr2 Yr3 Yr4 Yr5 Yr6 Yr7

How many years has it been since you qualified as a teacher? _______

Identifier No. (for analyst)

1. **The first three letter of you <u>mother's maiden surname</u> …………………………..**
2. **Your day and month of birth (please use double digits, e.g. 9th August = 0908) ……………………………..**

Thank you for participating in this study. If you would like to be further involved in a small study group with your class please fill in 'further interest' form and return it to the researcher.

FURTHER INTEREST FORM

I would like to be further involved in this study of children's science questions and teacher's responses and answers.

NAME:

SCHOOL:

YEAR LEVEL TAUGHT IN 2009:

PHONE NUMBER:

EMAIL ADDRESS:

APPENDIX B: SCIENCE QUESTIONS (9 TO 12 YEAR OLDS)

THE MOON

1. How was it made, and what is it made of?
2. What causes the marks on its surface?
3. Where do craters come from?
4. How does it shine?
5. How does the Moon get all its different shapes?
6. Where does it disappear to when we can't see it?
7. Why, if we travel in a car, does the Moon follow us?
8. How are eclipses formed?
9. What keeps it there in space?
10. Why do objects not float off the Moon?
11. Why can't we see the back of the Moon?
12. Why do so many things hit the Moon but not the Earth?

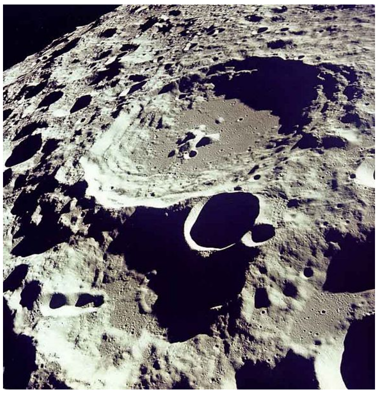
(Spargo & Enderstein, 1997)

APPENDIX C: STIMULUS PICTURES

1.

2.

3.



1. The Moon from space (www.assa.org.au)
2. Apollo astronaut Jack Schmitt on the Moon (www.eriklunsford.com)
3. Moon craters (www.scienceblogs.com)

APPENDIX D: INTERVIEW QUESTIONS

1. What phenomenon is represented in these three pictures? What is your understanding of the science concepts explaining them? *The three Moon pictures*
2. Can you recognise alternative conceptions the children might have from their questions? Do any of their questions raise red flags for you? *Handout of children's alternative conceptions in space science.*
3. Which of the children's questions do you think you would investigate with hands-on materials or models?
4. Research from the UK into children's questions in science has grouped questions according to categories based on the responses required from the teacher. Can you identify any of those categories in the list that you have got from the kids? *Handout of Harlen's question categories (2001).* Do you recognize these from your own classroom practice?
5. Here is a list of options that teachers have in the classroom for responding to or answering children's questions, from another study. These are the typical sort of responses or answers that teachers give in a classroom and there is quite a range there - from not answering at all to a brief answer on the spot, to doing an investigation. *Handout of Watts, Alsop and Gould (1997).* Do any of those surprise you? Which of them to you rely on?
6. Do the children's questions pose a problem for you in any way? Is there a difficulty that they raise or any issues that develop from eliciting or responding to children's science questions in the classroom?

APPENDIX E: DESCRIPTIONS OF INDIVIDUAL TEACHER OBSERVATIONS AND INTERVIEWS

Teachers 1, 3, 4 and 5 were chosen from the six study group teachers and were described and compared in terms of relevant headings to synthesize information and views. The teachers were chosen because they exemplified relevant factors explored in the present research about individual teacher's knowledge of science concepts, the pedagogical practices of teachers of science, and teachers' perceptions about the questions children pose. A summary of each case introduces the full descriptions on the following pages:

- Teacher 1 and her class exemplified a range of responses to children's science questions by a Year 6 teacher.
- Teacher 3 and her class exemplified the lack of confidence in science content knowledge that some teachers feel, plus a view of science that is representative of a body of knowledge to be transmitted.
- Teacher 4 and her class exemplified a graduate teacher's confidence in her science background knowledge and who recognizes different ways to deal with the children's questions depending on the type of question asked.
- Teacher 5 and her class exemplified a teacher's well-developed pedagogical content knowledge in science and the place of children's questions in an inquiry approach to teaching.

Teacher 1/Class 1

Context:

Class 1 was in the first room in a pod of three Year Six classrooms at a coastal Prep to Year 12 college. The college was on beautiful grounds with rooms spread apart in pods around shared covered areas, each joined by footpaths. The children were predominantly of European heritage. Each of the three Year six classes had access to Information Communication Technology in the room. These children had done a unit of work in Year Three about the solar system and were just beginning a unit about astronomers.

Teacher's process for collecting questions:

Teacher 1 decided to allow ten minutes for her class to ask questions about each of the three pictures so that her interview and the teacher observations in the follow up session would conclude by morning tea break. The children were eager to ask questions - eight of the twenty-four children in the class each asked several questions. During the recording of the children's questions one student commented to another about a classmate's question - "Why does he [the astronaut] have to wear that suit?" The whispered comment was "What sort of question is that?!" Teacher 1 kept the question-asking moving at a steady pace and moved around the room so that children were not left holding their hand up to ask a question for more than a minute or two. Teacher 1 responded to the children's questions with encouragement, she said "excellent question!" and "ok!" in a cheerful manner.

In the first ten minutes of gathering children's questions very few boys asked any. When they did ask questions it quickly became just as many as the girls. Only four boys didn't ask any questions throughout the session. One of these boys put his hand up during the session and said, "Do you want me to explain why?" (in response to a complex question from another child). The teacher asked him not to as this was the time to just ask questions however, he still went on to offer to answer every question asked by other children in the remainder of the session.

Children's science questions:

Class 1, asked mostly questions requiring a short answer, just like the other five classes. Their second most frequent category of questions was Complex Questions. The percentage of Complex Questions asked was the second highest of all the classes (Table 3). All of the classes asked questions about why the Moon appears to be white at times and yellow or grey at others. Class 1, and four other classes, asked questions about the phases of the Moon or the shapes the Moon appears to be at times (Table 5).

This was a class that didn't appear to ask questions just for the sake of being involved. Four of the children didn't ask a question at all and yet were observed listening and paying attention to what was happening. One of those children was a boy known for his extensive general knowledge. He was highly motivated during the session but was more interested in answering the questions than asking them. His answers were accurate.

Teacher confidence and scientific background knowledge:

When Teacher 1 gave scientific explanations as answers, they were accurate, such as her response about how the light from the Sun creates the phases of the Moon. When she recognized children's alternative conceptions she corrected them with scientific ideas, for example; she confirmed that there was gravity on the Moon, just less than on Earth when a child asked "Why does he float, like, when he walks?" and another child said it was because the Moon had no gravity. She responded to the children's questions confidently and she appeared to enjoy that stage of the process.

Teacher's responses to the questions:

When the recording of children's questions was complete, Teacher 1 participated in the follow up session where she was observed responding to the children's questions. Teacher 1 examined the list of questions on the board before she took action with a variety of responses to the children's questions. One of her responses was to turn the questions back to the children saying, "Can *you* answer any of these questions?" The boy who was eager to answer questions while they were being recorded obliged her at this point. His answers were accurate. Teacher 1 explained later in the interview that she turns the children's questions back to them in class and used other strategies: "I do a lot of 'what do you think' and also 'let us have a look at it together' and make that the next lesson" (Appendix 6, Teacher 1). She admitted that she didn't have all the answers in her responses to the children's questions but suggested they could find the answers together. When she came to the question "How long does it take to get the Moon?" she said, " I don't know how long it takes *now*, we'd have to look it up in our books" (Appendix 6, Teacher 1).

Teacher 1 answered the more straightforward requests for simple information and asked further questions to deepen the children's understanding. The children's questions were rephrased to include scientific terminology. For example, when a child said 'stages of the Moon' in a question, she clarified when she responded that it was 'phases of the Moon'. She also introduced 'waxing' to describe a Lunar phase in response to the question "What stage is it at?" Teacher 1 also grouped similar questions together to answer them, such as questions about the related ideas of asteroids and craters.

Teacher 1 broke a Complex Question down into a Yes/No Question to deal with it. She focused on the question "How does the Moon create light?" and asked the children "*Does* the Moon create light?" then she got clarification from them and went on to give an accurate scientific explanation of how the light from the Sun creates the phases of the Moon.

Hands-on investigations:

During the interview Teacher 1 named several concepts arising form the children's questions that would be best answered through investigation in her classroom. They were: how craters are formed; where is the Moon in space (using a model); the size of the Moon in relation to the Earth and the Sun; the phases of the Moon (using a torch and ball) and why we always see the same side of the Moon.

Teacher 1 had a variety of responses to the children's questions that showed she valued what they asked, perhaps her attitude to children's science questions had an affect on what they asked and whether they wanted to ask a question at all. She didn't appear to be intimidated by the complexity of the children's questions or about the amount of questions they asked on a variety of concepts, so it could be presumed she welcomed questions from her class rather than avoided or stifled them.

Teacher 3/Class 3

Context:

Class 3 was in the end classroom in the Year 6 pod, next to Class 2 and furthest from Class 1. These children were also just at the beginning of a unit of work about astronomers. Teacher 3 had some teacher aide time during the afternoon session, so the teacher's aide recorded the questions on a laptop at the back of the room while Teacher 3 facilitated the session from the front of the room. The questions were projected onto a screen in front of the board.

Teacher's process for collecting questions:

Teacher 3 began by showing the three pictures (Appendix 3), one at a time, and asking the children to share what they noticed about them. She accepted what they said and then asked for questions about the pictures. Teacher 3 encouraged the children's questions by responding with comments like "that's a really good question!", "yes" (with a nod of her head) and "ahh!". Class 3 had a library lesson at the end of the day, so their teacher chose to stop questions for each picture after ten minutes.

Children's science questions:

The children in Class 3 asked different amounts of questions. Fifteen children asked less than five questions each. The remainder of the class asked up to ten questions each. This class asked more Short Answer Questions than any other type, just like all the other classes. However, they also asked the most Complex Questions of any class.

Teacher confidence and scientific background knowledge:

In her interview with the researcher Teacher 3 was asked to give a scientific explanation for phases of the Moon:

R: …….are you able to explain to me how phases of the Moon occur?

T: It's the reflection of the Sun on the Earth that flicks off to the Moon rather than the Earth actually on the Moon.

This answer was not correct, however, the researcher believed that the teacher may have corrected herself given an opportunity. Asking what the teacher thought she would see of the Moon, if the Earth, Moon and Sun were in different positions relative to each other, extended the questioning and allowed the teacher to share what she did know. She used her hands to show correctly how the three bodies moved in relation to each other, however, she did not fix the incorrect notion of the light travelling to the Moon via the Earth's reflection.

She was also asked about why we see one side of the Moon from Earth:

T: And there is only the one face of the Moon all the time.

R: There is, and why do you think that is?

T: Because it doesn't spin.

R: It does actually.

T: Does it?

R: Yes, but it spins *so* slowly.

Teacher 3 discussed her understanding of gravity on the Moon in her interview:

T: And the fact that because there is no gravity everything is there forever or for an awful long time.

R: Now, there *is* gravity on the Moon.

Perhaps she meant to say ‘atmosphere’ rather than ‘gravity’ because in her questionnaire responses the only question she answered correctly was the question about gravity on the Moon. The questions she answered with alternative conceptions were those about the phases of the Moon and why we sometimes can’t see the Moon. She responded with ‘I don’t know’ to questions about the spinning Moon and the satellite characteristics of the Moon. Clearly, Teacher 3 struggled with some of the more complex lunar concepts. The fact that she used the ‘I don’t know’ response rather than having a guess seems to point to her having concerns about what she knows. This was also apparent in her responses to the children’s questions.

Teacher’s responses to the questions:

When it was time to respond to the children’s questions Teacher 3 approached them one at a time, in contrast to Teacher 1 who grouped questions together and responded to different questions in a variety of ways; by changing the questions, turning them back to the children to answer, putting them aside to be researched and answering them briefly on the spot. Teacher 3 tried to find answers to each question even though she was not directed to do so by the researcher. Her own inclination led her to this. She was not able to satisfactorily answer all the questions with scientific explanations, indeed it would be unfair to expect any generalist teacher to accurately answer, on the spot, questions like: ‘Why does the Moon light up at night?’; Why is it round?’ and ‘How was it formed?’ These questions require answers that are not brief and simple but rather explanations of complex ideas that need to be thought about and reflected on. They are also questions that could be best responded to with visuals, like a model or a digital resource that can represent large scales of space.

As she worked through the children’s questions listed on the screen she said: “Well, *I* think….”; “I really don’t know”…followed by her best guess; “I wasn’t sure if it was…..” and “That’s something we’d have to look up”. She did say that some answers could be found in secondary sources but predominately she attempted to give scientific explanations in answer to their questions. As the session progressed the children answered a lot of their own questions and she facilitated this well, nodding to individuals to have a go at an explanation, asking if anyone could answer the question and allowing conversation between two or more children to occur so they could argue a point. The children seemed empowered by her lack of conviction in her responses. Giving the class encouragement to answer their own questions was something she did regularly:

"Turn the question back - yes we do that. When we think about science - sometimes someone will ask the question like today and the kids will go "I know the answer" to that so you can turn it back on them that way. It's not so much to regain control but I guess it's a way of recognising the knowledge that other kids have on that subject and that they will be able to express that. " (Appendix 6, Teacher 3).

When Teacher 3 did see an alternative conception in a question she attempted to deal with it. "Why does the Moon disappear during the day?" was one of the questions asked by her class. She responded with: "*Does* it disappear?". Her class clarified that it didn't, and she went on to explain that it couldn't be seen well during the day because the day is so bright. This is not an accurate scientific explanation for why the Moon is not always visible. She did make it clear that it could sometimes be seen during the day but unfortunately her explanation didn't account for why it could be seen at certain times during the month in the daytime, even when the day was very bright.

<u>Hands-on investigations:</u>

Teacher 3 named four concepts from the children's questions as suitable for hands-on investigations. They were: phases of the Moon; meteors (sic) with a tub of a dust-like substance and several different sized and shaped objects; the difference between decomposing on Earth and on the Moon; past and present day astronaut's suits – a comparison. The final two ideas appear to be more suited to research from secondary sources rather than a hands-on investigation with the children.

In the interview Teacher 3 said she would be prepared for the children's questions in class because she would research the concepts herself before beginning the unit, this would certainly alleviate her concerns of not knowing the answers. It is interesting that despite not having confidence in her science content knowledge her immediate response to the children's questions was to try to give scientific explanations in answer to them. It doesn't appear to be an issue for the children though, as they still asked more Complex Questions than the other classes.

Teacher 4/Class 4

Context:

Class 4 was in the end classroom of an inner-city school, next to another Year 6 class that did not participate in the study. They had enjoyed a party during the previous session to celebrate a special event. Teacher 4 was new to the school as a graduate teacher but had a reputation as being a good teacher despite her lack of experience.

Teacher's process for collecting questions:

Teacher 4 began by showing the three pictures (Appendix 3), one at a time, and recording the children's questions on the whiteboard at the front of the room. She recorded their questions on the whiteboard arranging their questions around a central bubble containing the word 'photos'. In the beginning she kept questions separated by the photo they related to but eventually there were so many questions she had to just find space wherever she could to record them. She projected her voice, asked children seated in random positions around the room to pose a question and recorded them verbatim. She spent approximately ten minutes gathering questions for each picture.

Children's science questions:

The boys in Class 4 were first to pose questions. One boy asked two questions that were met with giggles from the other boys in the class. One of the questions was: "If asteroids hit the Moon why don't they hit the Earth?" Five children in Class 4 asked a question about each of the three pictures. They asked fewer questions about the photograph of the Moon in space than questions about the other two photographs of Moon craters and the astronaut.

Class 4 asked fewer questions in total than the other five classes. Most of their questions were Short Answer Questions. They asked fewer Yes/No Questions than the other five classes, except for Class 5.

Teacher confidence and scientific background knowledge:

In her interview with the researcher Teacher 4 identified gravity as another concept she could teach from the photographs. Teacher 4 seemed nervous about being observed by the researcher but demonstrated a very confident approach to dealing with the children's science questions and was happy to answer questions in her interview with the researcher. However, in her interview she did not answer the children's questions accurately.

> R: I just want to ask you two of the questions that the kids came up with. One of them was "Why aren't there stars in the background of the Moon picture?". Do you remember the Moon picture where the background was completely black? Have you got any ideas?

T: Well, it has an atmosphere just like the Earth has an atmosphere, obviously it is not as strong as that but also it could be dependent on things like that.

R: The other one was "Why is the Moon a gold colour and at night it's a white colour when we see it up in the sky"?

T: What they are seeing when they look up at the sky is they see the Moon, they see the light reflecting off the Moon and what they see is the white light reflecting off the Moon so therefore it doesn't matter what colour the surface is necessarily, it still has a white light bouncing off the Moon.

(Appendix 6, Teacher 4)

The stars are not visible in photographs of the Moon because the sunlight reflected off the Moon 'washes out' the background. They are visible to the astronauts though. Teacher 4 thought that it might be because of the Moon's atmosphere. The Moon appears do be different colours because of the angle it is viewed at and when it appears low in the sky. At these times the light reflected off the Moon filters through dust and vapour particles distorting the way it looks. Teacher 4 thought the Moon always reflected a white light but didn't explain why it sometimes appeared to be a different colour from Earth.

<u>Teacher's responses to the questions:</u>

Teacher 4, a novice teacher, redirected the children's questions to the whole class, saying "You should know this" and "Who can tell us about…". She appeared confident about her ability to handle the children's questions and didn't behave as if she needed to give accurate explanations to all of them. She jumped from one question to another on the web of questions recorded on the board and made links between them, saying "These questions are similar, they are both about……..what do we know about that?" and invited the class to construct the answer with her. When she gave scientific explanations as answers they were accurate and given with conviction. Teacher 4 appeared calm and in control of the process.

<u>Hands-on investigations:</u>

During her interview with the researcher Teacher 4 indicated that she would help the children to do investigations with hands-on materials to answer questions about craters, dark spots on the Moon, shadows and the astronaut's suit (Appendix 6, Teacher 4). It would be difficult to do investigations to answer questions about the space suit if the teacher does not have access to one, so this would be a concept for research rather than an investigation with materials. Teacher 4 also stated that she would not spend a lot of class time on some of the questions but would just give a brief answer to them, such as: Who was the second person to go to the Moon? (Appendix 6, Teacher 4).

Teacher 4 could identify different types of questions asked by the children in her class and had an effective response for each type. She didn't rely on one type of response, such as answering the questions with scientific explanations but rather chose a response suitable to the category of question that was posed. Her science background knowledge was not noteworthy but she was confident about her dealings with the children and their questions and it did not appear to hinder her.

Teacher 5/Class 5

Context:

Class 5 were in a room upstairs in a small, older inner city school. Teacher 5 was feeling unwell on the day of the researchers visit. She wasn't feeling energetic, so the researcher offered to gather the children's questions instead. The children sat at desks arranged in a horseshoe shape facing the board. The children could see each other and recording on the board clearly. It was a hot afternoon and the tin roof outside the room was making it clammy in the classroom but the children were still eager to ask questions.

Process for collecting questions:

After introducing what was going to happen to the class Teacher 5 sat at her desk at the back of the room and the researcher recorded the questions the children asked on the whiteboard. The researcher stopped recording questions for each photograph when the questioning slowed down and hands were no longer being raised. The researcher tried to give all the children an opportunity to participate by responding to raised hands from left to right across the room and back again.

Teacher 5 listened attentively to the children's questions and occasionally smiled and praised a child for forming a clear question or asking something that sounded interesting. She was curious about the questions they were asking and was eager to identify which children had asked them.

Children's science questions:

The children in Class 5 asked two or three questions each, except for one boy who didn't ask any. This boy had a diagnosis of Autism and had difficultly initiating communication. This class asked more Short Answer Questions than any other type, just like the other five classes. However, the remainder of their questions were Complex Questions, except for one Yes/No Question. They also asked the highest percentage of Complex Questions (Table 3), the same as Class 3. This was a classroom where oral language was highly valued and questioning was a skill that was taught formally to the children because of their varied literacy levels.

Class 1, 3 and 5 had a percentage range of Complex and Short Answer Questions that were similar. Class 5 were unique in one respect, they asked only one Yes/No Question (Table 3). The other five classes asked between 14% and 49% of Yes/No Questions. Class 1 and 3 had very similar numbers of all three question types.

Teacher confidence and scientific background knowledge:

Teacher 5 answered all of the science concept questions accurately on the questionnaire. In fact, she reworded some of the conceptual questions to better reflect her understanding of the phenomena. In the interview she spoke confidently about lunar phenomena and was able to identify valid concepts to teach from the children's questions and from the photographs as a starting point. Its interesting that all the teachers in the study group could identify three major concepts to teach from the photographs: i) phases of the Moon, ii) how craters are formed or the surface of the Moon, iii) space travel. Teachers 3 and 4 also mentioned gravity, although for teacher 3 it was 'no gravity'. Teacher 5 also named the orbiting relationship between the Moon and the Earth and also the Earth and the Sun and the concept of shadows and how that understanding could develop into an understanding of the Earth-Moon-Sun relationship. This seemed a broader view of the space ideas that could be taught from the photographs than the three concepts named by all the teachers earlier.

Teacher's responses to the questions:

Teacher 5 chose not to be involved in the follow-up session that consisted of responses to children's questions because she was feeling unwell, however, she was happy to be interviewed while the children did independent activities.

Hands-on investigations:

Teacher 5 was unwavering about the need to do hands on investigating in order to answer the children's questions, "You wouldn't be able to teach the basics of the Moon without a hands on investigation" (Appendix 6, Teacher 5). In answer to a question on the questionnaire about how she would respond to children's questions Teacher 5 chose 'investigation' and 'give a brief explanation' in response to all ten of the children's complex science questions. Most teachers favoured 'researching the answer from secondary sources' and 'turning it back to the children' as responses to the same questions. Teacher 5 was unusual in her conviction that hands-on investigation was the best response to children's complex science questions.

"You can investigate, given time, inclination and materials and stuff, you could investigate virtually everything" (Appendix 6, Teacher 5).

Teacher 5 was asked by the researcher how she would answer one of the children's Complex Questions from her class. The researcher had meant to use the term 'response' rather than 'answer' in case the teacher felt the need to give a scientific explanation. Despite asking directly for an answer (which to most would imply a scientific explanation) Teacher 5's immediate response was to give a brief explanation and then design an investigation.

R: Let's look at why the craters have a circular shape. If you got that one [question] in class and it put you on the spot, if you felt compelled to answer, what sort of answer would you give to that?

T: I would talk to them about the impact of something heavy going into something else and I would probably very quickly generate a quick experiment and they could test that. We could do it using sugar, dirt, rice or a lot of things. If you dropped something into any of those depending on the shape you would be able to test it very quickly and be able to get a visual of the impact of the site and I think once the kids see it they would know it.

(Appendix 6, Teacher 5).

She describes a teacher demonstration rather than an investigation, but does clarify that 'they could test that'. The researcher took that to mean that the children, not the teacher, would do the activity she described.

Teacher 5 discussed her understanding of how children learn and lamented how difficult it was to teach a complex concept in one moment in time when really she believed that the things worth knowing should be revisited regularly and treated in a fun way.

"It takes a lot to build up accurate picture for them, and it doesn't happen in one year in one term and with one teacher. The children can't be stressed when they are doing it - they've got to be having fun. They've got to investigate but they've also got to be able to take it on board at that moment. There's no one right way and no one wrong way you've got to just find it. It is every teacher's dilemma". (Appendix 6, Teacher 5).

Teacher 5 felt confident about her science understandings, had considered how children learn and could express her view of learning in the interview, she also had an opinion of the place of investigations in science and how children's questions aide investigations. Her perceptions would likely affect the culture of her classroom and the way she teaches, so perhaps the quantity of Complex Questions asked by her class was a result of this. However, Class 3 asked the same percentage of Complex Questions (37%) and their teacher lacked confidence in her ability to deal with the questions.

APPENDIX F: INTERVIEW TRANSCRIPTS

Teacher 1

Researcher: The pictures - what was your understanding of the science concepts behind them. The first one was the Moon.

Teacher: Probably what phase it was at.

R: I could tell from the way you were talking to the kids that you understand phases, so could you explain to me how the phases occur, how they happen.

T: Why we can see them is because the Moon is rotating around the earth and at its different stages with the sun………it's in its shadow as it rotates around the earth.

R: Now the astronaut picture – what are the science concepts in that one.

T: The discovery of our place in space and by doing that sort of stuff it helps us learn more about our own planet and where we fit and how we are going to survive.

R: The third one was the craters, the close up of the Moon.

T: I would think that would be more how things are formed so again replicating what possibly happened to our own earth, what happened then.

R: From the questions they have asked, are there any there that stand out to you as showing that the kids don't understand the concept.

T: There was one question about why we can't see the Moon in the daytime and we can see it at night when we had actually talked about that we can see it in the daytime, that was one. The colours, basically why is it purple, thinking that it could be purple. The cheese question. Maybe the concept of why is the Moon so far away in relation to everything else in the solar system. Maybe I need to look more on that, that it is our closest neighbour even though we feel it's a long way away in the big scheme of things it is very close. I would need to look more at the difference between asteroids and comets and meteorites and what's doing what. Where do they all fit in. We have not touched on that at all. What is inside a crater, what is on the bottom, whether or not they think it is like a volcano.

R: All those questions on the board. Do you think there are any there you could investigate with hands on materials or models.

T: Definitely hands on, the phases would be a good one to do. The relationship between the Moon and where it is sitting. If you did a solar system model, which I have done before in Year 3 because we did more of the solar system then. The size of the Moon in relation to the sun and the other planets actually it is quite small compared, so maybe a comparison of the size with models, that would be good. Definitely with a model and I havn't done it yet but with a torch to do the phases and the fact that we see the same side of the Moon.

R: Do you know why we only see the same side of the Moon.

T: Because it is rotating as well as earth…….walking around you are looking at it the whole way around. It's not turning at the same time…

R: Do you have overhead projectors in this school.

T: We do, I have data projector here.

R: They are better than torches for phases because they don't move. The problem with a torch is it gives kids the idea that the light source moves as well and it can create a little bit of confusion.

T: I should get the data projector out with a ball.

R: This is a list of types of questions by a lady in the UK called Wynne Harlen and she has done a lot of research into the types of questions that kids ask in science classes. These are the headings or categories that she puts them into. Are you able to see any of those type of questions in the list that you have on the board.

T: A request for simple facts, that is what they are after. Something you can investigate forever. There wasn't anything complex, I wouldn't think, no I think they were mainly simple facts …..

R: On the back of that there is a list of options that teachers have in the classroom for responding to or answering kid's questions, this is from another study. These are the typical sort of responses or answers that teachers give in a classroom and there is quite a range there from not answering at all to answer on the spot, to doing an investigation, those sort of things. Do any of those surprise you.

T: No, not really.

R: Are they the sort of things you do.

T: I do a lot of 'what do you think' and also 'let us have a look at it together' and make that the next lesson. Sometimes they will go home and find information on TV on the Discovery Channel.

R: Have a look at these handouts. This one is alternative conceptions. These are typically the type of things that children of this age group believe. You have identified some of them with the questions they have come up with. Kids will answer correctly in class the questions you pose and they will also give you back what you have already told them or what they have read in a book. It doesn't mean they really believe it and that often comes up later if they are in an informal setting and they think about a particular phenomenon like phases of the Moon. They might revert back to their original idea that the Moon has a light source even though they have been able to tell you that it doesn't. Occasionally you hear something that makes you think that they actually do have an alternative conception. There has been a lot of research that has shown that kids develop ideas from experiences and obviously they have got very limited experiences in their youth but they hold on to those all the way through their lives unless we challenge them. Usually school is enough of a challenge, or a book is, or a movie to help them to change their ideas but sometimes that doesn't cut it and it has to be a hands-on investigation. A little bit hard with this Earth and Beyond topic because it's all on a massive scale of time and space and school can't afford to send them into space! So you really have to rely very heavily, for some of those trickier concepts like phases of the Moon, on models and digital resources like on Scootle which you have already identified that you use. Having that real physical experience with it is important to help them to step over from reiterating what you are telling them to really believing it. So that is something that really should go into your unit quite a lot. Particularly in the earlier stages of the unit, experience before explaining. So have the experience within themselves before you give them a teacher talk and really get into what it means and give them the scientific terminology.

T: I've got to do the tides. I've struggled with that, that's very hard.

R: I would probably use digital resources for that. Have you been into Scootle for tides yet? I'm not sure what is on there. I know there are plenty of moon phases and that sort of thing. I'm not sure what is on there for tides, but I don't think it is something you can use sand and water and clay for. I think you would have to do a digital resource for that. There will be a model, a simulation for that. Observations are another good thing, marking the tide line at different times and looking for a pattern. You have the right environment here for it.

T: Being surfies, they know what to look for.

R: They probably do, more so than city kids. Make observations, create a pattern and if you can't have that real life experience or you need to build on it then use tide times in the newspaper as well and look for patterns. The alternative conceptions there are about 'the tide in and the tide out'. The tide is actually up and down not really in and out. That is the only thing that you have to be careful of that that terminology doesn't trip them up but other than that it is quite a complex thing to understand. Have a shot at it, they may not be developmentally ready to understand it but don't be shocked if you don't get a whole lot out of them. At the very least you could give them some experiences that later on they could recall 'oh we measured the tide I know we did that'. Then click it will happen when they are a bit older, if you can give them that experience. Do the teacher talk for the kids who are ready for it and those who aren't will get it later.

The other thing I was to give you is this. The kids questions is more on that Harlen information that there are different types of questions and you don't have to feel obliged to answer them, you don't have to know everything. Particularly those why questions. I noticed when you were dealing with the questions the why questions you didn't answer directly and that was great. People get caught with them all the time. You turned them into for example when you were asked 'why can something happen' you said 'does that happen' so you turned it into something you can investigate which is perfect. That is exactly what you want to do, you want to take away those why questions out of the classroom because they are there for people with encyclopedic brains and you want to turn it into something you can actually find out more about so kids say 'why is the sky blue' you want to ask them 'is the sky always blue – let's take some observations'. You already automatically do that which is just wonderful. It was instinctive, that's wonderful. That's a real clincher for teachers. I've heard pre-school teachers try to explain the answers to why questions and it's very difficult. You have to know the science yourself.

T: A lot of the times we don't. My sister is a high school science teacher so if anything I'd ask her.

R: Well actually that's a good idea – you need a back up.

T: I have to get my head around it first, even then they come up with things that you think 'should we do that'?

R: Just be aware that that's going to happen and particularly with boys you are going to find, I even find that the Year 2 there are boys that know more than I do. It's often boys, but not always. You'll be aware when that happens. But the thing to remember is that you probably have some alternative conceptions. 50% of teachers don't really understand phases of the Moon. 50% that is quite high so don't be worried if you think there is something you don't know, do go and look it up or ask your sister. Nothing wrong with that at all. Science is not common sense as people often think, it's actually quite complex and sometimes it's completely opposite to what your common sense tells you. So you can get tripped up a lot. Don't feel the need to answer all of their questions. Certainly turn them into something that could be investigated a little. What you want to do really is to go through those questions and decide which of them warrant an answer, which of them could be researched from a book which you have already started to do, and which of them you could give them a hands on experience with or at the very lease because of the subject matter could you do a model or a simulation. If you can build on that experience base for those kids a lot more of them will understand than if you just did and chalk and talk or out of the book.

T: I've doing my Masters on Teacher Librarianship and this whole thing about inquiry - it's quite new to me.

R: Teachers tend to think of themselves as having to know everything and having to lead the way and really what we need to do is push them ahead of us.

Now, you were talking about how in Year 3 they were doing the solar system and now you are sort of taking on the whole astronomy side of things which is a great idea. It's sort of science is a human endeavour which is in the new national curriculum, which is perfect. In regards to science concepts I would be making sure that they really understand how those phases of the Moon occur. That it is a reflection of sunlight, sometimes we can see more of the Moon and sometimes we can see less of the Moon. Just depends on our position in relation to the Moon and the sun given those real experiences with it and then get them to maybe perhaps draw a picture and explain their understanding and then you will really see whether they know it or not. That is something I would focus on.

Gravity was the other concept that came out of those pictures and they did mention that, didn't they?

T: They know their gravity concept. The questions was why does he float, like when he walks.

R: Then when they answered the question later one boy said there is no gravity on the Moon and you said there is gravity but not as much as on earth. The numbers are in there, about one sixth of the earth's gravity. So you can do a little bit with gravity. The forces that act in the universe are the same that are in the earth so how quickly does an object fall like a parachute, those sort of investigations can be transferred then to their understanding of space. So that moon being pulled in by the gravity of the earth is the same as a ball dropping on the floor. The hands on stuff you could do with earth bound gravity and then translate that understanding to planets moons………

T: Say if you had a balloon, bounce it up and it slowly bounces down would that perhaps give the same as the Moon, the gravity is still there but it is not like a ball, the difference between dropping a balloon and a ball could maybe be used…………..

R: Why doesn't the Moon have as much gravity? It is to do with its size. Objects with a large mass have a great pull. That's why we have very little pull towards each other, but it is there some none the less. Whereas the earth has a massive pull on us, we can't get away from it because it is a much larger object. Objects with a larger mass have a great pull. So I suppose anything you are doing balloon wise or ball wise you do need to remember that it is the mass and not whether it is air filled or not and that might confuse them. You could do some investigations into what affects how quickly an object falls. If you did something like a paper plane, can we change something to make it fall faster or you could just do pieces of paper, what affects how quickly this paper falls. We could use different types of paper, different shapes of paper, have holes in the paper, drop it from a higher or lower height and they will enjoy all that sort of thing. Then you can form some conclusions as well - air resistance keeps things from falling quickly, the gravity always wins and then you can relate that then to the planets.

Back to the questions for a moment. In this scenario or just generally in the classroom do you ever find questions to be difficult ……do they ever create any problems or is it usually smooth running?

T: No difficulty except that is if I don't know the answer. I think that happens quite often, especially in science. I don't suppose it is difficult, it's always that we get to it eventually. So I might not know straight away but I know where I can find out the answer.

R: Anything else you want to tell me that I have not thought to ask?

T: No.

Teacher 2

Researcher: These are the pictures that we showed the kids. Can you identify the science concepts that you would have to teach from those if you were going to use them in the classroom?

Teacher: I could use that for the craters hitting the Moon. We could start with phases, the reflection in the Moon, why it's round.

R: Can you explain to me how the phases happen?

T: What we see from earth? What we see from the Earth, its reflected from the sun. In regards to the position of the Earth, the Moon and the Sun.

R: And what would you use that one for?

T: The texture of the Moon's surface. Discuss if there is life forms on the Moon, if it is possible. The craters hitting it.

R: What about this one?

T: The first moon landing comes to mind straight away. The technology and how we are in space travel at the present time and what we are looking to do. The time line of the space shuttle, things like that.

R: So the questions that the kids asked. Looking through them can you see any that jump out at you as showing that the kids don't understand something. Are there any there that you think I'd better deal with them, I'd better do something with them?

T: It's an interesting one. I think that because we've just done a lot of the Moon stuff I think a lot of questions they can probably answer and they have asked them because of the stuff they've learned already. Things like how many landings have failed. You always talk about the positive things that have happened but we had a look at some of the disasters that happened but not in much detail so I think something along those lines would be …… too much for their knowledge.

R: Do you think any of the silly questions were legit?

T: No, not many of them.

R: There weren't any in there that made you think, they don't get the point, they don't understand what they're asking or their question shows that they don't understand something?

T: The silly ones were obviously getting off topic and had nothing to do with what we were trying to get but yes this one ………………… what would people find when they get on the Moon? So what are they actually going to the Moon for? Why are we travelling into space?

R: Having a look at the list can you tell which questions would be investigated with hands-on things or with models. Are there any in there that jump out as being suitable for that?

T: Things like the Moon's surface and the reflection stuff that could probably be done with hands-on stuff.

R: What sort of hands-on stuff would you do for the Moon's surface?

T: We watched a clip from "Mythbuster" and they showed how you could mix cement with something else, can't remember, to create a texture and a reflective material exactly the same as the Moon. The tests that they did on those "Mythbuster" videos were all the myths about the first landing, if it was a hoax or not, said that we created a lot of things. So you could probably take a few things from that and do some things with stuff there. You can do craters, throwing rocks into sand pits. You can always make the Moon in certain models as well.

R: What would you use moon models for if you made them?

T: You could use moon models to do phases and things like that if you had a light source. A vacuum thing, like at NASA. Moon and stars.

R: There were really hypothetical questions in there, weren't there?

T: They all come back to things like phases and textures.

R: This is a list of categories of kids questions developed by a lady in the U.K. who has done a lot of research into science and children's questions in science so she has grouped questions according to those categories. Can you identify any of those categories in the list that you have got from the kids? Do you recognize any of them?

T: Yes, there were a lot of requests for simple facts in there. There are a few of investigative questions. Some of them are a bit sillier than others. There are a couple of complex ones in there I think.

R: Can you find one, do you think?

T: Will the Moon one day become a crater in the earth?

R: Now have a look at the back of that. This is another research project that found that teachers tend to respond to, or ask questions in certain ways and this is the range of ways they do that. It varies from "I don't know" to "lets find out", to "lets investigate" that sort of thing. Do any of those surprise you?

T: No, they all seem fair. I think I've used them all.

R: Are there any you use more than others?

T: I guess that depends on what's available. Sometimes you might not know it and you just go I don't know that, we'll have to find out. You might not have access to anything at the time so it might be a homework task for them to do or something like that. Sometimes it could be forgotten about as well. I don't think I can say I use one more than the other. Not without mentally thinking about it all the time. I wouldn't say I'd admit ignorance more than the others though. I couldn't say one more than the other. If it was a mathematical question I'd be more confident, I'd know it most of the time anyway because of what we are studying we always do the research before we teach it. It would depend on the subject as well.

R: This one?

T: I don't do that one. I don't ignore a question. It would be very rarely if I did because it was something stupid. I always try and follow with an answer or a task to try and find the answer.

R: So do the kids asking questions either in this scenario or generally in the classroom when you are doing science. Do the kid's questions pose a problem for you in any way? Is there a difficulty that they promote or any issues that come up with that?

T: If you have long discussions like you see there they start getting silly. That can be a problem sometimes with this group. The best thing to do is to find out what they know and what they want to know so the questions are always good and then you can develop further from the questions they ask.

R: Thank you.

Teacher 3

Researcher: Just looking at the three different photos tell me what your understanding of the science concepts there are. Do you think you can recognize what's going on in the picture?

Teacher: This one I just think about the phases of the Moon, is that what you mean? That would be like I'd look at that as a teaching activity about the phases of the Moon and I think that would give them some information about this picture.

R: Yes, I think that's good for phases of the Moon as well. Good, are you able to explain to me how phases of the Moon occur?

T: It's the reflection of the Sun on the Earth that flicks off to the Moon rather than the Earth actually on the Moon. The Earth is spinning around the Sun and the Moon is spinning around the earth.

R: In that picture there how would that phase be occurring? What would be a full Moon? Where's the Sun?

T: The sun would be at this side and the Moon would be in front of the Earth.

R: So you're on the Earth looking up and there's the Moon, so where would the Sun be?

T: The Sun would have to be there.

R: OK, so if you were looking at a phase, let's say its like a crescent, like this, how would that be happening?

T: That would be happening because... you'd have to be on this side, the Sun would have to be over this side.

R: Yes, that's pretty much the way it works and the best way to do that is to do what you were doing with an overhead projector and a ball. They sound like they understand how phases of the Moon occur but really 50% of teachers have alternative conceptions.

T: It's a very difficult concept.

R: It is a very difficult concept. The Sun is basically in a position in the universe as is the Earth and Moon. The Earth and the Moon move as you mentioned and depending on where all three are, you see different phases of the Moon. So you might only see a tiny little piece here lit up or you might see almost all of it like that picture or you might see half of it. It just depends on where we are and it is in relation to the Sun.

T: One of the best things I've done, and I think it works best is the shoebox thing with the kids. The torch and the shoebox and look through the different windows.

R: Yes, that's good too. That's good because it's all stable. The problem with using a torch, which I mentioned to TEACHER 1 earlier, it's better to use an overhead projector because it stays in the same place. Once they start moving torches they start thinking the Sun is changing position to create phases.

T: Well, this torch stays in the one spot and you look in different windows around the box.

R: Yes, and you look at different perspectives.

T: Yes, and you've just got the little golf ball on top of the blue tack in the middle and you've got the whiteness and you can see the different crescents.

R: That's virtually it then, I think the 50% of teachers who don't really understand the phases of the Moon think that there are shadows cast on the Moon covering up parts of it and it's not that. It's really just that space is pitch black and so if the sun is shining on certain sections it will be lit up and you can see it. If it's not shining on it you can't see it because it's so dark.

T: And there is only the one face of the Moon all the time.

R: There is, and why do you think that is?

T: Because this doesn't spin.

R: It does actually.

T: Does it?

R: Yes, but it spins so slowly. So if you think of me walking around you. If I spin really slowly and move at the same time you are still going to see the same part of my face. That's hard for the kids to understand too but it spins super slowly, it takes a whole month to spin. You only ever see one side of it because it's spinning as well as rotating.

T: So the dark side of the Moon isn't always the same side of the Moon its just the side that's in the shade, that's not being lit up by the sun.

R: We see the same face all the time.

T: OK

R: Now what about this picture. What would you use that for?

T: I would use that to just show them a close up of what the Moon looks like, what the surface looks like. I don't even know which way this went.

R: No, actually, I don't either.

T: No?

R: From the southern hemisphere. This is a photo from the southern hemisphere, because it's different, depending on where you take the photo from. I think it's this way because I'm fairly sure that's the way it was presented when I printed it but I couldn't be 100% sure of that.

T: There are good shadows on here as well.

R: Some of the questions that came up were about light and the depth of the craters where the light was going in and that sort of thing.

T: But interestingly enough, I guess I'm a bit spoilt. These are great photos but these I would be presenting on the whiteboard. And the dust I suppose, everything they really said about it was pretty much covered.

R: Yes and what's the Moon made of, the dust.

T: And the fact that because there is no gravity everything is there forever or for an awful long time.

R: Now there is gravity on the Moon. Some of the kids mentioned gravity a few times so that might be something you want to teach with them. It's just a very small pull, just one sixth of the Earth's gravity. That's why they wear weighted down boots because they don't want to just take a small step and be pushed off into space. There is a very small pull of gravity. One of the kids, one of the girls, said "what would I weigh on the Moon?". Your mass would be the same but your weight would be different. You see the mass is the size or heaviness of you and the relationship to gravity is your weight but we tend to use it the other way around. In common language we tend to say how much do you weigh or I've lost weight but in fact what we are talking about is mass. So our mass would stay the same on the Moon but our weight would differ because our weight is the relationship between the mass and the gravity, which would be one sixth of our weight on the Earth. So that's something you might want to do with the kids. They could do their calculations - how much would a bag of sugar weigh?

R: Now what would you do with that picture?

T: With that one we would talk about landing on the Moon more as an historical thing and why did we go there - because we can and because we learn and that's what science is about and putting questions out and finding answers.

R: Great. Have a look at the questions. Look at any question that you think they don't understand something and I can tell from the question that they don't understand it or that they are going off on a bit of a tangent that's not quite right.

T: I think that so far they've got some really interesting questions like what would happen if it blew up.

R: That came up in one of the other classes too. They were quite inquisitive. They did have some very good questions didn't they?

T: How long can you survive on the Moon without a suit? - I thought, not that that was too bizarre, but I thought they really had no idea about the atmosphere if they could even ask that. Interestingly enough all the things about rubbish, lighting a candle, that was all really interesting.

R: Yes, I thought the rubbish one was interesting.

T: And the apple, if there was an apple there, I'm sure they were trying to say would it decompose.

R: Yes, they just couldn't find the words to say that.

T: The other one too. The oxygen tank - how can you use the oxygen when you are so far away from Earth? No idea that the oxygen was in a container. Maybe because it's a gas you can't see it.

R: I think you're right. I think maybe there's probably an alternative conception going on there.

T: It was a good idea that we had this before we've actually done any work on the Moon because their questions are so broad.

R: Yes, and they want to know the answer.

T: Yes.

R: Now from those questions can you find any in there that you would think would be good to do a hands on investigation with or that you'd use a model?

T: The phases of the Moon definitely. It would be great if you could actually get a suit, maybe even a fireman's suit, even though they are different. The weight of those things would probably be somewhere in the vicinity. Also the fact that this was done 40 years ago spacesuits, if they landed a man on the Moon now, most likely would look different from that.

R: I'd say the technology has moved on. Anything else you could use there or use a model with?

T: We could investigate lots, models and such. Maybe meteors?

R: How would you do that?

T: You could set up a tub of dust something that was the same consistency and maybe even different size objects, from different heights even to gather the different speeds.

R: That sounds like a fair test to me. Yes, just throw in and see what happens.

T: They could guess or hypothesize which size, weight would make different shapes, depths.

R: That's great.

T: You could do some decomposing and maybe we could look at the difference in the air that we have here as opposed to the Moon. Maybe there is some research that we could use to help us with that stuff so if it takes X amount of days for an apple to get to this point on Earth how long would it take on the Moon.

R: So what effects decomposition - is it the air or what the material is surrounded by.

T: All that kind of thing, that would be a hands on one. Will the Moon last forever - that's interesting.

R: Have a look at these. This is from a lady called Wynne Harlen in the UK who has done a lot of research in science and she says that children's questions tend to fall into these types of categories. So can you recognise any of those categories in what the kids have given you?

T: They are almost a hierarchy aren't they, simple facts, differently - how big is it, how far away is it. Investigable questions - what if this happened, if you did this what would happen. Complex questions - I think there were a few of those. If it gets hit by the rocks why doesn't it go out of its rotation? The wonder and interest - the one with the dome - put life on the Moon and fill it with oxygen, would that work. I think they were all very investigable questions. Why is the Moon moving away from Earth - I don't know if it is. Why so bulky?

R: Have a look at the other side. This is from another research study also from the UK and they're looking at the types of things teachers do or say when they are asked a question in the science classroom. So do any of those surprise you?

T: Ignoring the question surprises me. Generally there might be we'll get back to that later or I'm not sure. Just to completely ignore it suggests that you don't even respond to it, which is a bit ordinary. Give the best answer available for the moment - yes, I quite often do that and then double check with them, does that answer your question. But that's really hard too because even if you ask kids that most of the time they'll just say yes anyway. Admit ignorance and will need help - yes, I do that all the time. Turn the question back - yes we do that. When we think about science - sometimes someone will ask the question like today and the kids will go “I know the answer” to that so you can turn it back on them that way. It's not so much to regain control but I guess it's a way of recognising the knowledge that other kids have on that subject and then they will be able to express that. Yes and change it into a question for investigation - we do that. I think that's a really good idea. That strategy at KWL because they put all their questions up and then by the end of the unit they have an opportunity to go back and say yes we answered that and we answered that and it puts value to what they are actually asking. Science is difficult, science is very knowledgeable, there is so much of it and it is so factual. Yes, I'd be the first to admit it's not my strength. But at least if we have the questions there we can go and find the answer and learn it together sort of thing.

R: So do their questions ever pose difficulties for you?

T: Yes.

R: In what sense?

T: Knowledge most of the time. The kids are so well read, information is so readily available to them, they sit on the computer and find lots of information and sometimes it's not always the right information but they're using that as their basis so I have to make sure that what I'm giving them is correct, as much as I know of.

R: Yes, it's a different world now, isn't it? Wikipedia, and it's not always correct.

T: No, it's not, no.

Teacher 4

Researcher: First of all we'll just look at these pictures. I wonder if you can tell me what are the science concepts you would teach using those pictures, if any?

Teacher: The first one would be the difference between gravity on Earth and gravity on the Moon. We would also talk about looking at movement so push and pull, those sorts of things. The other one would be the phases of the Moon obviously, planet composition and size. Then in relation to that one as well, looking at how it came to look like that - so asteroids, the make up of the whole Moon from inside out. We would also look at the differences between what we need to live on Earth and what we need to live in space.

R: Have a look at these questions. Are there any there that to you raise a red flag and make you think that child is confused about a particular concept. Anything that worries you and you think you might have to do something about that particular question? Do you think that with any of those questions that the kids might have an alternative conception, something that is not scientific?

T: 'Why are there shady spots on the Moon', that is just an obvious one. If there are so many asteroids hitting the Moon how come only a small portion hit the Earth, I usually get asked.

R: Which of those do you think you could do a hands on investigation with?

T: Anything to do with craters – we could do a hands-on with those. Sand and golf balls. I believe you don't use sand. I thought flour, because flour holds its shape better than say dust.

R: Yes, sure. Anything else up there that you could do hands on lessons?

T: You definitely do things like what is the suit made out of? How much does it cost?
We could look at craters like why there are dark spots so by first creating the craters they could then put light on it pretending to be the reflection of the Sun and they can look at the shadows, where do they appear, why do they appear there.

R: Are there any of those that you could deal with a simple little explanation where you could just go "the answer to this one is" and you just tell them?

T: Probably not, I'd want to investigate them a bit further, I'm just giving an off the cuff answer here. How deep are the craters. I'd get them talking about how deep do you think they are. They would range in depth depending on the size of the object and probably is that another astronaut taking the photo, are there astronauts around?

R: What about "what is that thing on the astronaut's back? Who is that person walking on the Moon?" What would you do with them?

T: I would investigate it with the class. We are going to find out who the photo is of and what they need, so what is on their back. It wouldn't be something that I would spend a great deal of time with.

R: There are different types of questions children can ask. This lady here, Wynne Harlen has done a lot of research into children's science questions, she is a lady from England, and she proposes these categories that can split children's questions up. These are questions that are an expression of their wonder or their awe, philosophical questions, questions that request simple facts, more complex questions and then ones that you can investigate. Can you see an example of those on the board?

T: So what do you mean by philosophical questions?

R: I suppose anything that asks about the possibility of aliens or why are we here?

T: No, there are probably not any of those. Questions of wonder and interest definitely. I think a lot of those are wonder and interest. Simple facts would be things like what's on his back, who is it? Complex questions would be more like if some of the asteroids hit the Moon how come only a small portion hit the earth? Then obviously investigable questions would be things like how deep do those craters go, what made the craters.

R: There is quite a range there. These are typical teacher responses to kids questions, Australian research this time. They say that when faced with questions in a classroom, when time is short, these are the sort of things teachers will say. Do any of those surprise you?

T: I would like to do that for some of them. Give the best answer available for the moment. Does that mean whether or not it is correct?

R: Well, in theory, it would be because it is in your head which you would be relying on to be correct.

T: So in that sort of situation I would give the best answer available but I wouldn't have said does that answer your question, I wouldn't say that. Admit ignorance and say you need help.

R: Do you do that?

T: Not in the way that it said here. I'm not really sure, I'll have to look it up. I don't know that answer right away but either we can look it up together or you look it up for homework and come back and let me know or I'll get back to you. I tend to make it something about both of us……..they don't know the answer, neither do I.
Turn the question back to the people – that doesn't really help does it if they are asking the question, turning it back to them is not going to help. Unless it is one of these silly questions then I might say "and what do you think?" so in that sort of situation then yes. Definitely that last one is what I use.

R: So you would just rephrase them to make investigations?

T: Yes.

R: I just want to ask you two of the questions that the kids came up with. One of them was "why aren't there stars in the background of the Moon picture. Do you remember the Moon picture where the background was completely black. Have you got any ideas?

T: We, it has an atmosphere just like the earth has an atmosphere obviously it is not as strong as that but also it could be dependent on things like that.

R: The other one was "why is the Moon a gold colour and at night it's a white colour when we see it up in the sky"?

T: What they are seeing when they look up at the sky is they see the Moon, they see the light reflecting off the Moon and what they see is the white light reflecting off the Moon so therefore it doesn't matter what colour the surface is necessarily, it still has a white light bouncing off the Moon.

R: Great. Thank you, that's all I need. Thank you so much.

Teacher 5

Researcher: What science concepts you would possibly teach from those pictures, if any?

Teacher: You would use it as a prop for science.

R: So coming off from that what would you teach? (pointing to one of the pictures)

T: Why is the Moon illuminated? I noticed a couple of the children asked about the fact that it does not appear to be completely spherical there, that they could see there is a shadow here, you would be leading up to phases. You can obviously see craters when you look at it closely and there appears to be lines coming out from it, there is a lot of discussion there. The impact of craters and the effect of craters there is a lot of science there and the shadows of course.

R: What about the next one?

T: Once again I think shadows are a really big thing. The different sizes of the craters, the different depths of the craters, the texture that would make the kids guess about what the Moon feels like and looks like and what it is made of. One of the kids said sand, that it looks exactly like sand at the beach and it's being affected by water, water droplets. We could do a lot of science with that and we could make that pattern in art, there is a lot of stuff you could do with that.

R: Great, and this one?

T: History first. The fact that it's got mountains. Looking at it from a different perspective you can actually see how high the mountains on the Moon can be with the ridges, because you can't really tell what that is, that it must be the lip of a crater or something like that. It looks like a rim. The flag, the footsteps I thought was a great one because you can clearly see that the footsteps do actually stay. The imprint of his boot is quite clear. There is a mile of science here. I liked that question about why his arms were out straight, because I think that is a really sensible question. When they look at that in detail the kids think of a lot of different things – why is he wearing a pack on his back, why the helmet, why the light, never ending questions and they are all valid.

R: Just using the questions that are on the board, are there any questions there that tell you that a child is way off the scientific point of view. Are there any questions that raise a red flag and make you think that a child is right off point and I have to do something about that?

T: There were a couple of them that came up. Why is there a shadow on the Moon when there is no light that is a really obvious one. Some very basic knowledge about what a shadow is. That does not mean that once you have a short discussion that some children because it's such an unnatural listening technique ……a lot of kids just want to be heard, so they say anything. There is a lot of stuff like why is there no gravity on the Moon. They obviously have got some understanding.

R: That one stood out to me in particular, the one about the shadow. I think a lot of them obviously mean they don't have any prior concept or understanding but are there any others like one that stands out as showing that the children have an alternative conception to what the scientific view is, not just a lack of understanding but an alternative idea?

T: Why does the Moon really need craters. That is a very strange question. Some of the questions that are asked I really think they are more philosophical than scientific but I think they are valid in science.

R: While we are on that topic. Are there any other philosophical ones there other than the earlier one?

T: In the first lot there were a couple of them. I love that one, when did the first meteor hit the Moon. That's a beauty. If that isn't going to be a philosophical discussion, nothing is. Why is the Moon called the Moon. God called it the Moon. That's a classic one. Why do we have a moon? That is a scientific question. How did the Moon get there? How did the Moon ever exist?

R: If you were put on the spot. Let's look at why the craters have a circular shape. If you got that one in class and it put you on the spot, if you felt compelled to answer, what sort of answer would you give to that?

T: I would talk to them about the impact of something heavy going into something else and I would probably very quickly generate a quick experiment and they could test that. We could do it using sugar, dirt, rice or a lot of things. If you dropped something into any of those depending on the shape you would be able to test it very quickly and be able to get a visual of the impact of the site and I think once the kids see it they would know it. As I said with this with the water, it does look like droplets, like the waves have splashed onto the sand.

R: What about 'why isn't there any oxygen on the Moon?'

T: That's a good one. You would have to have a lot of stuff to show the children. There would be resources in the classroom that would tell you about the Moon's atmosphere. There is a lot in that question. The kids say oxygen as if that is the only thing we breathe. There is a lot of discussion there.

R: Can you identify on the board any questions that you would respond to using a hands on investigation?

T: There would be lots of them. You wouldn't be able to teach the basics of the Moon without a hands on investigation. Kids don't get this one unless they can see it. That business about the rotation and the fact that they are rotating - they are connected but they are disconnected. That is a really big thing especially for young children, it's big for adults. That business of something that is rotating around us but it's also rotating around something else and they are all rotating at different rates and that's huge. The other planets are all out there rotating too and kids get that really messed up, adults do too. It's because we actually don't have wonderful resources to show it. Even those things that you have they are often difficult to manipulate. All those different ways we have done it traditionally like you get kids holding things and you get lights and shadows and movements but none of it really shows exactly. The kids get mixed up with Mrs. White's holding this object and I'm holding this object and somebody is holding something else – it becomes quite a complex thing. Nobody has designed a really good resource for showing that.

R: You are right. When the kids get involved and are holding things they get hung up in the holding of things and the position of things, don't they. I wonder if digital resources would give us a hand.

T: The last time I taught this I got on to the NASA site on YouTube and they have amazing things, absolutely magnificient and I think kids should watch them, I think they should have access to them. There are amazing photographs and sequences and all sorts of things out there. The enormity of space is really hard. It's a wonderful subject what I think is hard is that our curriculum is so crowded. These kids did space in Grade 4, I taught them and we did a unit, but where do you start and where do you finish. So what they did was information reports that every child did and then they presented Powerpoint with pictures. I think it was valuable but it doesn't mean that I'm not kidding myself that every child got all those concepts. There's no way in the world that they could. What they did need to do was something in Prep, something in 1, something in 2 and it all needs to be reinforced. We need to have a system, the kids needs to understand the universe, yes they do. We can't teach it in Grade 4, not teach it in Grade 5, come back to it in Grade 6 and teach another part of it. We get bits of information and it all gets a bit tough and it changes. The kids say things like there is no atmosphere on the Moon. There is an atmosphere on the Moon but it's not the same as our atmosphere. That sort of stuff. It takes a lot to build up accurate picture for them, and it doesn't happen in one year in one term and with one teacher. The children can't be stressed when they are doing it, they've got to be having fun. They've got to investigate but they've also got to be able to take it on board at the moment. There's no one right way and no one wrong way you've got to just find it. It is every teacher's dilemma. Not just in science but in every subject.

R: This is Wynne Harlen from the UK who categorized kid's science questions in those groups and you have picked up on some of them already. So can you identify some requests for simple facts.

T: There are so many of them. I think they are the most common. Why do you need that type of clothing on the Moon? Why were Americans the first people on the Moon? That's got more than one element to it. A lot of them cross over. Why do you need gravity boots, who is the astronaut? They're really basic.

R: Interestingly the complex questions generally start with a 'why' or a 'how come'. How many of them do you see?

T: There aren't that many of them.

R: I think there are a lot of them, some of them are described as complex.

T: Some of them are disguised.

R: A lot of the kids asked complex type of questions that can't be answered with a simple yes or no. Are there any that you think are particularly complex that can't be answered particularly quickly and would need in depth explanations.

T: I think there are a lot of them I wouldn't attempt to answer. Even ones as simple as why are his arms out actually would take quite a lot of thought because the kids have actually put themselves in that position of having that sort of material on their bodies and being confined. There is an awful lot really. You could answer it by simply saying spaceman have to wear highly insulated suits but I mean it all leads to something else, to something else, to something else. There are hardly any questions there.

R: Investigative questions, you came up with some of those earlier.

T: There is no end to those either. You can investigate, given time, inclination and materials and stuff…… you could investigate virtually everything.

R: Now have a look at these, on the back. This is from an Australian group who researched teachers' responses to children's answers and they felt they had those five options. Do you use any of those in particular?

T: I try not to ignore the question ever. That would mean that if I had a child who said what about the aliens? I would not dismiss or ignore that question. I guess I would state that as far as we can tell there is no such thing as an alien. Even if it was as simple as that I would not disregard the question.

R: Are there any of those responses you would use more than the other.

T: This one is one that I use a lot. A lot of the time I would say to them, I'm not 100% sure about that and let's find out. Even if I think I know, science changes. There was a time in my life when I would have said the Moon has no atmosphere. Change the incident into a question, that's something I would hopefully use as often as I possibly could. What's this one, turn the question back to the people with what do you think. You know what, sometimes I ask those questions. If it is a very simple one and I am really confident about the answer, then yes I would be doing that. If you could clearly state why the Americans were the first people on the Moon. There is quite a lot in answering that question.

Teacher 6

Researcher: Can you tell me what you think the science concepts are that you would teach from those three pictures?

Teacher: History of the first men on the Moon, so you could take the historical component of it. The science of the Moon, what the Moon is make of, so the scientific side of things and also how are craters formed. Why are there holes in the Moon and such.

R: Now in particular the picture that shows almost the full Moon. What sort of other things could you get out of that?

T: The stages of the Moon, why the Moon changes every night. Why we can see the Moon some days and why we can't.

R: Now, it's a bit difficult because we have actually wiped off all the questions but we've got them all here on the camera and I thought if you wouldn't mind having a look at them, some are easier to see than others, and just tell me if there are any here that you would identify as being problematic. Like for example, if you had asked a question that shows you their understanding was way off the scientific view or if something like a red flag or I have to do something with that question, I have to re-teach that area.

T: Perhaps what are the names of the craters? Is there another Moon? That is probably something that you would have to deal with. This is about the astronaut in the picture they really focused on that, they wanted to know about him and stuff so that would be quite an easy lesson. Rather than being curious about what he is standing on but what is he wearing? How does he feel in that suit? Is it light or heavy in the spacesuit? How old is the astronaut? That type of thing. I did notice similar kids asked the same type of questions like ‘are there any other Moons?’. So that's good to see. Christian's questions were very off centre, a bit abstract, a bit of away I suppose from what everyone else interpreted.

R: How would you describe Christian as a student?

T: He is an interesting boy, he is not good at processing routine. He only focuses on what he is interested in so if something is boring you get nothing out of him.

R: He is interested in something?

T: Yes, he likes research or drawing. He is really interested in a board game that he is making at the moment. That's his focus.

R: Science would be right up his alley then.

T: Yes. He is into games and things.

R: Looking through those pictures again. Are there any there that you think could be investigated with hands on material?

T: All the questions about the craters - what forms craters, which we've done. Yes, the crater ones you can do hands on, the stages of the Moon.

R: How would you do that?

T: Paper mache and black paint or something. I don't know. I'm not sure. Or you can just use with a computer. We could make the Moon.

R: Like a model?

T: Like a model, yes. Like the craters the Moon would be the most hand on because you can do so much with it.

R: What would you do now if you just had those three random pictures?

T: With these three random pictures? I would probably put them into pairs and get them on the computer to try and find some knowledge or some evidence or something to share with us. Or maybe find facts that they now know. Just do that first because they're very into computers this class. That would be my first thing and then we would just come back together and have a chat and the two groups share what they found. That's what I would do.

R: And what about in general from the three pictures were there any questions there that you would just give a quick explanation to, like oh look the answer to this one is ...

T: Yes, some of the basic ones.

R: Yes, could you give me some examples about which ones would be suitable.

T: Well, the space suit one, the one about the man in the picture, you know. A little bit about the history - when that happened - what it was like. I'd probably show them a YouTube clip or something. Probably the ones about how big are the craters and all that stuff would be the ones to investigate. Use some resources to help us with that.

R: Sure. History ones.

T: Yes, they'd be the easy ones. Yes, short answer ones I suppose. Especially Christian because I'd probably lose him if I went too much into the direction I was in.

R: I'm just going to choose a question and put you on the spot to see if you can answer it. What about, is it a new Moon or a full Moon? Would you like to answer that?

T: Would they have looked at the Moon today or is that just a question.

R: That was one of the questions they had, do you remember the picture where it was almost a full moon. So if they asked if it was a new Moon or a full Moon what sort of answer would you give to that if you didn't have time to research it and you had to give it off the top of your head.

T: I'd say it's not a full Moon and then maybe I'd say to them what makes the full Moon and then bring them to the internet and investigate. If I wasn't prepared, that's what I'd do. If we were doing a lesson on the Moon, we'd have some cutouts and matching games.

R: This is a tricky one. Does the Moon spin?

T: OK so is this a kind of on the spot kind of question?

R: Yes, if you had to just dig into your own head to answer that one.

T: I don't know what I'd say. The Earth stays still and the Sun moves around it.

R: Other way. The Earth moves around the Sun.

T: That's right, you're right, yes.

R: It doesn't look like the Moon is moving because we always see the same side, but we spin quite quickly in a general, the Moon spins slowly every month. It doesn't appear to be spinning but in fact it is at a very slow rate. It's not something you observe so you don't give it much attention.
How about the question is there another Moon? I presume they mean in the universe.

T: For us from Earth there is one Moon but that's not to say that out there in the big wide, you know what I mean? Somewhere there is, miles away, that's what I'd have to say.

R: These are categories of children's science questions. This is from a lady called Wynne Harlen in the UK who has worked in science education for years and she categorizes the kids questions into these groups. Questions that are expressions of wonder like "Oh look at this" sort of thing. Philosophical questions - why are we here, are there aliens, that sort of thing. Requests for simple facts, complex questions and investigative questions. So are you able to identify any of those in what you saw from the kids.

T: So, what is it could be an expression of wonder. Simple facts could be the ones like the space suit, who is the man in the picture. Just simple ones, basic facts. More complex ones would probably be the crater ones. How deep is the crater? Can animals live in craters? How cold can the craters be? Some of those could be investigative questions. We could compare small and big craters by using different sized things. What is the Moon? What is the Moon made of? That could be a request for a simple fact.

R: This Wynne Harlen said that complex questions are the ones that require longer explanation or maybe understanding of different things, a variety of concepts to get this one answer but she also said that they usually start with ‘why’ or ‘how come’? We didn't actually get any of those which is surprising because they are usually the most frequent. We didn't get any why or how come type questions which would give you longer answers. Most of the questions were how big, how small, how many. They were really just requests for simple facts. A lot of the questions could be answered with yes or no.

T: Yes, we do often get quite of few of the why questions. As a class group in comparison to other classes I've had their very basic simple kind of kids. They are a very social group.

R: This is from an Australian group who researched teachers’ options about how they could respond to questions and this is what they found. These are the options that you have.

T: Ignore the question and change the subject. I don't know, lets find out. That's what I say. I would probably say ‘is that what you mean? If not, let's go and find out a bit more’. Admit ignorance, turn the question back to the people, what do you think? Yes, maybe just talk about it but I'd probably say to them that I actually don't know so let's find out. More so than try and make myself look right, you know what I mean?

R: Yes, you'd be happy to admit you didn't know about it.

T: If I wasn't sure about something I'd say hey l don't know, let’s find out.

R: Do you ever find that the kids asking questions presents a problem for you. Do you regularly ask them to ask questions?

T: Yes, they ask a lot of questions. We do middle schooling so there's a lot of group work, we do it for six/sevens so there's not a lot of whole class questioning it's more small group stuff. They’re happy with that type of thing.

R: Do you think that makes them feel more comfortable to ask questions or is it just the same as asking a whole class?

T: I think it's easier in a small group.

R: Have you had any other classes where they're not comfortable asking questions?

T: I've been up here in six and I've always done year six/seven so that's what I know. Having said that they are quite social. They don't mind making a fool of themselves. They're not self-conscious.

R: That's interesting.

APPENDIX G: QUESTIONS CHILDREN ASKED (IN THIS RESEARCH)

CLASS 1

Yes/No Questions	Short Answer Questions	Complex Questions
1. Was there ever life on the Moon? 2. Is there still life on the Moon? 3. Is that picture a hoax? 4. Has any asteroids hit the Moon? 5. Are there any aliens on the Moon? 6. Has a solar system hit the Moon? 7. Could there be life on the Moon? 8. Is there any liquid on the Moon?	9. What is the big, round circles on it? 10. What are craters? 11. What stage is it at? 12. How many stages are there? 13. Where is the Moon in the solar system? 14. Why do people think that it's made out of cheese? 15. Why has it got little holes and stuff? 16. When did people discover the Moon? 17. How many days does it take to go to the Moon? 18. Why are there shadows on the Moon? 19. Why are their outfits white? 20. Why are there like hills on the Moon? 21. Why does he have to wear that funny suit? 22. Why is the Moon so rocky? 23. How did they make the suit? 24. Why does he float, like when he walks? 25. What is it? (the photo of the Moon craters) 26. Why are there holes? 27. Why does the man look like concrete? 28. What are the rocks made out of? 29. What's inside the crater, what's down the bottom? 30. Why are there so many craters? 31. How do the craters (sic) form to hit the Moon?	32. Why does the Moon have to be round? 33. How does the Moon create light? 34. Why does it have a dot on the top or bottom? 35. Why are there two different colours? 36. What makes the two different colours? 37. What makes the different stages? 38. How come you can't see it in the daytime but you can see it brightly at night? 39. Why is in the picture the Moon yellow and when we look out at it its grey? 40. Why can't you see any stars from the Moon? 41. Why is the Moon so far away? 42. Why are they big and small [the rocks], why can't they all be the same size? 43. Why do big rocks hit the Moon?

CLASS 2

Yes/No Questions	nonsense questions
1. Is the Moon's dust the same as Mar's dust? 2. Could anything live on the Moon? 3. Did astronauts take that picture? 4. Can you dig up the Moon with a shovel? 5. Does the Moon have its own moon? 6. Could you live on the Moon? 7. Is there water on the Moon? 8. Is there any moisture on the Moon? 9. Could you track something on the Moon? 10. Have any animals been on the Moon? 11. Can plants grow on the Moon? 12. Is there any water on the Moon?	13. Could the Moon go cabooie? (blow up) 14. Would grass grow on the Moon? 15. Has anyone died on the Moon? 16. Have astronauts ever been to the wrong planet? 17. Can a cow jump over the Moon? 18. Has anyone made a TV show on the Moon? 19. If there is grass on the Moon, can there be space cows?
Short Answer Questions	**nonsense questions**
20. How does it get so rocky? 21. Why are there so many craters on the Moon? 22. How deep are the craters? 23. Are the craters made by comets or asteroids? 24. How many times has the Moon been landed on? 25. Is there anything else, apart form craters on the Moon? 26. How long would it take to walk around the Moon? 27. How big can the craters be? 28. What is the Moon made of? 29. How much moon landings have failed? 30. How many rovers have been on the Moon's surface? 31. How many craters are on the Moon? 32. Is the Moon soft or hard? 33. How many flags are on the Moon? 34. How long is the longest time an astronaut has been on the Moon? 35. What is the highest temperature there has been on the Moon? 36. How many people have been on the Moon at once? 37. Who's the oldest person who's been on the Moon? 38. What is the lowest temperature on the Moon? 39. Who has been the youngest person on the Moon? 40. What's in the core of the Moon? 41. How much layers of the Moon is there? 42. What is the weight of the Moon? 43. How many people have landed on the Moon? 44. Is that Neil Armstrong? 45. Who is the astronaut? 46. How many countries go to the Moon? 47. What do people find out when they are on the Moon? 48. When astronauts got to the Moon, how long do they stay? 49. Have they ever actually crashed into the Moon while trying to land? 50. Why don't the people float up in the air? 51. Has there been any women on the Moon? 52. How do vehicles stay on the Moon? 53. When was the photo taken? 54. How far has someone walked on the Moon? 55. Which country first sent someone into space? 56. Is the space clothes heavy? 57. Does it feel hot or cold in a space suit? 58. If that is Neil Armstrong, how come he doesn't have a red stripe?	66. Has anyone fallen off the Moon? 67. Has anyone been lost on the Moon, and then found? 68. Can you take photographs on the Moon? 69. Could you have a bushfire on the Moon? 70. Did he (the astronaut) get back to Earth? 71. Has anybody fainted on the Moon? 72. Could you drive a car on the Moon? 73. Can you ride a bike on the Moon? 74. Would electronics stay on the Moon? 75. Has anyone ever been run over by a rover on the Moon? 76. Can you build a house on the Moon? 77. What do astronauts carry in their manbags? 78. Can you build a stadium on the Moon? 79. Where do they go to the toilet on the Moon? 80. Could you paint the Moon orange? 81. Has anyone ever built another space suit and used it on the Moon? 82. Has anyone tripped and crashed on the Moon? 83. Has anyone ever worn the wrong space suit? 84. How come I can never see the frog face? 85. Can you blow the Moon up with a missile or something like that? 86. How big is the frog face? 87. How much phases of the Moon in a light year? 88. Could the Moon go to the size of a tiny ant in a trillion years? 89. Will the Moon evaporate with Earth in 2012?

59. How far can you see on the Moon? 60. How much does a space suit cost? 61. How high can you jump on the Moon? 62. Are there more than one kind of space suit? 63. Is it true that there is a froggy face on the Moon? 64. Can the Moon get any bigger? 65. Will the Moon one day become a crater in Earth?	
Complex Questions	nonsense questions
90. Why are there only 8 phases of the Moon? 91. Why is the Moon yellow in this photo? 92. Can the Moon become closer to the Earth? 93. Why are there darker patches on the Moon? 94. Why isn't the Moon square? 95. Why does the Moon light up the sky at night?	

CLASS 3

Yes/No Questions	Short Answer Questions	Complex Questions
1. Does it change colour? 2. Has there been life on the Moon? 3. Is there any core and lava on the Moon? 4. Does it ever get closer to Earth? 5. Will the Moon last forever? 6. If you cracked a rock, would it have water in it? 7. Would life be able to be stable if you put a dome around it? 8. Is the Moon a big meteor? 9. Was there life on the Moon? 10. Do little bits scrape off to be meteors? 11. Is it cold on the Moon? 12. Is it always dark on the Moon? 13. Is there gravity on the Moon? 14. If you made a footprint on the Moon and you came back years later, would it still be there? 15. Can you move any part of your body in the suit? 16. Would it be a struggle to keep your feet on the ground?	17. What is it made out of? 18. Is there mountains on the Moon? 19. How did it get its name? 20. Why are the craters a khaki colour? (*photograph error*) 21. Why can't you live on the Moon? 22. If you jumped on the Moon would you stay up in the air? 23. How heavy is the Moon? 24. If you measured the Moon out, how long would the Moon be in centimeters? 25. Is the grey bit hills, or is it flat, or is it a ditch? 26. Why is there so much dust? 27. Why is there no living things on the Moon? 28. How long has the Moon been around for? 29. Exactly how many craters are there? 30. What is it made out of? 31. How old is the Moon? 32. How much air is in the suit? 33. How does the oxygen tank give him air so far away? 34. Who is the person in the suit? 35. How many people have been on the Moon? 36. Why do they wear the suit? 37. What do you wear and take with you? 38. How long can you survive on the Moon without the suit? 39. How many footsteps are there on the Moon? 40. How much would you weigh and what would it be like on the Moon? 41. How long does it take to get to the Moon? 42. How does the suit work? 43. Why was moon dust such a problem? 44. How far away is the Moon from Earth? 45. What is the temperature on the Moon?	46. Why does the Moon light up at night? 47. Why is it a golden colour? 48. Why are there streaks on the bottom? 49. Why does the Moon disappear during the day? 50. Why is it a different colour? 51. Why is it a full moon, half moon, that shape? 52. Why is it round? 53. Why can't it be a planet? 54. Why are there no clouds? 55. What would happen if you were digging into the middle of the Moon? 56. How was it formed? 57. Why is it so bumpy? 58. Why is it grey? 59. Is the Moon the planet with the most craters and why? 60. How come the bigger the crater holes the darker they are? 61. Why does it look like Earth? 62. If rocks hit the Moon, why does it not go out of its rotation? 63. Why is this one a golden colour? 64. Why do more asteroids and meteors hit the Moon [than the Earth]? 65. What would happen if it blew up? 66. Why does the Moon only circle Earth? 67. How did the Moon form? 68. Why do people want to go to the Moon? 69. If there is no gravity how does space stay up? 70. If I left rubbish on the Moon what would happen [to it]? 71. If you put an apple on the Moon, what would happen [to it]?

CLASS 4

Yes/No Questions	Short Answer Questions	Complex Questions
1. Was the photo taken in space by a different astronaut? 2. Does the dark side have more craters than the light side? 3. Is that the only colour on the Moon? 4. Is that the largest crater there on the Moon?	5. How many craters are there on the Moon? 6. When and where would that suit be made? 7. What is the suit made of? 8. How far away is the picture taken from the Moon? 9. How big do the asteroids and the craters get? 10. How much would the suit cost? 11. What made the craters on the Moon? 12. How small is the smallest crater on the Moon? 13. How long would the Moon's surface stay like that? 14. Why are there shady spots on the Moon? 15. Who was the second person to go to the Moon? 16. Why is that suit made out of that material? 17. Where did the flag come from in the background? 18. How big is the crater in the picture? 19. How big do the asteroids and the craters get? 20. How deep are those craters? 21. Is that a waning or a waxing moon? 22. What does the flag look like and is it the same as other flags?	23. How come the black background is so clear? Why isn't anything happening? 24. If so many asteroids have hit the Moon, how come only a small portion have hit the Earth? 25. Why is the Moon so sandy? 26. Why aren't there stars in the background? 27. Towards the edges of the Moon why does it get brighter? 28. Are the dark spots craters? What happened to all the asteroids that made them?

CLASS 5

Yes/No Questions	Short Answer Questions	Complex Questions
1. Is there life on the Moon?	2. How come it looks like it has a little bit of craters but when you come closer it has more? 3. Why is the Moon bumpy? 4. Why do you need that type of clothing to go to the Moon? 5. Why were the Americans the first people on the Moon? 6. Why are his arms out? 7. Why does it look like he's on sand? 8. Why do you need space suits in space? 9. Why does it look like there's a wall behind him? 10. When did the first person land on the Moon? 11. Who is the astronaut? 12. Why does the astronaut jump? 13. Why do you need gravity boots? 14. Does the Moon really need craters? 15. How deep are the craters? 16. How did the craters get there? 17. How does the Moon over there (in the crater) look like an alien landed in it? 18. How come the Moon has craters? 19. Who named the Moon the "Moon"? 20. Why are craters so important? 21. Who discovered the craters? 22. Why are the craters a circular shape? 23. Why does the Moon have holes in it? 24. When did the first meteor hit the Moon?	25. Why does it have black spots? 26. Why is the night sky black? 27. Why is the Moon that colour? (brownish) 28. Why is part of the Moon black? (bottom part) 29. Why is there a moon? Why do we have to have a moon? 30. Why is the Moon round? 31. Why doesn't the Moon have a shadow? 32. How did the Moon ever exist? 33. Why is the Moon brownish in the picture but when we actually see it its white? 34. Why is there a shadow on the Moon when there's no light? 35. Why is there no gravity on the Moon? 36. Why did the first steps get left on the Moon? 37. Why do people visit the Moon? 38. Why isn't there oxygen on the Moon?

CLASS 6

Yes/No Questions	Short Answer Questions	Complex Questions
1. Is there water on the Moon? 2. Is there another moon? 3. Can anything grow on the Moon? 4. Is the Moon squishy? 5. Are there any living things on the Moon? 6. Does the Moon spin? 7. Can someone live on the Moon? 8. Is it hard to walk on the Moon? 9. Is it difficult to get into a space outfit? 10. Is there any more craters? 11. Can animals live in craters? 12. Are there any new craters on the Moon? 13. Can you put a glass roof over the crater and live there?	14. What are the names of the craters? 15. What makes craters? 16. How old is the Moon? 17. How much does the Moon weigh? 18. What does it feel like? 19. How many craters are on the Moon? 20. How many times can the Moon fit into the Sun? 21. How cold is it on the dark side of the Moon? 22. What do we (humans) weigh on the Moon? 23. What is inside the Moon? 24. How big is the Moon? 25. What is the Moon made of? 26. Is it a new moon or a full moon? 27. How much gravity is on the Moon? 28. How cold is the Moon? 29. How far away is the Moon? 30. What does the Moon smell like? 31. What colours are on the Moon? 32. How many footsteps did Neil Armstrong and his crew make on the Moon? 33. How old is the astronaut? 34. Is the spacesuit light or heavy? 35. How many people have landed on the Moon? 36. What time did he land on the Moon? 37. How fast can you go and stay on the ground? 38. What is the difference between an Earth jump and a moon jump? 39. Who is the man in the picture? 40. Who was the first man on the Moon? 41. How do we get there? 42. How long were they on the Moon for? 43. How many flags are on the Moon? 44. How long does it take to travel to the Moon? 45. What is it? (the craters) 46. How deep is the crater? 47. How deep is the biggest crater? 48. What forms craters? 49. How hard are the rocks in craters? 50. How many craters are there? 51. How big is that crater ‘thingy’? 52. How small can craters be? 53. How big can the craters get? 54. How cold can craters get?	

APPENDIX H: ACU ETHICS APPROVAL

AUSTRALIAN CATHOLIC UNIVERSITY

Human Research Ethics Committee

Committee Approval Form

Principal Investigator/Supervisor: Dr. Barbara Odgers Brisbane Campus

Co-Investigators:

Student Researcher: Mrs Katherine Harris Brisbane Campus

Ethics approval has been granted for the following project:

Supporting science inquiry in primary school classrooms - Children's science questions and teachers' responses and answers. (Children's science questions and how teachers deal with them)

for the period: 18 February 2010 to 31 December 2010

Human Research Ethics Committee (HREC) Register Number: Q2009 53

The following standard conditions as stipulated in the *National Statement on Ethical Conduct in Research Involving Humans* (2007) apply:

(i) that Principal Investigators / Supervisors provide, on the form supplied by the Human Research Ethics Committee, annual reports on matters such as:

- security of records
- compliance with approved consent procedures and documentation
- compliance with special conditions, and

(ii) that researchers report to the HREC immediately any matter that might affect the ethical acceptability of the protocol, such as:

- proposed changes to the protocol
- unforeseen circumstances or events

adverse effects on participants

(Committee Approval.dot @ 28.06.2002)

The HREC will conduct an audit each year of all projects deemed to be of more than low risk. There will also be random audits of a sample of projects considered to be of negligible risk and low risk on all campuses each year.

Within one month of the conclusion of the project, researchers are required to complete a *Final Report Form* and submit it to the local Research Services Officer.

If the project continues for more than one year, researchers are required to complete an *Annual Progress Report Form* and submit it to the local Research Services Officer within one month of the anniversary date of the ethics approval.

Signed: K. Pashley. ..... Date: 18 February 2010

(Research Services Officer, McAuley Campus)

(Committee Approval.dot @ 28.06.2002)

APPENDIX I: INFORMATION LETTERS AND CONSENT FORMS

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Brisbane Sydney Canberra Ballarat Melbourne

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Email: **edfac@patrick.acu.edu.au**
www.acu.edu.au

INFORMATION LETTER TO PRINCIPALS

TITLE OF PROJECT: **Children's science questions and how teachers deal with them**

PRINCIPAL SUPERVISOR: **Dr. Barbara Odgers**

STUDENT RESEARCHER: **Kathy Harris**

PROGRAMME IN WHICH ENROLLED: **Masters of Education (Research)**

Dear Principal

I am writing to seek your participation in the research project *Children's science questions and how teachers deal with them,* as part of my Masters of Education (Research).

The study is an exploration of teacher's perspectives about children's science questions. It will investigate what types of questions children ask in the classroom and how teachers respond to and answer those questions. Children's ability to pose and investigate questions is an important part of science inquiry but very few studies have explored the question-asking behaviour of children in primary science classes or how teachers respond to those questions. It would be beneficial to science teaching and learning to know more about children's science questions and how teachers think they would respond to and answer those questions.
There are two activities for participants. Teachers who volunteer can be involved in just the first activity, or in both.
The first means of participation is a questionnaire for all willing teachers on staff. If they choose to participate, teachers will be provided with an information letter and a consent form to sign. The questionnaire can be distributed and collected by the Curriculum Support Teacher on staff and will take no longer than 15 minutes to complete at the end of a staff meeting, at your convenience, late in Term 1 or early in Term 2. Answers will require the teachers to tick rather than write. Responses will be anonymous and the data will be carefully safeguarded to ensure that the teacher's anonymity and that of your school are preserved. The questionnaire will explore teacher's answers and responses to children's science questions. It will also invite teachers to declare if they are interested in being further involved in the study as part of the study group.
The second means of participation is as part of a small study group for ten (10) volunteers of Year Six (or a composite including Year Six). Teachers can volunteer for the study group by completing a form for expressing interest in being involved further in the study. This form will be distributed with the questionnaire. Teachers who volunteer for the study group will not meet as a group, but will be required to discuss their ideas about children's science questions in an individual, face-to-face interview

with me and do a brainstorming activity with their class. The interview with me is intended as a coaching session for teachers to develop their skills and understanding of how to deal with children's science questions. This will occur later in Term Two, on a date chosen by the teacher that suits the class timetable and school events. After the interview they will do a follow-up session with their class. Schools are busy places, so the study group tasks are short so teachers do not loose substantial teaching time. The task the teacher and students participate in is part of the current science curriculum and not 'an extra' in their day.

The children involved in the study will be in the Year Six class of a volunteer teacher. They will look at photographs of the Moon and ask their teacher questions that they would like to know the answers to. Their voices will be recorded. Later, they will participate in a follow-up science lesson with their teacher to answer their questions. Information letters and consent forms will be forwarded to all participants (teachers, parents/guardians, students).

I anticipate there will be no risk to your staff or students, and no pressure will be put on you or your teachers at any stage to participate in the study (the questionnaire and/or the study group). If you agree to participate in the study, your school, and individual teachers, may withdraw at any time.

Any questions related to the project *Children's science questions and how teachers deal with them* can be directed to me or my principal supervisor at, McAuley Campus, Australian Catholic University.

Australian Catholic University Research Projects Ethics Committee has approved the research project. If you have any questions about this project, please feel free to contact:

Chair, Research Project Ethics Committee
C/- Office of Research,
Australian Catholic University, McAuley Campus
1100 Nudgee Road, Banyo, QLD 4014
PH: 36237100

In the event that you have any complaints about the way you have been treated by the study or a query that I as principal investigator have been unable to satisfy, please feel free to contact the above address. Any complaints will be treated in confidence, investigated fully, and you will be informed of the outcome.

If you approve of your school participating in the study please send an approval letter on school letterhead to the researcher by post.

Yours sincerely

Kathy Harris

Student researcher
kharris@bne.catholic.edu.au
School of Education, Brisbane Campus (McAuley), PO Box 456, Virginia, QLD 4014

PRINCIPAL SUPERVISOR: Dr Barbara Odgers
Lecturer, Science Education

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Email: **edfac@patrick.acu.edu.au**
www.acu.edu.au

INFORMATION LETTER TO TEACHER PARTICIPANTS (questionnaire)

TITLE OF PROJECT: **Children's science questions and how teachers deal with them**

PRINCIPAL SUPERVISOR: **Dr. Barbara Odgers**

STUDENT RESEARCHER: **Kathy Harris**

PROGRAMME IN WHICH ENROLLED: **Masters of Education (Research)**

Dear Teacher,

You are invited to participate in the research project *Children's science questions and how teachers deal with them,* as part of my Masters of Education (Research). Participation is not obligatory.

The study is an exploration of teacher's perspectives about children's science questions. It will investigate what types of questions children ask in the classroom and how teachers respond to and answer those questions. Children's ability to pose and investigate questions is an important part of science inquiry but very few studies have explored the question-asking behaviour of children in primary science classes or how teachers respond to those questions. It would be beneficial to science teaching and learning to know more about children's science questions and how teachers think they would respond to and answer those questions.

Participation requires the completion of a questionnaire. The questionnaire will take no longer than 15 minutes to complete at the end of a staff meeting in Term 2, chosen by your principal. Answers will entail ticking rather than writing. Responses will be anonymous and the data will be carefully safeguarded to ensure that your anonymity and that of your school are preserved. The questionnaire will explore teacher's answers and responses to children's science questions. It will also invite you to declare if you are interested in being further involved in the study.

Most research about questions is focused on the questions teachers ask but there is a growing recognition of the importance of the children's questions as a means to interest them in science and as a planning and diagnostic tool for teachers. This research will add to the data the education community has about children's questions and how teachers deal with them and it will help you to further your understanding and interest in science teaching and learning.

A consent form will be distributed with the questionnaire and should be returned together in the prepaid envelope. Refusal to participate or withdrawal at any time will not affect your employment. Any questions regarding this project should be directed to the Student Researcher and the Principal Supervisor:

Kathy Harris; kharris@bne.catholic.edu.au
Dr. Barbara Odgers; ACU, School of Education, PH 36237342

This study has been approved by the research committee at Brisbane Catholic Education.

This study has also been approved by the Human Research Ethics Committee at Australian Catholic University. In the event that you have any complaint or concern about the way you have been treated during the study, or if you have any query that the Supervisor and Student Researcher have not been able to satisfy, you may write to the Chair of the Human Research Ethics Committee care of the nearest branch of the Research Services Office. Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

QLD: Chair, HREC
C/- Research Services
Australian Catholic University
Brisbane Campus
PO Box 456
Virginia QLD 4014
Tel: 07 3623 7429
Fax: 07 3623 7328

Thank you.

Dr. Barbara Odgers — Kathy Harris

Principal Supervisor — Student Researcher

Australian Catholic University
Brisbane Sydney Canberra Ballarat Melbourne

McAuley Campus (Banyo)
1100 Nudgee Road Banyo, QLD 4014
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www.acu.edu.au

CONSENT FORM

TITLE OF PROJECT: **Children's science questions and how teachers deal with them**

PRINCIPAL SUPERVISOR: **Dr. Barbara Odgers**

STUDENT RESEARCHER: **Kathy Harris**

PROGRAMME IN WHICH ENROLLED: **Masters of Education (Research)**

I .... *(the participant)* have read and understood the information provided in the Letter to Teachers. Any questions I have asked have been answered to my satisfaction. I agree to complete the questionnaire, realising that I can withdraw my consent at any time without comment. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way.

NAME OF PARTICIPANT: ____

DATE:_______________________________

SIGNATURE:_________________________

____

SIGNATURE OF PRINCIPAL SUPERVISOR:

DATE:………………………..

SIGNATURE OF STUDENT RESEARCHER:

DATE:.......................………

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INFORMATION LETTER TO STUDY GROUP PARTICIPANTS (TEACHERS OF YEAR 6)

TITLE OF PROJECT: **Children's science questions and how teachers deal with them**

PRINCIPAL SUPERVISOR: **Dr. Barbara Odgers**

STUDENT RESEARCHER: **Kathy Harris**

PROGRAMME IN WHICH ENROLLED: **Masters of Education (Research)**

Dear Participant,

Thank you for expressing interest in being further involved in a study group of teachers of Year Six (or composite classes including Year Six) to investigate the science questions children ask and how teachers either answer, or respond in other ways, to those questions.

As one of the teachers involved in the study group you will do two science tasks with your own class and will have an individual, face-to-face meeting with the researcher at your school. This will occur in Term Two on dates you choose, that suit you, your class timetable and school events.

The first science task is to ask your class to pose questions about photographs of the Moon. Their questions will be recorded (audio only) and should take approximately half an hour. Then you will do a lesson with your class, which will again be recorded (audio only) and should take approximately 45 minutes. Finally, you will meet with the researcher to discuss those questions and how you think you could deal with them. This should take approximately half an hour. The recordings will be transcribed to analyse the interactions about the questions between teachers and children.

Teachers often work alone in their classrooms, so having an extra person present might feel a little uncomfortable, however, this is an opportunity to share your understanding and experience and an occasion for you to develop professionally. The researcher will assist you to recognise different types of children's questions and suitable ways to deal with them to help you further your understanding about children's science questions. Schools are busy places, so the required tasks are short so you do not loose substantial teaching time. The tasks meet current curriculum guidelines and are not 'an extra' to your teaching requirements.

Most research about questions is focused on the questions teachers ask but there is a growing recognition of the importance of the children's questions as a means to interest them in science and as a planning and diagnostic tool for teachers. This research will add to the data the education community has about children's questions and how teachers deal with them and it will help you to further your understanding and interest in science teaching and learning.

Sometimes our busy lives get in the way of what we want to do, so if you do not wish to participate or if at any time you want to withdraw consent and discontinue participation in the study you can, without giving a reason. Involvement is voluntary and so not participating or withdrawing from the study will not disadvantage you or affect your employment in any way. Only the researcher will have identifying information about the participants during the research and this will be removed when the results are being discussed, so that you will not be identifiable by anyone except yourself. There is no risk to you in this study, other than the minor inconvenience of using some of your classroom time for science tasks. As a participant in the study group you would be provided with feedback about the results of the study and copies of any publications arising from the research.

Any questions regarding this project should be directed to the Student Researcher and the Principal Supervisor:

Kathy Harris; kharris@bne.catholic.edu.au
Dr. Barbara Odgers; ACU, School of Education, PH 36237342

This study has been approved by the Human Research Ethics Committee at Australian Catholic University. In the event that you have any complaint or concern about the way you have been treated during the study, or if you have any query that the Supervisor and Student Researcher have not been able to satisfy, you may write to the Chair of the Human Research Ethics Committee care of the nearest branch of the Research Services Office. Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

QLD: Chair, HREC
C/- Research Services
Australian Catholic University
Brisbane Campus
PO Box 456
Virginia QLD 4014
Tel: 07 3623 7429
Fax: 07 3623 7328

If you agree to participate in this project, you should sign both copies of the Consent Form, which you will receive when you meet with the researcher, retain one copy for your records and return the other copy to the Principal Supervisor or Student Researcher.

Kathy Harris

……………………………………….
Student researcher

Dr. Barbara Odgers

……………………………………….
Principal Supervisor

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CONSENT FORM

TITLE OF PROJECT: **Children's science questions and how teachers deal with them**

PRINCIPAL SUPERVISOR: **Dr. Barbara Odgers**

STUDENT RESEARCHER: **Kathy Harris**

PROGRAMME IN WHICH ENROLLED: **Masters of Education (Research)**

I .... *(the participant)* have read and understood the information provided in the Letter to Participants. Any questions I have asked have been answered to my satisfaction. I agree to participate in the study group: a session in the classroom, audio recorded (approximately 45 minutes) and one interview with the researcher (approximately 45 minutes), realising that I can withdraw my consent at any time without comment. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way.

NAME OF PARTICIPANT: ____

SIGNATURE : ____________________________________DATE: ________________

SIGNATURE OF PRINCIPAL SUPERVISOR: ________________________________

DATE:……………………….

SIGNATURE OF STUDENT RESEARCHER: ________________________________

DATE:……………………….

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INFORMATION LETTER TO PARENTS/GUARDIANS

TITLE OF PROJECT: **Children's science questions and how teachers deal with them**

PRINCIPAL SUPERVISOR: **Dr. Barbara Odgers**

STUDENT RESEARCHER: **Kathy Harris**

PROGRAMME IN WHICH ENROLLED: **Masters of Education (Research)**

Dear Parent/Guardian,

Your child has an opportunity to participate in a study to investigate the *science questions children ask and how teachers deal with them* as part of my Masters of Education (Research). Participation is not obligatory.

The study is an exploration of teacher's perspectives about children's science questions. It will investigate what types of questions children ask in the classroom and how teachers respond to and answer those questions. Children's ability to pose and investigate questions is an important part of science inquiry but very few studies have explored the question-asking behaviour of children in primary science classes or how teachers respond to those questions. It would be beneficial to science teaching and learning to know more about children's science questions and how teachers think they would respond to and answer those questions.

Your child's teacher will ask the class to pose questions about photographs of the Moon and later will do a follow-up lesson with the class to deal with the questions. It should be an interesting activity for your child and will demonstrate to them how their questions are valued. The researcher will record the sessions (audio only) and transcribe the recording to analyse the interactions about the questions between teachers and children. All data will be confidential.

Most research about questions is focused on the questions *teachers* ask but there is a growing recognition of the importance of the *children's* questions as a means to interest them in science and as a planning and assessment tool for teachers. This research will add to the data the education community has about children's questions and how teachers deal with them and it will help your child's teacher to further their understanding and interest in science teaching and learning.

Schools are busy places, so the study group tasks are short so teachers do not lose substantial teaching time. The tasks meet current curriculum guidelines and are not 'an extra' to schoolwork.

If you are happy to have your child participate in asking science questions then please sign and return to the class teacher. If you do not wish your child to participate they will carry out an individual, supervised science task in another room, such as the library or the office. If you choose not to have your child participate in the study their education or communication with their teacher will not be affected.

Any questions regarding this project should be directed to the Student Researcher and the Principal Supervisor:

Kathy Harris; kharris@bne.catholic.edu.au
Dr. Barbara Odgers; ACU, School of Education, PH 36237342

This study has been approved by the Human Research Ethics Committee at Australian Catholic University. In the event that you have any complaint or concern about the way you have been treated during the study, or if you have any query that the Supervisor and Student Researcher have not been able to satisfy, you may write to the Chair of the Human Research Ethics Committee care of the nearest branch of the Research Services Office. Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

QLD: Chair, HREC
C/- Research Services
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Tel: 07 3623 7429
Fax: 07 3623 7328

Thank You.

Dr. Barbara Odgers	*Mrs. Kathy Harris*
Principal Supervisor	Student Researcher

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INFORMATION LETTER TO STUDENTS

Children's science questions and how teachers deal with them

Dear Student,

My name is Kathy. I am a student, just like you. I am interested in learning about school science.

I'm going to work with your teacher on a science activity. In the science activity you and your friends can ask questions about some pictures. The pictures are photographs of the Moon.

Your voice will be recorded when you are asking questions and I will listen to it later because I am interested in the questions you ask in class when you are learning science.

It's ok if you don't want to be part of the science activities with me. You can stay in another room and do a task until we are finished. If you have questions or you are worried about this you can talk to your teacher or principal at school.

I'm really looking forward to meeting you!

Kind Regards,

Kathy

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PARENT/GUARDIAN CONSENT FORM

TITLE OF PROJECT: **Children's science questions and how teachers deal with them**

PRINCIPAL SUPERVISOR: **Dr. Barbara Odgers**

STUDENT RESEARCHER: **Kathy Harris**

PROGRAMME IN WHICH ENROLLED: **Masters of Education (Research)**

I .... (*the parent/guardian*) have read (*or, where appropriate*, have had read to me) and understood the information provided in the Letter to the Parents/Guardians. Any questions I have asked have been answered to my satisfaction. I agree that my child, nominated below, may do a classroom science activity with his/her teacher (a brainstorming activity to pose questions and a follow-up activity to deal with the questions). It will take approximately 45 minutes and will be audio taped. I realise that I can withdraw my consent at any time without affecting my child's education. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify my child in any way.

NAME OF PARENT/GUARDIAN: ______________________________________

SIGNATURE: __________________________ DATE:_____________________

NAME OF CHILD: _________________________________

ASSENT OF PARTICIPANTS AGED UNDER 18 YEARS

I ……………………… (*the participant aged under 18 years*) understand what this research project is designed to explore. What I will be asked to do has been explained to me. I agree to take part in a brainstorming session and a follow-up science lesson in which my voice will be recorded. I realise that I can withdraw at any time without having to give a reason for my decision.

NAME OF PARTICIPANT AGED UNDER 18: ______________________________

SIGNATURE: _______________________(of child) DATE: __________________

SIGNATURE OF PRINCIPAL SUPERVISOR: _____________________________

DATE:………………………..

SIGNATURE OF STUDENT RESEARCHER: _____________________________

DATE:......................………