INTRODUCING THE MOON TO SOUTH AFRICAN NATURAL SCIENCE CLASSROOMS.

Lesley Kelfkens

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Some South African natural science teachers' understandings of lunar motion, phases and eclipses and the effect of an intervention with models and activities on the understandings and teaching of a case study subset of these teachers.

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DECLARATION

I declare that this dissertation is my own, unaided work. It is being submitted for the Degree of Master of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted for any degree or examination in any other University.

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ABSTRACT

This dissertation concerns the problem that natural science teachers with limited astronomy backgrounds have to teach new curriculum content about lunar motion, phases and eclipses. My study aims to establish: 60 teachers' knowledge of lunar phenomena through surveys; whether an intervention incorporating models and activities is effective at improving a case study group's understandings; how the case study teachers use these activities and models in the classroom. My results indicate that the majority of natural science teachers have little formal astronomy education. Only two teachers held a scientific understanding of lunar phenomena. The intervention led towards a more scientific understanding amongst the case study group. Scale is essential for developing an understanding of lunar phenomena and models are extremely beneficial, but participants experience spatial problems when viewing models from an external perspective. I propose in-service training in small groups for building knowledge and increasing confidence for teaching this content.

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CHAPTER 1 INTRODUCTION

1.1 Preamble

"In every civilization, every age, mankind has looked up at the Moon.
Four thousand years ago, huge stones were moved to mark its motions.
Four hundred years ago, crude telescopes were turned towards it.
And just a short time ago, we walked upon the surface of the silver shrine of Hecate.
It is no 'lesser light made to rule the night'.
How strange and wonderful it is, casting its silver mantle on the sidereal world".

David Whitehouse (2001:304)

Whitehouse's (2001) words give an indication of the fascination that the Moon has held for the human race over the centuries. I experience that same sense of wonderment and awe when I look at it and so this has drawn me to be interested in and excited by the field of astronomy education research. Besides my own personal interest, in this chapter I want to show how and why the topic and the participants were selected for this study as well as how the research relationship between the participants and curriculum content matter came about. I will also establish the conceptual framework for my study.

1.2 Research Background: Motivating Factors

I conducted a pilot study concerning pre-service teachers' understandings of Moon phases (Kelfkens, 2005; Kelfkens & Lelliott, 2006) during my Honours year. This study was made up of two sample groups: seven primary school student-teachers and fifteen secondary school student-teachers. Both groups did an astronomy component in their respective courses – the primary student-teachers in a first-year geography in education course and the secondary school student-teachers in a second-year science curriculum studies course. With both groups, data were collected pre- and post-instruction by means of questionnaires and interviews to determine the change in conceptual understanding of the student-teachers with regards to lunar phases. The pilot study showed that although there was an increase in the amount of scientific concepts, none of the student-teachers held a completely scientific understanding of the phases of the Moon after completing their respective introductory astronomy courses. These student-teachers will go and teach in some of the very schools surveyed in the current study, which was conducted in the same city as the pilot study. As Trundle, Atwood and Christopher (2002:634) comment, "because educators are charged with developing a scientifically literate society, a potentially serious problem is presented by preservice and inservice teachers who themselves hold alternative conceptions about concepts … that are targeted by the (curriculum)".

Furthermore, a theme called 'Planet Earth and Beyond' was recently incorporated into the South African natural sciences curriculum at the General Education and Training (GET) level (Department of Education, 2002). The curriculum document states that one of the "Core Knowledge and Concepts" (Department of Education, 2002:71) prescribed within this theme for the senior phase (Grades 7 to 9) is utilizing the motion of the Moon and Earth to provide explanations for lunar phases and eclipses. Other astronomy topics are included in this section of the curriculum, but I decided to omit these as they would have made the scope of this study too broad.The content matter in this theme is completely new to the natural science syllabus and this, together with the pilot-study results (Kelfkens & Lelliott, 2006) raises concerns that in-service natural science teachers are inadequately prepared to teach 'Planet Earth and Beyond' and that those natural science teachers trained before the advent of the new curriculum would have no astronomy background unless they studied geography during their teacher training or have attended in-service training courses. This led me to select in-service natural science teachers as the participants for this research, focussing on the Moon's phases and eclipses as prescribed in the curriculum document (Department of Education, 2002).

Once I had established the participants and area of the curriculum that I wanted to incorporate into this study, I looked towards the research literature for further guidance.

1.3 Trends in the Research Literature

Several astronomy education researchers comment on how few studies have been done on one or other aspect of this field. Bailey & Slater (2003:20) contend that "what little systematic research has been conducted on the teaching and learning of astronomy is scattered among many journals over the years". They suggest that this could be because it is a recently emerging research field and point out that the *Astronomy Education Review,* which is entirely devoted to the field and the first of its kind, only started publishing at the end of 2001. Stahly, Krockover and Shepardson (1999) comment on the scarcity of research with an emphasis on the scientific understandings and misconceptions about Moon phases among primary school learners. However, Barnett, Keating, Barab and Hay (2000) do not share these viewpoints: "Over the past decade there has been a proliferation of studies (116 studies since 1988….) reporting students' difficulties in understanding basic astronomical phenomenon (sic)" (2000:134). Moreover, SABER Astronomy (2006) list a total of 150 journal articles in their bibliography of astronomy education research as at the 10th of July 2006 so I don't think that the criticism of a shortage of astronomy education research is applicable any more. There *is* a dearth of astronomy education research done in South Africa, though. I am aware of only one printed in an international journal, which was a study conducted by Lemmer, Lemmer and Smit (2003) of 232 South African university students' ideas about the universe. In the nine volumes of the African Journal of Research in Mathematics, Science and Technology Education (AJRMSTE) that have been published to date, there were no articles on astronomy education research.

Much of the astronomy education research relates to understandings pre- and post- instruction either for learners (e.g. Stahly *et al.*, 1999; Barnett & Morran, 2002), university students (e.g. Barnett *et al.,* 2000); and more commonly, for student-teachers (e.g. Trundle *et al.*, 2002, 2007; Callison & Wright, 1993; Atwood & Atwood, 1996). Several of the studies also focus on determining the astronomy knowledge of in-service teachers without any form of intervention (e.g. Brunsell & Marcks, 2003; Summers & Mant, 1995). From this discussion, it can be seen that studies with in-service teachers have usually focused on establishing their knowledge with no pre- and post- test situations. This is probably because such a study would have to coincide with an in-service training course. In their review of astronomy education research, Bailey and Slater (2003) only mention one such study. My own data collection time period did not coincide with any in-service training courses and so I decided to run an intervention myself with a small group of willing teachers, in order that I could do some pre- and post-measurements, even if they would be on a small scale.

Very little research focuses on in-service training for teachers where a new topic has been introduced into the curriculum. As King (2001) comments, studies concerning the success of alterations to the syllabus which incorporate new subject matter are relatively uncommon. I found only three papers concerning the introduction of Curriculum 2005 in South Africa of relevance to science in the African Journal of Research in Mathematics, Science and Technology Education (AJRMSTE). These three papers all report on different aspects of the same research project, the Mpumalanga Secondary Science Initiative (MSSI). The first concerns science and mathematics educators' views of Curriculum 2005 (Aldous, 2004). Another used case studies and looked at how the new curriculum was being put into practise by some science teachers (Rogan, 2004) and the final one was an evaluation of learner accomplishment according to the objectives on the curriculum (Hattingh, Rogan, Aldous, Howie & Venter., 2005). My research is different to these in that it specifically looks at the new content in the curriculum, whereas these three papers looked more at the practical aspects of implementing the curriculum in terms of outcomes and assessment. So this was a further incentive for conducting this research.

King's paper (2001) provided a further area of interest for this research taking it beyond merely testing for conceptual understandings. King conducted a study ten years after an earth science knowledge area was introduced into the natural science curriculum in the United Kingdom. He mentions before the NCS curriculum was introduced in the United Kingdom, biology, physics and chemistry were taught as separate subjects at the junior high school level. This is similar to South Africa, except that physics and chemistry were both taught under the umbrella of 'physical science'. King also points out that the majority of the British science educators were experts within their subjects but knew little about teaching "other 'traditional' science subjects, and usually no experience at all of teaching 'nontraditional' science" (2001:637). The same could be said of science teachers in South Africa.

The purpose of King's (2001) study was to assess teachers' perceptions of how successfully they were teaching the earth science knowledge area and to find factors hindering their teaching proficiency, so that proposals for improvement could be put forward. He found that secondary school science educators teaching this earth science knowledge area had an inadequate earth science education. Moreover, their learners' performance in earth science in national examinations was weak and science educators' foremost resources of earth science information and knowledge were fellow science educators and science textbooks written for GET-level learners. This paper led me to speculate whether South African science teachers are experiencing similar difficulties with incorporating 'Planet Earth and Beyond' and if so, how they are coping with them. So besides investigating teachers' understandings of Moon phases and eclipses, this paper motivated me to also investigate the added dimension of what was actually happening in South African schools.

1.4 Research Problem and Questions

I have cited personal interest, the pilot-study, the introduction of astronomy content into the natural sciences curriculum and the dearth of astronomy education research in South Africa as motivating factors for this research. Furthermore, the literature indicated a gap regarding *in-service* teachers' understandings of Moon phases and eclipses using pre- and post-test methods as well as teachers' attitudes towards teaching this topic in their classrooms.

1.4.1 The Research Problem

Teachers trained prior to the advent of the new curriculum are unlikely to have had an astronomy component included in their degree. The findings of qualitative research show that prior to instruction, the majority of individuals have alternative conceptions regarding the reason for the Moon phases (Trundle, Atwood & Christopher, 2007). According to the curriculum document, natural science teachers are expected to teach about lunar phases and eclipses. So the problem is, how are they meant to do this if they've had no formal education on the topic, hold alternative conceptions and view lunar phases and eclipses as unimportant and as the domain of the geography department? These concerns were shared with me by several teachers during informal conversations about the curriculum changes prior to my research. The purpose of this study therefore, is to ascertain science teachers' education and knowledge of lunar motion, phases and eclipses and to establish their thoughts on its importance and place in the natural science syllabus.

1.4.2 Research Questions

In the light of the background established and the research problem, I set up the following research questions as the focus of my study:

a. What are senior phase natural science teachers' understandings of the Moon's motion, phases and eclipses?

b. What are selected senior phase natural science teachers' understandings of the Moon's motion, phases and eclipses after an intervention with activities and models?

c. How are activities and models on the Moon's motion, phases and eclipses used in the science classroom by a small group of senior phase natural science teachers?

1.5 Conceptual Framework

In this section, I will discuss the context and design of the research. Next, I will establish the research paradigm and my positionality and finally I will give a brief explanation of the methodology I used in this study.

1.5.1 Context and Design of Study

This study was conducted with 60 secondary school teachers from both private and state schools in Johannesburg, South Africa. A sub-set of this group comprising five teachers from two private schools was studied in greater depth. The entire sample group completed questionnaires which were designed to ascertain teachers' knowledge of lunar motion, phases and eclipses and to obtain information concerning teachers' level of education on this topic, their experience in teaching it and their attitudes towards its inclusion in the natural science curriculum. Follow-up interviews were conducted with the subset sample group of five to provide richer information on the data supplied in their questionnaires. I ran an intervention session with the small sample group to explore the concepts relevant to explaining lunar phases and eclipses with the use of models and activities. Two of the teachers then taught a module on lunar phases and eclipses to their Grade 8 learners, which I observed. Follow-up questionnaires and interviews were conducted with all five teachers to gauge the effectiveness of the intervention session and particularly the use of models, at improving their scientific understanding. As this study is limited to 60 participants, most of which were from private schools, the study is not representative of South African schools. More detail is provided about the sample groups and setting in chapter 3.

This is a dissertation as opposed to a research report and so it is a larger study. The first research question and the research literature provided the rationale for the investigation of the subsequent questions. Furthermore, the third research question was necessary as it provided closure: once the intervention was completed, it was significant to observe what the teachers actually did with their newfound knowledge and resources.

1.5.2 Research Paradigm and Researcher Positionality

Sikes (2004) explains that a research paradigm is “a basic set of beliefs that guides action” and that recently, “the two main paradigms that have influenced educational research are the scientific, positivist, objective, quantitative paradigm and the interpretative, naturalistic, subjective, qualitative paradigm” (2004:18). My research does not strictly fall into either paradigm. The procedures used and data collected to answer the first research question are more positivistic in nature. I used questionnaires to establish 60 natural science teachers’ knowledge of lunar motion, phases and eclipses. Their knowledge was classified according to predetermined typologies based on scientific facts. I collected further data with a small case study group from an intervention and classroom observation. This data related to how learning took place in a situated learning context and how the teachers used their pedagogic content knowledge to transform the intervention material into material suitable for teaching to Grade 8’s. This would fall more into an anti-positivist approach, as the procedures used and data collected here attempted “to obtain softer facts, and insights into how an individual creates, modifies and interprets the world in which they find themselves” (Opie, 2004:8-9).

My positionality is my philosophical standpoint and essential assumptions about ontology, epistemology and human nature and agency (Sikes, 2004). My ontological assumptions relate to how I view social reality. As my research paradigm has both positivistic and interpretative aspects, so my ontological assumptions will have both objective and subjective aspects. The objective aspect relates to how I view the survey part of my study, which I consider to be something which can be "observed and measured" (Henning, 2005:17), "independent and objectively real" (Sikes, 2004:20). In contrast, I view the case study part of my research as "as socially constructed, subjectively experienced and the result of human thought as expressed through language" (Sikes, 2004:20). My epistemological assumptions, or my beliefs concerning the attainment of and passing on of knowledge (Opie, 2004) follow from this. The surveys would produce knowledge from objective, quantitative data (Sikes, 2004) and the case study would produce knowledge that is considered to be the participant's own due to her personal awareness and reflections (Opie, 2004). Sikes (2004) explains that assumptions regarding human nature and agency relate to how people are perceived to behave in the world. So in the survey part of my research the participants are perceived "to behave in a predetermined or reactive way" (Sikes, 2004:23) whereas in the case study, people are seen to "initiate action and make choices (and to) … act voluntarily and out of their own free will" (Sikes, 2004:23).

1.5.3 Methodology

Sikes (2004:16) describes methodology as "the theory of getting knowledge, to the consideration of the best ways … by which data that will provide the evidence basis for the construction of knowledge about whatever it is that is being researched, is obtained". This study could be termed a "survey case study" (Henning, 2005:34), as it makes use of both surveys and a case study. I chose to do this type of study, as I wanted to have sufficient data to compare to other studies regarding types of understandings of lunar phases and eclipses. I also wanted to go beyond presenting just numbers and percentages. Rather, the participants' feelings and attitudes (Opie, 2004) as well as some of their own words and the complex nature of the interaction between the participants (Leedy, 1997) will also be revealed through the descriptive nature of qualitative research. So the survey part is quantitative and the case study part is qualitative. The survey case study methodology will be described in more detail in chapter 3.

1.6 Structure of Dissertation

In this chapter, I have explored numerous factors motivating this research. The participants have been briefly introduced as well as the research relationship between the participants and the curriculum content. I have established the research problem: in-service natural science teachers are expected to teach lunar phases and eclipses in the new curriculum with limited or no astronomy background. Therefore, my research questions aim to establish teachers' knowledge of the Moon's motion, phases and eclipses, whether an intervention with models and activities is effective at establishing a scientific understanding of these concepts and how the models and activities used in the intervention are used by teachers in the classroom. I have also discussed the trends emanating from the research literature. The themes emerging from these trends and others, such as the use of models in research, will be developed further in chapter 2, as well as the theoretical framework for the study, which centres on situated learning. I will explore some of the concepts fundamental to this view of learning, such as legitimate peripheral participation. Teachers' pedagogic content knowledge will also be explored in chapter 2, as this is another theoretical framework with particular relevance to the third research question.

In chapter 3, I will outline the methodology and research procedures used in this study in more detail. I will explain how I designed, piloted and carried out the questionnaires and interviews. I will show how I designed and ran the intervention to fit in with the model of situated learning and explain the selection of the activities used in the intervention and describe them. I will also explain how I conducted the observation sessions, paying special attention to the teachers' pedagogical content knowledge in presenting the activities. Also in chapter 3, I will discuss the role of models in this research in more detail. I will also give a more detailed description of the sample groups and how they were selected, explain my role as researcher, discuss the ethical considerations of this research and give an account of validity and reliability as pertains to this research.

I decided to do the methodology for the data analysis together with the results to allow for easier reference and so that they would still be fresh in the reader's mind. I will outline the data analysis and results for the survey part of this study in chapter 4 and for the case study in chapter 5. In these chapters, I will also discuss the results and relate them back to the theoretical framework and research findings established in chapter 2. Validity, reliability, precision and trustworthiness issues will also be discussed in these two chapters as appropriate. Finally, I will respond to the research problem and give answers to the research questions in chapter 6. Also in this chapter, I will draw conclusions, reflect on the study, discuss the research limitations of the study and offer some recommendations based on what I've learnt and also suggest some issues for further research.

CHAPTER 2 LITERATURE REVIEW AND THEORETICAL BACKGROUND

2.1 Literature Review

2.1.1 Introduction

Reading the literature on research in astronomy education, I have found that some common themes emerge. In this literature review, those emerging themes that either provide motivation for this research or are relevant to my research questions will be discussed. Some of these themes were introduced in chapter 1 and include difficulties in understanding lunar phases and eclipses, the use of models in astronomy education research, the relevance of scale in understanding lunar phases and eclipses and the introduction of new astronomy material into the science curriculum.

2.1.2 Difficulties in Understanding Lunar Phases and Eclipses

A common theme that emerges from the literature, is the difficulty experienced in understanding the concepts of lunar phases and eclipses. Stahly *et al.* (1999) report that their research with Grade 3 learners verified that it is difficult to fully understand the concept of Moon phases. These difficulties are not limited to primary school learners. As Stahly *et al.*(1999) point out, previous research has found misconceptions concerning Moon phases from primary school level to beyond university level and the fact that Moon phases appears at primary school level is noteworthy, considering that people from more mature age groups still have misconceptions after teaching has occurred.

These difficulties don't just lie with lunar phases and eclipses but extend to other astronomy topics as well. For instance, Atwood and Atwood (1996), in their study of 49 primary school student-teachers' understandings of the causes of the seasons, found that not one student-teacher held a scientific understanding on both the questionnaires and interviews with models. Brunsell and Marcks (2005:39) used the Astronomy Diagnostic Test (CAER, 1999) to determine the "baseline astronomy knowledge" of 142 primary and high school science teachers from Wisconsin in the United States. Generally, they found that the teachers surveyed were "lacking a deep, coherent understanding of astronomy concepts" (2005:38). Two questions in this diagnostic test relate to the Moon's motion, phases and eclipses. One quarter of the grade R-4 teachers, just over half of the grade 5-8 science teachers and two-thirds of the senior science teachers could accurately pinpoint the Moon's location at a particular phase. The majority of teachers (77% to 95% across the three groups) were able to correctly answer a question which dealt with the full Moon's appearance six hours after rising. Generally, Brunsell and Marcks found that considerable misconceptions existed among these teachers concerning the motions of the Earth and Moon and that many of them were not able to relate "the concepts of rotation and revolution to positions of the Earth (and) Moon… and to observation" (2005:43). With a few exceptions, the senior science teachers exhibited the greatest astronomy comprehension, followed by the Grade 5-8 teachers and the junior teachers showed the least. This is probably because secondary school teachers would have received the most in-depth tertiary education on astronomy.

Summers and Mant (1995) looked at primary school teachers' understandings of 'The Earth's place in the universe' in the curriculum for England and Wales. This is similar to the South African curriculum's 'Planet Earth and Beyond'. Their research questionnaire contained 57 closed items (true / false / not sure/ don't know) as well as some background questions and adhered to the identical order of concepts as given in the curriculum document. There were 120 participants (88% female), consisting of 66 in-service teachers and 54 recent teacher graduates, who had not completed an Earth-science component as part of their Post Graduate Certificate in Education training. Only 19% of the participants had taught curriculum content relating to Moon phases. The vast majority of the 57 questionnaire items related to core subject matter in the primary school syllabus (Summers & Mant, 1995). The areas where the teachers came out strongly with regards to their knowledge about the Moon were: that the Moon can from time to time be seen during the day, that it is not always in the same position in the sky, that the Moon revolves around the Earth and that it is smaller than the Earth. Very little knowledge of and a large amount of confusion concerning the phases of the Moon was apparent, with the majority stating that the phases were caused by a shadow (usually the Earth's) blocking the Moon. Several respondents thought that the Moon had a part to play as a cause for day and night and less than 50% knew that half of the Moon is always lit up by the Sun.

Some other studies concerning difficulties in understanding phases and eclipses are presented in Section 2.1.3 on page 16 and Section 2.1.4 on page 38 rather than here, as they also cover the themes of 'models' and 'scale'.

2.1.2.1 Summary: Difficulties with Lunar Phases

I have given examples of difficulties with understandings of lunar phases amongst primary school learners and teachers. These are not the only papers in this review that explore difficulties in understandings – it is a common theme throughout the sections that follow as well. Once I had written this section, I identified another gap in the research literature: astronomy education research tends to look at understandings of a variety of astronomy concepts and those specific to the Moon almost always focus on phases. Very few look at eclipses. For instance, the Astronomy Diagnostic Test (CAER, 1999) used by Brunsell and Marcks (2005) only includes one question on eclipses and it relates to a solar rather than a lunar eclipse. Not one of the 57 questionnaire items in the research by Summers and Mant (1995) included something on eclipses. I found only two papers that look at lunar phases and eclipses in some depth, which are those of Barnett and Morran (2002) and Barnett *et al.* (2000). Both of these will be discussed in the next section.

2.1.3 The Use of Models in Astronomy Education Research

From the papers I have reviewed, not much of the astronomy education research prior to the 1990s incorporated the use of three-dimensional models. Instead, most of this research was done by surveys or multiple choice questionnaires (Stahly *et al.*, 1999). In the last 15 years there has been an increase in the use of such models and some of these papers will be discussed in this section. Three-dimensional models were used in the classroom teaching in Stahly *et al.'s* (1999) research and they refer to the participants also making their own three-dimensional models in the interview context. What is disappointing, though, is that very little detail is provided as to what these models consisted of and how they were made. The same can be said for Callison and Wright's (1993) research and that of Parker and Heywood (1998) who mention that models were used in their research, but don't provide any detail about the models used. The research by Callison and Wright will be discussed in Section 2.1.4 on page 38 and Parker and Heywood's research in this section.

Stahly *et al.*(1999) researched the nature of learners' understandings of the phases of the Moon. Their study, with four Grade 3 learners at a primary school in mid-west America, was conducted within a constructivist framework. It investigated the children's understandings both before and after teaching on the Moon phases, through the use of questionnaires and interviews, in which the participants drew diagrams and made three-dimensional models to assist with their explanations of the Moon's phases. The participants were chosen according to "teacher recommendations, academic ability, gender, and verbal ability, to reflect the composition of the class" (1999:162). In the first lesson, the participants' understandings of the Moon's phases were established. In subsequent lessons, learners completed activities which emphasized the concept that the Moon can be seen because it reflects light from the Sun and the learners worked with three-dimensional models of the Sun-Earth-Moon system, in which they watched the changing shape of the Moon coinciding with a changing position of the Moon relative to the Earth and the Sun. When inaccuracies in the learners' diagrams were found, concepts presented in previous lessons were re-examined. One of the activities involved learners making a picture of the Moon phase which would be observed with a particular positioning of the Sun, Moon and Earth and in another activity they had to do the opposite i.e. give pictures of the positions of the Sun, Earth and Moon, which corresponded to a particular Moon phase. "The intention was to give students a broader range of experience in moving from the Moon phases to the Sun-Earth-Moon positions, and vice versa" (Stahly *et al*., 1999:164).

In the pre-instruction questionnaires and interviews, the learners' answers seemed to contain more alternative conceptions and less narrative when compared to the post-instruction answers. Prior to instruction, two of the participants held a mixture of scientific and alternative understandings. They both understood that the Moon revolves around the Earth as being an important factor in observing the lunar phases and both held the misconception that one's geographical position on Earth would determine the

Moon phase. One of these participants did not indicate an awareness of the role that the Sun plays in observing the phases and didn't include the Sun in her diagrams. A third participant cited the Moon's revolution as a factor causing the lunar phases. However, he was unable to provide much explanation as to why the Moon's revolution of the Earth plays a part in the observation of the phases. The remaining participant in the Stahly *et al.* (1999) research study held the misconception that cloud cover determines the lunar phase. This is a fairly common misconception that has been reported in at least five other studies (e.g. Trundle *et al.*, 2002). In my previous research (Kelfkens, 2005), I speculated that this misconception appears to be less prevalent in the Southern Hemisphere. Kelfkens and Lelliott (2006) did not find this misconception at all amongst 22 pre-service teachers in South Africa and Cameron and Lelliott (2006) found this misconception amongst less than 3% of 57 Grade 7 and 8 learners and likewise with less than 3% of 59 university students. Kelfkens and Lelliott (2006) proposed that this is because there is far less cloud cover at night in South Africa compared with the Northern hemisphere. However, Dunlop (2000) found this misconception amongst 3% of 67 learners in a study conducted in Auckland, New Zealand and he makes specific reference to the fact that the weather is often cloudy in New Zealand. So it would probably be more accurate to postulate the misconception of clouds causing the Moon phases is less frequent in areas where the night sky is seldom cloudy, as is the case in Johannesburg, South Africa.

Stahly *et al.* (1999) concluded that the learners' understandings of Moon phases altered to some extent after teaching, with some of them incorporating scientific conceptions. Of the two participants who had held some scientific views before instruction, one seemed to have achieved a scientific grasp of the material post-instruction, even tangibly changing her own position in order to look at the Styrofoam Moon from the Styrofoam

Earth's perspective. However, each participant appeared to improve at his/her own pace. Another of the participant's responses showed that he had incorporated certain scientific conceptions, but largely there was an absence of core knowledge concerning the Moon phases. Furthermore, Stahly *et al.* (1999) found that the learners formed ideas incompatible with the scientifically accepted viewpoint. They give the example of a participant who improved in understanding, but continued to struggle in the post-interview with the idea of one's geographical position on Earth as the cause of the phase observed, despite having answered this correctly on the post-questionnaire. He was confused and reverted back to his original view from the pre-instructional data. Stahly *et al.* (1999) contend that these findings have important ramifications for the teaching of Moon phases.

Mant and Summers' (1993) study related to primary school educators' comprehension of the subject matter in 'The Earth's Place in the Universe' – the U.K. equivalent to 'Planet Earth and Beyond', since the researchers were aware that hardly any of these educators would have had education on this beyond high school level. Specifically, their research questions concerned what primary school educators knew regarding objects and phenomena observed in the heavens and their "structural mental models for the universe as a whole" (Mant & Summers, 1993:106). They interviewed an opportunity sample of 20 teachers in order to determine their ideas about day and night, seasons, lunar phases, planetary motion, scale in the solar system and the connection between the stars, planets and the solar system. In this discussion, I will only focus on the aspects of their study which are relevant to my study, namely sky observations (specifically for the Moon) and lunar phases. Although scale is relevant to my study, the questions on scale investigated by Mant and Summers (1993) did not focus on scale in the Sun-Earth-Moon system, but rather on the position of planets in the solar system.

Various objects were used in the interview context. These ranged from diagrams on cards to three-dimensional models and a variety of differently-sized spheres. For the sky observation questions, the model consisted of a piece of plasticine which symbolized a mountain. A small figurine was positioned on top of the mountain to signify an observer. The combination was then placed on a larger piece of cardboard which was cut in the shape of a circle. The edge of the circle symbolized the horizon. Interviewees were told to picture themselves as the figurine on the mountain and asked what they would observe over the course of an entire day. For questions on the Moon phases, Mant and Summers (1993) supplied paper and pens, an Earth globe and the differently-sized spheres for the teachers to use, to support their accounts.

With regards to lunar motion, most of the teachers (80%) knew that the Moon isn't stationary in the sky but very few (10%) knew that it follows roughly the same path as the Sun across the sky. For lunar phases, 15 (75%) knew that the Moon orbits the Earth. Only two (10%) were able to give a scientific explanation for lunar phases and the most common misconception among 80% of the participants was the eclipse understanding i.e. the Earth's shadow or something blocking the Sun's light from reaching the Moon. Mant and Summers (1993) comment that the teachers didn't know that half the Moon is always lit up by the Sun and that the amount of the illuminated half seen depends on the relative positions of the Sun, Earth and Moon.

Mant and Summers (1993) found a total of 13 assorted universe models amongst their participants. Within these models they developed a set of hierarchical concepts and stages and classified their participants' understandings of the Earth's place in the universe accordingly. Out of the 20 teachers, four (20%) were classified as having a scientific understanding of the universe and the remainder were classified as having an alternative understanding. This paper is valuable to me as several of the questions asked in the interviews are similar to my questionnaire items and so I will be able to compare my results to these.

Suzuki (2003) also used models in his research concerning student-teachers' understandings of the Moon. He conducted a case study during two research seminars in science education for student-teachers who were members of the Research Group of Science Education at a Japanese university. These 1½ hour discussion groups were held once a week. The first discussion group consisted of four final-year student-teachers who were going into teaching the following year and the other contained four undergraduate student-teachers preparing to complete research in the following year. Research concerning teaching about the Moon, undertaken by one of the final year student-teachers was also included in this study. All the student-teachers had done astronomy in their second and third years of study but had not examined the Sun or Moon themselves over prolonged periods of time.

The aim of Suzuki's research was to determine methods by which primary and lower secondary school student-teachers "reconstruct their ideas in conversations about science" (2003:892). In particular, he examined the following questions:

- "How do I engage prospective teachers in thinking together about the Moon?
- What ideas about the Moon do the prospective teachers express?" (Suzuki, 2003:896).

The student-teachers observed the Moon at a time and place that was convenient for them. During the discussion groups which the student-teachers generally held amongst themselves, they gave an account of their Moon observations, discussed the Moon, and tried to make sense of what they had seen. A variety of models were provided by the researcher when necessary including spheres, a light and a sizeable Earth's globe. On occasion, the student-teachers constructed their own models. For example, a student suggested gluing a doll onto the Earth's globe to represent an Earth-based observer. Other students proposed utilizing the scope of either a small camera or video recorder for the doll's eyes in order to obtain the Earth observer's viewpoint. Moreover, they talked about astronomy information that they had assembled themselves. Finally, they planned and taught each other astronomy lessons, followed by a reflection on these lessons. Diagrams made by the student-teachers on a blackboard were also used during the discussion groups. Suzuki (2003) did not find the familiar misconception amongst the student-teachers that the Moon's phases are caused by the Earth's shadow falling on it. I say 'familiar misconception' in the light of Trundle *et al.*'s (2002) research in which this was the most common misconception found and they also cite the same result across 11 other studies, comprising in excess of 3000 subjects ranging from primary school learners to senior science teachers. Suzuki (2003) also found that the student-teachers experienced difficulties when attempting to explain Moon phases as observed from the Earth or in three-dimensions from outside the solar system.

Parker and Heywood (1998) point out that prior to the introduction of the new curriculum in England, primary school teachers had not taught astronomical concepts and they contend that in order to assist these teachers to grasp the necessary concepts requires more than just presenting the scientific explanation to them. They argue that pedagogic content knowledge (PCK) is also essential to this process in that teachers need to understand and know how learning occurs, be conscious of the essential elements which facilitate the learning process and be aware of how their learners try to understand “abstract ideas which do not resonate with their experience and view of the world from the observations they encounter” (1998:504).

Three groups of 89 students in total formed part of their research: the first was a group of first-year Bachelor of Education (B.Ed.) students; the second was a group of PGCE (Post Graduate Certificate in Education) students; and the final group consisted of primary school teachers attending an in-service training course. None of the B.Ed. students were science majors, the PGCE students had come from a variety of backgrounds with regards to their initial degrees and although the primary school teachers had taught some of the ‘Planet Earth and Beyond’ material, none of them had studied the relevant astronomy concepts in their own tertiary studies. The participants were required to draw diagrams explaining the reasons for night and day, seasons and lunar phases. This was followed by instruction and then they drew another set of explanatory diagrams for the same phenomena. Post-instruction, they were also asked if they thought their original understandings had changed and if so, what they thought were major contributors to this change. The reason Parker and Heywood (1998) did this was for the teachers to identify which factors affected their own learning and compare this with the way pupils learn.

In my discussion here, I am only going to focus on aspects relevant to my study. Lunar phases were not covered by all three research groups – only the PGCE students and the primary school teachers. Parker and Heywood (1998) noted that the reasons for lunar phases were difficult concepts for the majority of these participants, particularly the concept of the relative positions of the Sun-Earth-Moon system. With regards to understandings, 10% of the PGCE group and 18% of the teachers had a scientific understanding of the cause of lunar phases. Most (47%) of these two participant groups held an alternative understanding of the cause of lunar phases and 17% had no conceptual understanding. Of those that held an alternative understanding, the vast majority (96%) attributed the phases to a shadow falling on the Moon, mostly the Earth's shadow and sometimes the shadow of a planet. The balance held a partially scientific understanding. They also found that the majority of both participant groups were familiar with the fact that the Moon orbits the Earth, the terminology for the phases and observable phenomena related to the Moon's motion.

Afterwards, many participants remarked that the teaching demonstrations and use of models to explore their thoughts had been much more successful at helping them to envisage the astronomical phenomena. Parker and Heywood (1998) contend that the models were vital for participants to expound on and communicate their thoughts. In addition, models played an essential role when participant groups presented their ideas to one another. Some concerns that arose were that participants struggled to visualize rotation and revolution at the same time and transfer information between diagrams or written material and three-dimensional moving models. Fanetti (2001) in Section 2.1.4 on page 38, comments on the problem of participants' interchangeable use of 'rotation' and 'revolution'. Likewise, Parker and Heywood (1998) note the interchangeable use of the terms 'spin' and 'orbit'. So even the use of 'spin' and 'orbit' rather than 'rotation' and 'revolution' doesn't solve the problem of confusing the meanings of the words, as in everyday English, they are all used synonymously. Parker and Heywood (1998) contend that models are the best way to address the difference between the two as their meanings also cannot be easily conveyed in a diagram.

Trundle *et al.* (2002) looked at primary school student-teachers' understandings of Moon phases both before and after teaching. Their pre-instruction results were based on three groups: 15 student-teachers completing a primary science methods course, not due to have any astronomy teaching, and two physics groups of 21 student-teachers each, both of which were to receive astronomy teaching specifically aimed at Moon phases. Data for the methods group and one of the physics groups (group A) were collected by interviews with models, whereas physics group B used drawings in their interview responses. The reason why only one of the physics groups used models related to one of Trundle *et al.'s* (2002:637) research questions: "Does using a three-dimensional model… during pre-instruction interviews have instructional value?" During interviews, the student-teachers were initially required to give oral accounts of their understandings of the cause of Moon phases. Thereafter, some of the student-teachers were requested to use a three-dimensional scale model which consisted of three spheres to represent the Sun, Earth and Moon to add to their oral accounts. The student-teacher was external to the model used in the interview. Here, the Sun was a yellow ball with a diameter of 10cm and two white balls represented the Earth and the Moon, with diameters of 3 cm and 1 cm respectively. The model used in the astronomy teaching was different to that used in the interview. In the teaching, the student-teacher was internal to the model, in that the student-teacher was looking from an Earth observer's point of view. This was because the student-teacher's head represented the Earth. The Moon was a white ball with a 10cm diameter and the Sun was an ordinary light bulb, which was lit up.

Over 90% of all subjects provided one or more alternative explanations (Trundle *et al.*, 2002). The most common alternative conception across all three groups was that the Earth's shadow falling onto the Moon is the reason for its phases. This response was provided by a total of 18 out of the 57 subjects. A total of 35 subjects did not appear to comprehend that the Moon revolves around the Earth and almost all of the subjects did not know that half the Moon is always lit up by the Sun throughout the cycle of phases. Both these findings were not reported with this rate of occurrence in earlier research.

Trundle *et al.* (2002) also found some new things: an additional five perceptions on the causes of the Moon phases (the Sun's revolution about the Earth and Moon, an alternating quantity of light from the Sun to the Moon, the directness of the Sun's rays onto Earth, alternating distances between Sun and Moon or Earth and Moon and that an unexpectedly high number of primary school student-teachers did not know that the Moon's orbit is geocentric). Their post-tuition results showed that a higher than anticipated number of participants held either a scientific view or fewer alternative conceptions than before: physics group A - 71.4% and physics group B – 80.9% evidenced a scientific understanding post-teaching as opposed to 9.5% and 0% respectively before teaching (Trundle *et al.*, 2002). Concerning models, Trundle *et al.* (2002) found that using the model to explain the three-dimensional occurrence of the Moon's phases appeared simpler for the student-teachers and put them more at ease. The use of the models also provided fuller explanations to the interview questions. The authors concluded that overall, there is much value to be obtained by using three-dimensional models in research investigating the phases of the Moon.

Trundle *et al.* (2007) did a continuation study with 12 of the female participants from the previous one (Trundle *et al.*, 2002). From the findings of the initial study, the final classification of these 12 participants indicated that their understanding of Moon phases was less scientific when compared with the full group, where 77.8% had achieved a complete scientific understanding as opposed to 66.7% of the 12 participants in this study. The continuation study was conducted 6-13 months after teaching in the original study and these results were compared to the pre-instruction and immediate post-instruction results conducted in the initial study (Trundle *et al.,* 2002). The researchers conducted delayed post-interviews with eight student-teachers six months after they finished the physics course and the remainder they interviewed 13 months after the course. The time difference was due to a different enrolment time for the science methodology course for some of the student-teachers. During this 6-13 month timeframe, no course work dealt with Moon phases and no reports concerning any major Moon happenings appeared in the newspaper or on television. They wanted to see if the time lag affected the student-teachers' understanding of Moon phases because there is usually a time lapse of several months from when student-teachers receive teaching on Moon phases and when they teach it to learners. Trundle *et al.* (2007:305) comment that "it is assumed that a teacher's conceptual understanding is one of several factors influencing instructional effectiveness".

The codes and method of classification were the same as in the original study. In the pre-instruction interviews in the original study (Trundle *et al.,* 2002), seven of the 12 student-teachers were found to have an alternate understanding of the cause of lunar phases. Four were classified as 'alternative fragments' as they gave more than one alternative explanation and the 12th student-teacher had been found to have no conceptual understanding of the cause of lunar phases. No alternative conceptions were present amongst these 12 student-teachers in the post-instruction interviews, where eight were classified as having a full scientific understanding and the other four a partially scientific understanding.

In the delayed post-interviews conducted in the continuation study (Trundle *et al.,* 2007), seven student-teachers were classified as having a scientific understanding of lunar phases. Interestingly, Trundle *et al.* (2007) found that not all seven had been classified as 'scientific' on the post-interviews. Two had been classified as 'scientific fragments'. Their understanding had matured during the time delay. Nonetheless, two student-teachers were classified as ‘alternative fragments’ and another as having one alternative explanation. Trundle *et al.* (2007) state that the implication of these three results is that these student-teachers had not amalgamated the scientific explanation and so not restructured their original understandings. These three student-teachers therefore obtained the same classification as they’d originally obtained in their pre-instruction results (Trundle *et al.,* 2002). Trundle *et al.* (2007) hypothesize whether “the status of the scientific explanation had fallen below that of one or more alternative frameworks” (2007:313).

Trundle *et al.* (2007) developed four classification schemes to explain whether and how the student-teachers’ understanding altered. These classification schemes were termed “growth and stability”, “continuous growth”, “partial decay” and “full decay” (Trundle *et al.*, 2007:313). ‘Growth and stability’ was used to describe those whose understandings remained the same from the post- to delayed post-interview. The two student-teachers whose understanding improved to a scientific understanding by the time of the delayed post-interview fell into the ‘continuous growth’ category. The ‘partial decay’ category was used for those whose understanding changed from ‘scientific’ to ‘scientific fragments’ and ‘full decay’ for those who reverted back to their pre-instruction alternative understandings.

Trundle *et al.* (2007) conclude that for most of the student-teachers, the sought after conceptual change endured over the 6-13 month time period prior to delayed post-interviews. They conclude further that possibly for the three student-teachers who went back to the alternative explanations given in the pre-interviews “the status of the scientific framework was higher at post-interviews, at which time it was strongly associated with the physics course, and the alternative explanations were relegated to lower status” but several months later “the status of the more strongly held alternative explanations was higher and these explanations were dominant” (Trundle *et al.*, 2007:321). Another conclusion was that those student-teachers with a single alternative understanding were less likely to go back to an alternative explanation than those with more than one alternative understanding, as only one of the seven who were originally classified as ‘alternative’ reverted back to an ‘alternative’ classification, whereas two of the four classified as ‘alternative fragments’ reverted back to the same multiple alternative explanations. This finding is interesting because Trundle *et al.* (2007) point out that it makes more sense that it would be more difficult to change a single alternative understanding because it is assumed to be more strongly held than multiple alternative understandings. They propose that those with a single alternative understanding are possibly “more likely to engage in a comparison of the critical elements of their initial framework” (Trundle *et al.,* 2007:321). With regards to models, another conclusion made is that the “psychomotor modelling activity is particularly critical” (Trundle *et al.,* 2007:321). They noticed that there was a substantial difference in how much time and exertion the student-teachers gave to the activity once a scientific explanation for phases had been distinguished.

Barnett and Morran (2002) conducted a ten-week study with 14 Grade 5 learners. These learners were enrolled in a specialized science class which took place three times a week. The researchers’ aim was to see if these learners were able to “develop an understanding of the complex relationships between the Moon’s phases and eclipses, and whether science instruction needs to directly address student alternative frameworks to promote conceptual change” (Barnett & Morran, 2002:865). With regards to the Moon’s phases and eclipses, they specifically wanted to see if the learners were able to thoroughly explain how Moon phases are similar to and different from eclipses of the Moon and Sun. Barnett and Morran made use of pre- and post-intervention interviews with the entire group. For the intervention, they used an eclectic instructional approach as the theoretical framework, which incorporated whole-class discussions; individual, group and whole-class activities and the use of three-dimensional moving computer-generated models. The program they put together for the intervention began with activities which explored easier concepts such as the Earth's shape and gradually built up to more difficult and interconnected concepts such as eclipses and consisted of six major assignments. In this research paper, their emphasis is on the final two assignments, which were "the position of the Moon relative to the Earth during its different phases, and … the Moon's phases and lunar and solar eclipses" (Barnett & Morran, 2002:861). They based their program syllabus on previous research and the Challenger Centre's space curriculum (Barnett & Morran, 2002).

At the start of each major assignment, Barnett and Morran (2002) asked the learners to journal all their ideas concerning the Sun-Earth-Moon system. At the conclusion of each class, they had to go back to their journals, review what they'd written and note any changes in their conceptions. During the major assignments, the learners worked together in small groups. They had to hypothesize, do research on the topic with the help of some probing questions, make Moon observations on a daily basis and use the three-dimensional computer-based models to explore their hypotheses and ideas. At the end of each major assignment, the learners gave a short report-back on what they'd found and how their conceptions had altered during the assignment. Different models were also used in the pre- and post-intervention interviews, which consisted of a collection of spheres to represent the Sun-Earth-Moon system. The learners were also asked to make diagrams on some paper during the interviews to complement their verbal responses.

Barnett and Morran (2002) used a rubric to classify the learners' responses and these responses were given a value from zero (no conceptual understanding) through to four for a full scientific understanding. The learners' mean score on the pre-interviews was 1.14 and increased to 2.92 on the post-interviews. During the pre-intervention interviews, the researchers found that the majority of learners had difficulties with explaining the cause of lunar phases. In particular, they battled to elucidate the relationship between the phases and the relative positions of the Earth, Sun and Moon. The highest score on the pre-interviews was '2', which was awarded to six of the learners with some scientific fragments and four were classified as having no conceptual understanding, with the rest falling inbetween. Other findings on the pre-interviews were that the six learners who had some scientific fragments were able to attribute lunar eclipses to the Moon falling into the Earth's shadow but were unable to relate a lunar eclipse to a full Moon. They found that quite of few of the learners confused solar and lunar eclipses. Furthermore, three of the learners placed the Moon at first or third quarter position when asked where full Moon was and explained that the Moon needed to be beside the Earth, for the Sun's reflected light to be visible from Earth. The Earth's shadow and its rotation were two of the alternative explanations given for the cause of lunar phases but Barnett and Morran (2002) do not provide a list of all the alternative conceptions found or the prevalence of each alternative conception.

Barnett and Morran (2002) comment on some useful aspects of interviewing that came to the fore during the pre-interviews (Barnett & Morran, 2002). They say that "through the interview process it was evident that the students were constructing their understanding of the concepts *in situ* and that the interviewer's questions were catalysts that encouraged the students to re-evaluate their understanding" (2002:868). In addition to providing useful knowledge about the learners' ideas, the interviewing process disclosed how individuals constructed their ideas.

On the post-interviews, four were classified as having a full scientific understanding, and a further five were able to explain the cause of phases and eclipses but were unable to explain the difference between a full Moon and a lunar eclipse and so had developed some conceptual understanding. The remaining five had limited or alternative understandings but none were classified as having no conceptual understanding in the post-interviews. From the journals and the classroom report-back sessions, Barnett and Morran (2002) also found that the activities played a vital role in developing the learners' understandings. One of the recommendations made by Trundle *et al.* (2007) on the basis of their results was that student-teachers should write down their hypotheses regarding observations and causes of lunar phases pre-instruction and then on a regular basis during teaching, to contrast what they'd learnt with their hypotheses. They contend that this would be complemented by conversation and putting their ideas down on paper – both in small groups. They propose that the latter be the final thing student-teachers should do after a nine-week study. This is exactly the approach used in the Barnett and Morran (2002) study published five years earlier. In their paper, Barnett and Morran concluded that the journaling and classroom discussions "not only assisted students in keeping track of their understandings, but also provided a conduit through which students could develop an awareness of their existing understandings and how their understandings changed during the course" (Barnett & Morran, 2002:873). I didn't make use of journaling in my study as time constraints didn't allow for it. Like Barnett and Morran's (2002) study though, my activities required research, Moon observation, making hypotheses and using three-dimensional models to test the teachers' hypotheses on the cause of lunar phases and eclipses.

Further, I have looked at some research done with university students who were not student-teachers. Barnett *et al.* (2000) conducted a study of eight undergraduate university students, commencing a trial introductory astronomy course. This was another paper that looked at eclipses as well as phases. The trial astronomy course required the students to build three models in pairs or threes using Virtual Reality modelling software and they were interviewed both before and after the course. The first model the students had to build was a three-dimensional, stationary model of the celestial sphere with the Earth at the centre. The purpose of this model was to teach the students basic astronomy terms, the reason why seasons occur and to build a firm foundation on which to develop further ideas in astronomy. The second model they had to build was a three-dimensional moving model of the Sun-Earth-Moon system. The students had to explore "orbital paths, periods, distances between, rotational rates, and the relationships between" (Barnett *et al.,* 2000:136) the Sun, Earth and Moon as well as draw comparisons between their model and the real thing in order to discover the limitations of their models. Finally, they had to build a moving model of the solar system, which accounted for "the rotational and revolutional rates of the planets, and the relative sizes and distances between the planets. … The similarities and differences between the planets' orbital motions, spins, interior structures, Moon systems, and atmospheres" (Barnett *et al.,* 2000:136) were also explored.

Prior to the course, Barnett *et al.* (2000) found that the majority had a poor understanding of the causes of the Moon's phases and eclipses. The software had an extremely effective instructional value, as seven of the students achieved a scientific understanding of the Moon's phases and eclipses by the end of the course. They report that the effectiveness of the software was linked to the fact that it permitted the students to build three-dimensional models and observe these models from various points of view and that these models enhanced the students' capacity to envisage abstract ideas.

Finally, I have also examined two studies which involved the use of a model – the Earth's globe – in the interview context. Although this is not exactly related to my study, the findings concerning the use of a model are relevant to my study, as they provide the incentive and know-how for the use of models in an interview context.

Twenty five Swedish children from Grades 1, 2 and 5 participated in a study by Schoultz, Säljö and Wyndhamn (2001). Semi-structured interviews were used with the Earth's globe placed in front of the child from the start of the interview, with the first question concerning whether the child could identify this object. They found that all the learners could correctly identify the Earth's globe, could easily talk about what can be observed by looking at the globe as well as the relevance of the colours used on the globe. It was also obvious to all but two of the children, that the shape of the Earth is spherical. Moreover, no additional models of the Earth were found amongst these children and they appeared to be completely comfortable with the fact that people can live in the Southern Hemisphere without 'falling off' the Earth. Seventeen of the learners were able to attribute this phenomenon to gravity. Here, the older children were noticeably better at explaining the concept of gravity. Schoultz *et al.* (2001:114) deduce that it is essential to view "reasoning from a discursive and situated point of view" as well as a "tool-dependent activity". They maintain that the learners' statements during interviews were based on a source, namely the Earth's globe, which they can relate to. The globe enables contemplation during discussion, as it acts as a "prosthetic device" (2001:115) for reasoning and producing knowledge. This provided a good incentive for making use of models during interviews in my study.

Vosniadou has conducted many research studies, sometimes in collaboration with colleagues (Vosniadou, Skopeliti & Ikospentaki, 2005; Vosniadou & Brewer, 1994), much of which has been published in academic journals. For instance, Vosniadou and Vosniadou & Brewer conducted a succession of research studies which indicated that primary school learners experience problems comprehending the idea of people able to live all around the outside of a rotating Earth (Vosniadou *et al*., 2005). The large number of published studies by Vosniadou is indicative of how influential she is. Schoultz *et al*.'s (2001) paper criticizes earlier work done by Vosniadou and her colleagues on learning and mental models of the Earth and the day-night cycle. They contend that for children, interviews may be a theoretical problem because traditional types of discussion are pre-established via a series of high-speed questions, which children may find significantly difficult to manage. Schoultz *et al.* claim that this is a reason for the considerable variance in their results as compared to the previous research done by Vosniadou. They claim that the theoretical framework used in Vosniadou's research provides an unjustifiable bias towards "unobservable entities of a rather dubious ontological status" (Schoultz *et al*., 2001:109) and contend that this relates to a lack of consideration of the situated character of children's thinking.

Vosniadou, Skopeliti and Ikospentaki (2005) produced a response to Schoultz *et al.'s* (2001) criticism. Vosniadou *et al.* (2005) investigated the use of a model, namely the Earth's globe in order to see how children's previous knowledge affects the manner in which they utilised the globe to rationalize the Earth's shape. They predicted that children who had problems with comprehending the Earth's shape without utilising the globe would continue to have these problems despite the globe being at hand. Vosniadou *et al.*'s

(2005) sample group consisted of 42 primary school children in Athens, Greece, twenty of these being Grade 1 learners and the rest of the group, Grade 3 learners. A questionnaire was compiled to be used in an interview situation, with the first eight questions designed to ascertain how the learners characterised the Earth without utilising a globe. The learners had to answer questions orally, make use of diagrams and build models out of play-dough as they answered the respective questions. Then their diagrams and play-dough models were removed and the learners were given an additional six questions together with the globe.

Vosniadou *et al.* (2005) found that with the first eight questions, the Grade 3 learners gave a larger amount of technically accurate answers than the Grade 1 learners. Moreover, the researchers were able to allocate the learners to a distinct model of the Earth. These models were based on those found in previous research. With the remaining six questions used together with the globe, Vosniadou *et al.* found an improvement in the total amount of technically accurate answers. However, there was also an increase in discrepancies in the learners' responses, making it more difficult to allocate the learners to a particular model of the Earth's shape. Lastly, the majority of learners appeared to be oblivious to the alterations in their answers as well as their discrepant answers after being shown the globe.

In response to the criticisms levelled by Schoultz *et al.* (2001), Vosniadou *et al.* (2005) found that the results of the first eight questions confirmed the findings of Vosniadou's previous research. From the latter six questions used together with the Earth's globe, Vosniadou and her colleagues (2005) concluded that only the older children benefitted from using the Earth's globe when constructing a scientific explanation for the Earth, that several children alternated between using the Earth's globe and their own previous knowledge when answering questions and that the children who did this were ignorant that in the process, they were presenting conflicting ideas. Vosniadou *et al.* (2005) argue that the Earth's globe on its own is insufficient to bring about a change in ideas during teaching and that children also need explication to allow for mediation between their previous knowledge and the new ideas presented by the Earth's globe. They argue further that if children do not fully comprehend an idea, they repeat their errors when the globe is absent. They conclude that explication does "not have a place in a radical socio/cultural approach. They make sense only in a theory that assumes that children think, and believe, and have internal representations" (Vosniadou *et al.,* 2005:350) and so refute Schoultz *et al.'s* (2001) criticism of their theoretical framework.

2.1.3.1 Summary: Models

Although the papers included in this section focus on models, it can be seen from the findings that the difficulty with understanding of astronomical concepts is echoed here as well. As in the previous section, several of these papers report numerous misconceptions regarding the cause of lunar phases. In the case of Trundle *et al.*'s (2002) study, the two most frequent misconceptions for the cause of phases were the Earth's shadow falling on the Moon and the Moon's rotation. These misconceptions are also reported in Barnett and Morran's (2002) research. This section has also emphasized that research on the Moon has covered very little on lunar eclipses and that difficulties are also experienced in understanding eclipses. For instance, Barnett and Morran (2002) found that learners struggled to explain the connection between a lunar eclipse and full Moon and several learners confused solar and lunar eclipses.

Furthermore, the papers in this section have provided good motivation for using models. Some of the reported benefits of models include putting participants at ease and providing more detail in the interview context

(Trundle *et al.*, 2002). Both Trundle *et al.* (2002) and Schoultz *et al.*'s (2001) comment that models seemed to make it easier for the participants to explain their understandings in a clearer way. Barnett and Morran's (2002) paper also explores the benefits of interviewing and using activities, both of which are relevant to my study.

2.1.4 The Relevance of Scale

The aim of Fanetti's (2001) research was to obtain an idea of the degree of alternative understandings of lunar phases and to see if there is a strong connection between these alternative understandings and an inaccurate conception of scale in the Sun-Earth-Moon system. Fanetti used pre- and post-instruction questionnaires to conduct her research with approximately 400 university students in an introductory astronomy course at Iowa State University. The questionnaire consisted of two open questions, one which was intended to draw out the reason for lunar phases and the other which asked the students to draw a scale diagram for the Sun-Earth-Moon system on a piece of paper with dimensions 21.25 cm by 27.5 cm. In the scale question, the students were guided to do the scale for both size and distance.

Teaching on the lunar phases in the introductory astronomy course consisted of a lecture incorporating an explanation of lunar phases with textbook diagrams, a project in which the students had to do a scale model of the solar system and 17 group discussions on the work presented in lecture. A few of the groups did additional activities that centred specifically on the relationship between scale in the Sun-Earth-Moon system and phases of the Moon. One of these activities formed the basis for Activity 2 (Appendix D on page 239) in my research. The other activity they did was very similar to the description of Activity 3 in Appendix D on page 239. In these additional activities, the students were asked to identify the presence of shadows in the hope of challenging the eclipse alternative conception of the cause of lunar phases.

Fanetti (2001) reports her results under 3 groupings: A, B and C. Group A was the entire sample group of all students that took part in the study. Groups B and C were both sub-sets of group A and both groups attended the lectures, discussion groups and completed the project, but only group C students did the additional activities which specifically explored the relationship between scale and phases of the Moon. She found that 10% of all students had a scientific explanation for the cause of lunar phases both pre- and post-instruction, but that more students had a greater number of scientific fragments post-instruction and she concludes that the instruction was helpful at increasing the students' scientific understanding. However, the additional activities did not have the desired effect of increasing understandings of lunar phases with group C. The most common alternative conception was the eclipse explanation for the cause of lunar phases. In group B, the amount of students who considered the phases to be caused by the Earth's shadow falling on the Moon decreased by 6% post-instruction but in group C, the amount of students that gave this explanation increased by 13% post-instruction. Fanetti (2001) ponders whether the emphasis on the word 'shadow' during the first additional activity had the opposite effect i.e. rather than students remembering that no shadows were visible on the Moon in the scale model, they latched onto the idea of shadows and this resulted in the fairly significant increase in this concept post-instruction. The movement of the Earth was the second most common alternative explanation but with the students using the words 'rotation' and 'revolution' interchangeably, Fanetti (2001) states that it is difficult to accurately break down this category further.

Most students could not draw the correct scale diagram even after instruction, despite being able to correctly state what the scale should be. The values of the scales stated by the students were the same as the values given during instruction. Again, group C posed problems in the scale results concerning the relative sizes of the Earth and Moon. Despite the fact that they did the additional activity on scale, their results on the post-instruction questionnaire were worse than group B's. Although there was a decrease in the number of students who believed the Moon to be closer to the Earth than one Earth diameter, 59% of students in group B still believed this to be true post-instruction. In the post-questionnaires for group C, there was a significant change towards the correct distance. Fanetti (2001) concludes that the additional activities were extremely beneficial at correcting the misconceptions regarding the distance between the Earth and Moon. Only 4% and 3% of groups B and C respectively were able to correctly scale both sizes and distances post-instruction, which was a slight improvement on the pre-instruction results. Unfortunately, Fanetti (2001) did not find "a significant connection between students' explanation of lunar phases and the scale models of the Earth-Moon system" (2001:67).

I found it interesting that Fanetti doesn't include the size and distance of the Sun in her scale discussion, as I think this is as relevant to understanding why the Sun's rays are able to reach the Moon on the opposite side of the Earth as the distance of the Moon from the Earth. Although my research questions do not include an investigation into the relationship between scale and lunar phases, it is relevant to the activities I've chosen and like Fanetti, I think that a scientific understanding of the phases must incorporate a solid understanding of the scale of the Sun-Earth-Moon system.

Although Callison and Wright (1993) don't specifically study the influence of scale on lunar phase understandings, they do look at the effect of spatial ability. At the end of their paper, they make an important recommendation regarding the importance of scale and so I have included this paper in the 'scale' section of the review rather than the 'models' section.

Callison and Wright (1993) studied the consequence of three different teaching approaches on 76 primary student-teachers' understandings of the Sun-Earth-Moon system. Their first two research questions looked at whether previous knowledge and the degree of their spatial skills would have some bearing on participants' capabilities for clarifying their observations. A third research question asked if "the level of reasoning ability (would) affect concept completeness, conceptual change, or conceptual development" (1993:2) and the final research question inquired about the outcome of a teaching method with models on participants' capabilities for understanding lunar phases.

The student-teachers in this study were in four different classes. All of them did Moon observations over the course of a month. Then Callison and Wright (1993) interviewed some students, whom they chose at random. This was followed by teaching where three of the four classes made use of physical models – the remaining class were expected to cultivate mental models. As mentioned earlier in this chapter, Callison and Wright provide no descriptions of the models used. After teaching, a post-instruction questionnaire was given to the student-teachers and the same questionnaire was given to them two weeks later. In addition, post-interviews were conducted with the same student-teachers who completed pre-instruction interviews.

With regards to the effect of using models, Callison and Wright (1993) found "significant positive categorical shifts" (1993:7) in the groups that received teaching with models. This was not found for the control group. However, the method they used for their analysis (Chi-square) only revealed a shift in a minimum of two categories, but could not reveal which ones had shifted so they were only able to conclude that the use of models doesn’t have a harmful outcome on understandings. Also, they found no significant difference in results between the post-instruction and delayed post-instruction questionnaires. Callison and Wright (1993) concluded that previous knowledge played a major part in understandings of the lunar phases. They based this conclusion on their pre- and post-interview findings. They were unable to find a significant connection between the level of spatial skills and scientific understandings but comment that the group that was taught without physical models stated that they wanted resources to construct models and attempted to use whatever was available to construct models. “This behaviour appears to endorse the need for concrete objects to define a space and to manipulate within a space an individual’s mental ideas” (Callison & Wright, 1993:9). An important recommendation they make concerns the use of scale. They consider the fact that scale wasn’t used in their study to be a limitation of their study and hypothesize that it is significant, particularly for the construction of mental models. The researchers were unable to answer their third research question as there was only a noteworthy relationship in one of the four groups. They suggest this as an area for further research.

2.1.4.1 Summary: Scale

Unfortunately, Callison and Wright (1993) are only able to provide recommendations regarding the importance of scale in understanding lunar phenomena and Fanetti (2001) was unable to report any conclusive findings regarding the connection between scale and understanding lunar phases. However, both papers once again emphasize the difficulties associated with understanding lunar phenomena. Fanetti’s (2001) research also reports on problems associated with the interchangeable use of the words ‘rotation’ and ‘revolution’.

2.1.5 New Curriculum Content

A paper which investigates the introduction of new astronomy content into the science curriculum is that of King (2001). King collected his data by means of questionnaire items which requested opinions using a Likert scale. The questions were divided into six categories: age and gender of the teachers and the socio-economic area of the school; teachers' subject specializations and the extent of their earth science foundation; issues arising in teaching the earth science component, such as teachers' self-assurance and pleasure in teaching the component; the development of the earth science scheme of work; resources consulted; and opinions regarding more assistance for teachers in the form of resource matter and in-service training.

Results were based on 164 respondents in schools across the socio-economic spectrum. Amongst the teachers who taught natural science, 26.9% were biology, 42.8% chemistry, 26.8% physics, 1.0% geology and 3.0% other specializations. The vast majority (135) of the teachers hadn't covered any earth science in their degrees, but 31 of these had learnt some earth science in school. Of the remaining 29 teachers, only seven had a degree in earth science, a further ten had a degree which included an earth science module and 12 had done a degree which covered selected earth science subject matter. Two of the questions concerning teachers' opinions on teaching an earth science component are of particular relevance to my study. These are questions B: "How confident do you feel in teaching National Curriculum earth science?" and D: "What do you feel is the overall importance of earth science to the National Curriculum of Science?" (King, 2001: 649). The answers to question B indicated moderate confidence (with a mean of 2.7 on the Likert scale) and the responses to question D indicate a lesser opinion regarding the value of the earth science component (mean of 3.2 on the Likert scale).

King (2001) is of the opinion that the moderate level of confidence displayed by the teachers is misguided when considered with his other findings concerning the teachers' poor foundations and knowledge of earth science and the poor performance of learners in the earth science section of the national examinations. Despite all this, the finding that the teachers viewed the earth science to be of moderate importance was both contrary to expectations and quite encouraging for those promoting earth science to remain in the natural science curriculum in the future. In chapter 1 (Section 1.3 on page 3), I mentioned that another interesting finding in the King (2001) study was that the resources used by the participants to teach the earth science component were high school textbooks and other science teachers. Also, only 4% of the participants had attended in-service training aimed at the earth science component.

Jenkins (2000) produced a similar study to King's (2001), but it is more general than King's in that he looked at the overall effect of a new curriculum on high school science teachers in the United Kingdom, whereas King focussed specifically on the effect of the introduction of the earth science component into the science curriculum in the United Kingdom. In this discussion, I will only focus on the aspects of Jenkins' study which relate to the earth science component, as this is what is relevant for my study.

Jenkins' (2000) findings are based on a survey completed by 296 science teachers of which he used data from 239 teachers. The reason for the difference in numbers is that he removed teachers from the sample group who started their teaching careers after the introduction of the new curriculum. Four problem areas arose in the analysis of the questionnaires.

The first relates to teachers' autonomy to select instructional activities. One of the major gripes in this problem area amongst chemistry teachers in particular, related to the introduction of the earth science component. The teachers felt that valuable chemistry content had been lost through the introduction of earth science content, that finding suitable hands-on activities was tough and that they felt unconfident about teaching content outside their area of speciality. The second problem area was the decline in time available for practical work in the laboratory. One teacher felt that the amount of earth science content had constrained the time available for practical laboratory work in other areas. The other two problem areas were "the range of laboratory activities undertaken by pupils" and "pupils' enjoyment of science" (Jenkins, 2000:331). Nothing was reported in these two areas that related directly to the introduction of the earth science content.

2.1.5.1 Summary: New Curriculum Content

The implications of King's (2001) findings are that the teachers in my study may also have a misguided confidence for teaching about the Moon's motion, phases and eclipses and that this combined with their value of its importance will require some recommendation for its place in the curriculum for the future. It would also be interesting to see how comparable my results are with King's (2001) in terms of resources used by teachers and willingness to attend in-service training and to see if any of the teachers in my study share the viewpoints of those in the Jenkins (2000) study.

2.2 Theoretical Framework

2.2.1 Introduction

In this section, I will establish the theoretical framework of my research. The first research question is positioned in the context of constructivism, as questionnaires and interviews are used pre-intervention to establish teachers' background knowledge and post-intervention to ascertain whether the intervention was successful at altering the case study group's misconceptions. How this was done is explained in more detail in Chapter 3. The constructivist view of learning is discussed first below, followed by two other theories that played a smaller role in analysis: situated cognition and pedagogic content knowledge. Situated learning theory has some relevance to the second and third research questions is that of situated learning, which is one of the learning theories from the constructivist school of thought: "the theoretical perspective that we find useful for our purposes is a version of constructivism that sees considerable merit in situated accounts of learning" (Cobb & Bowers, 1999:4). Research concerning teachers' pedagogical content knowledge will also be discussed here, as it is relevant to my third research question (Section 1.4.2 on page 7).

2.2.2 Constructivism

Driver, Guesne and Tiberghien (1985) explain some of the essential ideas behind constructivism. Some of these are that people "construct their own meanings" (1985:2) and these constructions affect how future knowledge is obtained. Also, learners in the science classroom have previously constructed their own ideas through day to day occurrences, about the subject matter being studied in class, even though they may never have received formal teaching on this subject matter. These ideas are not always scientifically correct and don't necessarily change, even if they are contradictory to the educator's explanation. Driver *et al.* (1985) contend that the learners either ignore these contradictions or assimilate them into their existing ideas and what is assimilated differs from person to person. Carr, Barker, Bell, Biddulph, Jones, Kirkwood, Pearson and Symington (1994) state that teaching requires an interaction with the learners' conceptions which involves persuading learners to state their ideas followed by a deliberation of whether a different idea proposed by the teacher makes more sense. The learner would need to consider the new idea to be more useful and provide a better explanation than her previous ideas before any change can take place. "Procedures in which there is more conversation about learning provide a better base for further learning. The open negotiation of meaning, and appreciation of the partial nature of the learning achieved, also model a better image of science" (Carr *et al.,* 1994:150).

Carr *et al.* (1994) extend this idea to words in science that have alternate meanings to the way they are used in day to day spoken language. They give the example of the word 'energy' and how it is used in everyday language when talking about food as a supply of energy for the body's needs or the need to conserve energy by not wasting electricity. This is very different to how scientists use the word 'energy' and so they contend that these different uses for the same word are also a source of alternative conceptions. Furthermore, learners may sometimes notice an idea that contrasts their own, but "simply noting such a discrepant event however is not necessarily followed by a restructuring of that student's ideas – such restructuring takes time and favourable circumstances" (Driver *et al.,* 1985:6). Trundle *et al.* (2007:304) remark that the "conceptual limitations that adults exhibit, including teachers, are often very much like those documented in children".

Another point made by Carr *et al.* is “how we feel about the ideas presented in our learning experiences affects our learning about them (1994:149). An implication of this for my study would be that teachers with an interest in astronomy may be more open to learning about Moon phases and eclipses than teachers who have little or no interest in this area. Related to this is the framework in which learning occurs, as this determines how knowledge is constructed (Carr *et al.,* 1994). In other words, an individual may find it easier to learn something within a framework that she is familiar with or interested in. A further idea proposed by Carr *et al.* (1994) is that of connectedness. They argue that teachers cannot successfully cultivate or change understandings through one encounter or a couple of solitary encounters. There has to be a definitive examination of the connectedness between concepts. Also the depth of examination will depend on the level and foundation of the learner (Carr *et al.,* 1994), be they student or adult. In summary, Carr *et al.* state that “learners need time to consider … prior meanings (of concepts), to consider new ideas, to explore new ideas, to link them to other existing ideas, and to construct new meanings knowing what the requirements are for this reconstruction” (1994:158).

The ideas of constructivism presented by Driver *et al.* (1985) and Carr *et al. (1994)* as well as Trundle *et al.’s* (2007) observation that the constructivist philosophy is applicable to adults and therefore teachers as well, provided the motivation to use questionnaires to establish teachers’ understandings of lunar phases and eclipses, which would be helpful in developing the intervention activities.

2.2.3 Situated Learning

One of the theoretical frameworks that forms the basis of my research, is that of situated learning. In this perspective of learning, “the activity in which knowledge is developed and deployed… is an integral part of what is learnt" and "situations… co-produce knowledge through activity" (Brown *et al.*, 1989:32). Some central ideas to situated learning are tools, enculturation, cognitive apprenticeship and legitimate peripheral participation. Brown *et al.* liken knowledge to tools in that both are able to only be completely appreciated through utilization and also, utilizing them involves altering the operator's worldview and taking on the context of the culture. This also provides motivation for my third research question i.e. how the case study group of teachers would use the activities and models on the Moon's motion, phases and eclipses in their teaching. Through teaching, the participants in my study would have further opportunity to utilize their knowledge and skills. Furthermore, Brown *et al.* contend that in order to utilize tools in the way that specialists utilize them, a learner needs to become part of a community's culture, much like an apprentice would and so learning is a means of enculturation.

Cognitive apprenticeship is explained by Brown *et al.* (1989:37) as a means by which learners are enculturated "into authentic practices through activity and social interaction". They explain that this happens by educators encouraging learning, either by making their implied knowledge plain or by demonstrating their tactics to learners in genuine activity. Thereafter, educators and peers aid learners' endeavours at completing the activity and ultimately they enable the learners to carry on without assistance. Mousley (2003:333) adds that "any social interaction is shaped and constrained by the features and norms of the particular context in which it evolves; so action takes place not merely *in* or *on* an environment, but *with* it". Hanks (1991) explains that a particular learner obtains performance skills by physically taking part in the learning procedure, under the limited constraints of legitimate peripheral participation. In this way, the learner only does as much as he/she is capable of within a community of more capable peers and the educator (Hanks, 1991). Lave (1996) adds that anywhere that learners engage for significant, continuous lengths of time, learning is evident as the learner gradually participates more and takes more responsibility for the completion of the task.

2.2.4 Pedagogic Content Knowledge (PCK)

Pedagogic Content Knowledge (PCK) is the other important theoretical framework that has played a significant role in my research. Van Driel, Verloop and De Vos (1998:673) explain that PCK relates to educators' "interpretations and transformations of subject-matter knowledge in the context of facilitating student learning". Significantly, it takes into account the fact that learners come into the classroom with prior knowledge and misconceptions (Van Driel *et al.*, 1998). Shulman (1986:9), who coined the phrase 'pedagogic content knowledge' has this to say about it: "within the category of pedagogical content knowledge I include… the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of representing and formulating the subject that make it comprehensible to others". Shulman also points out that no one representation is better than another and so the educator must have a variety of strategies for purposes of representation. He points out that educators obtain these strategies from research findings or experience.

Mulhall, Berry and Loughran (2003) consider PCK as a way to contemplate and delve into the knowledge and know-how that expert educators possess for teaching specific subject matter to specific learners to enhance comprehension. They propose that inexperienced teachers or teachers with experience who haven't previously taught a particular topic probably have minimal, if any, PCK in that subject area. Considering that the Moon's motion, phases and eclipses is new to the curriculum in South Africa, the case study teachers in my study could potentially have little PCK in this subject area.

Mulhall *et al.* (2003) interviewed expert teachers who were highly regarded by their colleagues, both on their own and in groups, to gather data on what the expert teachers considered to be the fundamental ideas for teaching about chemical reactions to Grade 10 learners. Mulhall *et al.* (2003) created two systems which would work together to epitomize the expert teachers' PCK concerning chemical reactions. One of these systems was the "CoRe (Content Representation)" and the other was "PaP-eRs (Pedagogical and Professional-experience Repertoires" (Mulhall *et al.,* 2003:6). Mulhall *et al.* (2003) explain that the CoRe "provides an overview of how teachers approach the teaching of the whole of a topic and the reasons for that approach - what content is taught and how and why - in the form of propositions" (2003:6) and they point out that fundamentally, a CoRe signifies the instruction of specific content to a specific grouping of learners. In order to create the CoRe for the chemical reactions subject area, Mulhall *et al.* (2003) asked the expert teachers what they considered to be the "big science ideas" (2003:7) or fundamental concepts critical to understanding this subject area.

On the other hand, "PaP-eRs are narrative accounts of a teacher's PCK for a particular piece of science content" and "are intended to represent the teacher's reasoning, that is, the thinking and actions of a successful science teacher in teaching a specific aspect of science content (Mulhall *et al.,* 2003:9). I have included a definition of this system to complete the picture of Mulhall *et al.'s* (2003) ideas about PCK but this system would not have relevance for my study as it falls outside the scope of my research questions.

The overall purpose of Mousley's research "was to analyse what teachers do to develop children's mathematical understanding" (2003:333) and in this paper she particularly looked at what a pair of Grade 2 mathematics teachers did in their classrooms to develop their learners' understandings of 'rotational symmetry' in the context of situated learning. Mousley (2003) focuses on the teachers' understanding rather than that of the learners, which is similar to my study. The mathematics lesson reported on in Mousley's (2003) paper was on the same content and was planned together by the teachers. Both teachers received input from the researcher and from a fellow colleague.

Mousley (2003) notes that there were many similarities between the two teachers prior to the lesson they taught: they both had heard the explanations on rotational symmetry from a colleague and the researcher; their background knowledge on the topic appeared to be roughly the same; they had comparable proposed outcomes for the lesson to be taught and they used the same materials to teach the lesson. However, Mousley, (2003) found that their lessons were different. For instance, one of the teachers (Ruth) started her lesson by revising the concepts taught in the previous day and then instructed the children how to make the rotational patters without explaining why they had to be done in that way. The other teacher (Trina) spent a greater deal of time at the beginning of her lesson on the names of the shapes which were to be used in the activity and the reason for the terminology. Mousley (2003) attributes the differences between the lessons to the "enacted curriculum in their classrooms" and concludes that "the social activity … seemed to have the strongest bearing on what mathematical ideas were made available to the children" (2003:337). The teachers in my study will be doing the same activities in the intervention and planning together how they are going to teach them. Mousley's (2003) paper indicates that I will need to expect that there will be differences in their lessons despite the similar input they will receive in the intervention.

During his research, Suzuki (2003) asked all his participants to draw up lesson plans, which they taught to one another during the discussion groups and then appraised each others' lessons. Suzuki did this because he wanted the students to develop their own content knowledge and at the same time see how to assist others to learn and be conscious of the ways in which others may conceptualize things. In this way, Suzuki's (2003) research went beyond merely looking at the students' conceptual understanding – he also attempted to develop their PCK.

Parker and Heywood (1998) ascertain that "reinterpretation (is the) core issue in supporting teachers' learning" and how successful reinterpretation is, would depend on "a mechanistic causal explanation, which is coherent to the (teacher)" (1998:514). This relates to their statement that it is not sufficient to just present the scientific explanation, teachers' PCK also needs to be addressed. They argue that PCK is a core standard for teacher training because it allows them to "identify and make explicit the underlying conceptual frameworks which the learner is likely to have difficulty with in becoming enculturated into the scientific interpretation of events" (1998:518) and this is best accomplished through self-examination of their own learning, which was one of the procedures used in their study.

2.2.5 Conclusion

It was intended in this study that learning would occur from a situated perspective i.e. within a group and through the use of activities and models (the learning tools), to develop the teachers' pedagogic content knowledge of Moon phenomena. Furthermore, this learning would occur through the processes of enculturation and legitimate peripheral participation, as the teachers would probably have varying degrees of knowledge. The idea was that they would attempt to do tasks with my assistance where necessary and eventually complete them on their own by the time they teach the material. From this description, it is clear that this is a situated perspective of learning. During the intervention and the teaching, I hope to observe how they transform their knowledge, activities and models into something understandable for their learners. I also hope that the outcome of being involved in this study would be an improvement in the participants' content knowledge and how to transmit this knowledge to their learners.

CHAPTER 3 METHODOLOGY AND METHODS

3.1 Introduction

As mentioned in chapter 1, my chosen methodology for this research is a "survey case study" (Henning, 2005:34). I investigated research question 1, which addresses teachers' understandings of the Moon's motion, phases and eclipses with questionnaires and research questions 2 and 3 with a case study. Research questions 2 and 3 concerned the case study teachers' understandings of lunar phenomena after an intervention with models and activities and then how these teachers used these models and activities in their classrooms.

Fraenkel and Wallen (1990) describe survey research as a large-scale investigation of people's responses to questions concerning specific subject matter. They contend that there are three features that survey research must incorporate. Firstly, the information gathered should illustrate some attributes of the teaching population of which that group is a sub-set; secondly, questions are used as the chief data collection method and finally, that the data are gathered from a sample and not the entire population.

On the other hand, a case study can be regarded as "any social entity that can be bounded by parameters and that shows a specific dynamic and relevance, revealing information that can be captured within these boundaries" (Henning, 2005:32). My case study incorporated interviews, an intervention and observation conducted with a small sub-set of the survey sample. Henning (2005:34) calls this a "bounded system" and explains that such a system concentrates on "specific people in a specific place, engaging in specific activities in a specific time". Further, Henning continues to say that “if a study … uses predominantly written survey questionnaires and is conducted within the parameters of a ‘bounded system’ … such a study may be called a ‘survey case study’” (2005:34). Stake (1995; 1998) has some valuable comments about case studies. He claims that the paramount function of a case study is that it improves “existing experience and humanistic understanding” (1998:7). He also points out that the case study is about “particularization, not generalization” (1995:8), by which he means that when one undertakes a case study, one becomes intimately acquainted with that case for “what it is (and) what it does” (1995:8), rather than being concerned with how it differs from other case studies. Further, prominence is placed on the uniqueness of the case, which entails knowing how the case is different from others but the most important thing is knowledge of the actual case (Stake, 1995). My study relates to Stake’s (1995) observations in that I am interested in the five case study teachers as individuals i.e. each teacher’s understanding for what it is rather than for comparison purposes.

3.2 Research Design

3.2.1 Piloting

By piloting, I mean the “specific pre-testing of a particular research instrument … (with) … a small group of volunteers who are as similar as possible to the target population” (Van Teijlingen & Hundley, 2001:1-2). Piloting is important for a number of reasons. For instance, Van Teijlingen and Hundley (2001) point out that piloting can show if the planned instruments are unsuitable or too complex. Opie (2004) points out that piloting an instrument yields important information regarding the time taken to complete the instrument, the clarity of instructions, questions and layout, omissions and the opportunity for any feedback comments by the pilot sample.

I approached five senior-phase natural science teachers to pilot the questionnaire (10% of the intended sample) and two to pilot the interview (20% of the intended sample). The pilot teachers taught at similar schools as the research participants and so were representative of the participants. For the purposes of the pilot questionnaires only, I asked the respondents to note the time when starting and completing the questionnaire, so that I could determine how long the questionnaire would take to complete. I also asked them to comment on any questions that were unclear or layout that was confusing. The information sheets and consent forms were included for both pilot questionnaires and interviews.

The piloting resulted in two minor adjustments to the questionnaire. The diagrams in question 5 on the Moon's motion, phases and eclipses were labelled "A" and "B" and these labels were referred to in the question to make the question clearer. Question 7 on lunar eclipses did not yield enough information and an additional question on lunar eclipses was added (question 6) in order to provide more information on the cause of a lunar eclipse. The final questionnaire is shown in Appendix A on page 219. No changes were made to the pilot interview as these questions did not present any problems for the pilot respondents. So the pilot interview given in Appendix B on page 226 is both the pilot and final interview. Although the interview questions did not present any problems, piloting the interviews was useful in that it gave me practice in setting out the models, asking questions in a logical manner and probing.

3.2.2 The Survey

In order to address the first research question, Section 1.4.2 on page 7, I designed a questionnaire to ascertain natural science teachers' understandings of the content matter relating to the Moon in the curriculum for ‘Planet Earth and Beyond’ (Department of Education, 2002) and whether or not they are teaching this content matter. I hoped to obtain at least 50 responses from natural sciences teachers in order to make some comparisons with other studies such as Barnett and Morran (2002) and Trundle *et al.* (2002). This goal was achieved and is discussed more fully in Section 3.6 on page 72. This formed the survey part of the research.

In designing the questionnaire, both open-ended and closed questions (e.g. multiple choice; true/false questions) were used. Open-ended questions are preferable as they don’t lead participants (Opie, 2004). One problem with closed questions is that participants may have misconceptions which are not included as one of the alternatives on the questionnaire (Stahly *et al.*, 1999). However, from previous experience, I have found that sometimes participants don’t answer open-ended questions with the detail that the researcher intended or they may not express themselves well in writing (Kelfkens, 2005), making it difficult to correctly classify the participant’s understanding and so I decided to use both. Fanetti (2001) experienced similar problems with open questions, which is evident in her discussion of her piloting results. She mentions how she had to change the wording of her questions to extract more detail from her respondents in the final version of her questionnaire. My questionnaire (Appendix A on page 219) contained a section of questions on the Moon’s motion, phases and eclipses and a section on background questions, some of which were my own questions and others were taken or adapted from previous research (Barnett & Morran, 2002; CAER, 1999; Comins, no date; King, 2001; Summers & Mant, 1995; Trumper, 2001). The participants completed the questionnaires during September and October 2006.

3.2.3 The Case Study

To address the second and third research questions (Section 1.4.2 on page 7), I set up a case study group. This group answered the questionnaire and then I interviewed them in order to provide more detail and clarity to their questionnaire responses. I then ran an intervention session with these teachers to demonstrate some models and activities for the Moon's motion, phases and eclipses. The teachers participated during the intervention and made the models and completed the activities. The intention was that the teachers would use the materials from the intervention session to teach a module on the Moon's motion, phases and eclipses to one or more of their classes in the senior phase and that I would observe these lessons. This part of the case study would address the third research question (Section 1.4.2 on page 7).

After the intervention, follow-up questionnaires and interviews were conducted with the case study group to ascertain how effective the intervention session was. This part of the case study was intended to answer the second research question. Questions in the post-questionnaires were not changed from the pre-questionnaires, as it is my experience that doing this makes the questionnaire difficult to analyse. At the end of the post-interviews I asked the participants for some feedback on the usefulness of the intervention session and for those that taught the 'Moon' module, how they found the teaching.

3.2.3.1 Interviews

"Interviews are communicative events aimed at finding what participants think, know and feel" (Henning, 2005:79). With regards to interviews, Barnett and Morran comment on the usefulness of probing questions, which sometimes resulted in learners reconstructing their answers and that interviews provide much more detail of both conceptions and the thinking process of learners. This provided motivation for using interviews in this study. I designed interview questions to supplement the questionnaire and to probe answers provided in the questionnaire. Interviews (Appendix B on page 226) contained questions on the Moon's phases and eclipses and were taken or adapted from the interview questions in Trundle *et al.* (2002), Barnett and Morran (2002) and some were my own questions. I used a structured protocol for the interviews.

Before the interviews took place, I asked each participant to sign a consent form and at the start of the interview, I confirmed again verbally that each person was comfortable with me videotaping the interview. I also attempted to set participants at ease and thanked them for participating. A model was used in the interview context, as shown in Figure 3.1 on page 61. It consisted of a large yellow ball to represent the Sun, an Earth globe which was smaller than the 'Sun' and a small, white polystyrene ball to represent the Moon. The 'Sun' was placed on a yellow plastic base to prevent it rolling around, but the base could be freely and easily moved by the interviewee if desired. The Earth's globe was mounted on a stand, also light and easy to move and the 'Moon' could just be picked up by the interviewee and moved around as desired. For practical purposes, the model was not to scale but the Earth was bigger than the Moon and the Sun bigger than the Earth. A diagram sheet showing the phases of the Moon in random order was also used and a pencil and paper were provided in case the interviewee found it easier to draw than explain. I also provided a torch in case the interviewee wanted to simulate the Sun shining. All of this was explained to the interviewee before I commenced the interview. I conducted the pre-interviews during the last week of September 2006 and all of the post-interviews on the 20th of November 2006.

Figure 3.1 Interview Model

3.2.3.2 The Intervention

The literature I have reviewed and the activities I sourced would provide the CoRe (Mulhall *et al.,* 2003) for the fundamental concepts relating to the Moon's motion, phases and eclipses and the intervention session in my study would provide the forum to present and explore these fundamental ideas for teaching this content to Grade 8 learners. The activities and models I used for the intervention were selected for direct relevance to my research questions i.e. they would hopefully develop an understanding of the Moon's motion, phases and eclipses. In addition, I included an activity on the scale of the Sun-Earth-Moon system, as it has direct bearing on an understanding of the Moon's motion, phases and eclipses: "scale might have permitted subjects to realize their errors in their own model explanations, most especially the eclipse … (model)" (Callison & Wright, 1993:11). The elevation activity is important because it gives a three-dimensional experience of the relative motions of the Earth and Moon and attempts to draw a distinction between the Earth's rotation causing the rising and setting of the Moon and not the phases. The Earth's rotation is a fairly common misconception for the cause of the Moon's phases. It was the second most common misconception in Trundle *et al.*'s (2002) study and is reported in Barnett and Morran (2002) as well. The activities that were covered in the intervention session are shown in Appendix D on page 239. My study is similar to that of Mousley's (2003), in that I will provide the activities to be taught in the lessons and the teachers will all do the same activities together in the intervention session and plan how they are going to teach the activities together. A difference between our studies is that Mousley (2003) interviewed her teachers before and after the lessons whereas I interviewed the teachers before and after the intervention as this was appropriate for my research questions.

The intervention session took place after school on Monday the 2nd of October 2006. I firstly thanked the teachers for their participation and for giving up their time to help with my research. Unfortunately, one teacher was unable to attend the session as she was ill. I introduced the research assistant who had come to assist with videotaping the session. I pointed out that either the research assistant or I may make notes during the course of the afternoon and explained the purpose of these field notes. I assured them that nothing said in the course of the afternoon would be taken in a judgemental way and that it would remain confidential. Further assurances were given in the information sheet for the Intervention (Appendix E on page 243) and the teachers signed the consent forms.

Next, I handed out the 'I saw the Moon' worksheets (Appendix I on page 261). I explained that I wanted them to give this worksheet to their classes as soon as possible, so that the learners would have time to do some observation of Moon phases before lessons on this topic started. (The teachers had received copies for themselves to do prior to the intervention). I did this because the results of my prior research (Kelfkens, 2005; Kelfkens & Lelliott, 2006) suggested that the pre-service teachers had done very little Moon observation and I had recommended that prolonged observation of the Moon could possibly have challenged some of their misconceptions. The teachers were concerned about where they were going to fit in the teaching of this module before examinations started. I told them I would like about three lessons based on the materials we would be going through in the intervention session. I explained that we were going to do three main activities that afternoon, hence three lessons to be taught: an activity on scale – Activity 1; an activity on phases and eclipses (Activity 3), and an activity on the motion and elevation of the Moon (Activity 4). There was a second activity on scale (Activity 2) that we were just going to discuss, but not do, but which would give them an alternative for their lessons. The teachers were relieved that it wasn't to be longer than that, but some still appeared concerned about fitting it in. I assured them that they could fit in the teaching wherever they had a gap and if they weren't all teaching at the same time, it was actually helpful, as I couldn't be in more than one classroom at a time, anyway.

Then we started with Activity 1 (Appendix D on page 239). It was imperative to do this activity first, as a follow-on activity (Activity 3 in Appendix D on page 239) demonstrating the Moon's phases and eclipses would only work properly if the distance of the Moon from the Earth was kept more or less to scale. The activity was adapted from one given to second-year physics curriculum studies students completing a Bachelor of Education (B. Ed.) degree. The original activity (Gundry, 2005) involved supplying a scale which the students had to use to build a scale model of the solar system. I kept the same scale and limited the activity to building a scale model of the Sun-Earth-Moon system (Activity 1 in Appendix D on page 239). The aim of this activity was to give the participants an idea of the relative sizes and distances of the Sun-Earth-Moon system and then to make a model of this to scale.

The second activity (Activity 2 in Appendix D on page 239) was designed as an alternative to the first i.e. teachers would have a choice whether to use Activity 1 or 2 to teach the idea of scale. The reasoning behind including an alternative scale activity was the use of exponential numbers for the scale in Activity 1. I was concerned that Grade 8's would not have the mathematical ability to work with the scale. However, I thought that Activity 1 was extremely valuable for the teachers to do, as it would improve their own understanding of the scale. Activity 2 was based on one of the additional activities described in Fanetti's (2001) research with students in an introductory astronomy course. As not all the students had a mathematical background, she used this activity so that the students wouldn't have to do any mathematical calculations. As I had the same concerns about the mathematical abilities of Grade 8's, this motivated me to include a slightly modified version of Fanetti's (2001) activity in my study.

Activity 3 (Appendix D on page 239) was selected to demonstrate the Moon's phases and eclipses. This activity was adapted from Gundry (2005) and HARTRAO (no date). Background notes about phases and eclipses, diagrams showing the order of the Moon's phases and useful websites were supplied, but it was stressed that the teachers could use different resources in their teaching if they wished to do so. I also supplied models that I had made. An overhead projector lamp represented the Sun, a participant's head represented the Earth and white polystyrene balls mounted on wooden kebab skewers represented the Moon. In the original HARTRAO activity, a white ping pong ball had been mounted on a wooden dowel stick with glue. I purchased polystyrene balls instead as they were cheaper but battled to glue these on to a dowel stick. I then thought of using the kebab skewers, which was a much quicker and easier alternative. Once these are mounted, a blob of glue can be placed at the base of the polystyrene ball just to hold it in place on the skewer. These are shown in Figure 3.2 below. I explained that I had mounted them on sticks so that when they are held in the light, one's hands don't cause shadows on the 'Moon'. As an alternative to their heads being the 'Earth' in this activity, I also had several blue balls (roughly the size of the Earth's globe used in the interview context) that they could use instead.

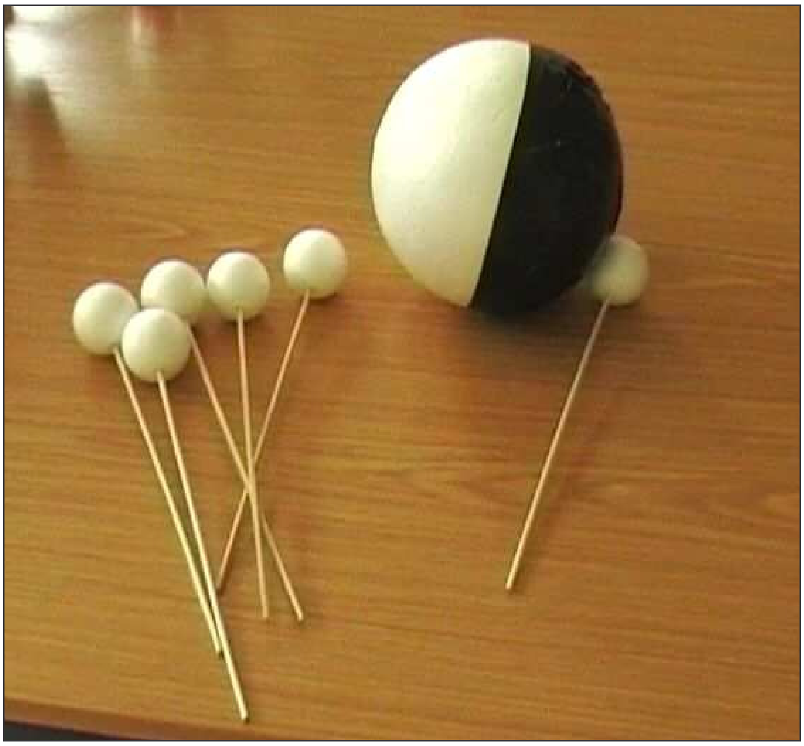


Figure 3.2 Models used in Activity 3 & 4

The idea behind this activity was for the participants to use the model and work as a group in order to observe and explain the Moon's phases and eclipses. They had to set up the model and use it to show the order of phases as in the diagrams and then use their own knowledge and understanding together with the notes supplied to provide a plausible explanation. The reason why scale is so important for this activity is that if the Moon is placed too close to the Earth, a lunar eclipse occurs all the time at full Moon. The intention was for participants to explain why this should **not** be the case.

Courtney requested all the answers to the activities as a reference so that they could be sure that they'd fully understood the material. I agreed and promised as much support as needed. They could phone or email me with any requests for help and I would be happy to provide it. Afterwards, I gave the teachers some guidance notes (HARTRAO, no date) for this activity i.e. what should be seen, answers to questions and some demonstration photographs reminding them how to do the activity. I spoke to them about the light bulb in the pictures in these notes and commented that it's better to use an overhead projector because the light is much brighter. I also showed the teachers how to do the same activity outside in the Sun if they weren't able to get their classrooms dark enough. It's the same idea, but one uses the real Sun and holds a tennis ball at arm's length. The head still represents the Earth and then one swivels around and looks at 'phases' on a tennis ball. This alternative was suggested in the HARTRAO (no date) notes.

The final activity (Activity 4 in Appendix D on page 239) related to the Moon's elevation. The idea for this activity was taken from a lecture I had observed in 2005, given to a group of first-year geography in education students, completing a B.Ed. degree. The model used here is that of a white polystyrene ball representing the Moon, with one half of the Moon blacked out to represent the side of the Moon facing away from the Sun. In order to understand the Moon's motion and elevation more easily, this model emphasizes the importance of looking at the Moon at the same time every night. In order for this demonstration to be more effective, I had supplied a Moon observation schedule (Appendix I on page 261) to the participants prior to the intervention, so that they would already have a feel for where the Moon would be in the sky just after sunset.

Before looking at the model, we discussed the first four questions of this activity. This was really an introduction to get them thinking. These questions concerned the path of the Moon across the sky and where and why it rises and sets. If they'd done some Moon observation, they could use this to help them. As this is a whole class activity, the Moon needs to be bigger than the models used in Activity 3, so that everyone can see it. I had used a black rubbish bag and sticky tape to black out one half of the Moon. As this proved to be rather fiddly, I used black duct tape instead for the models I provided for the participants to use in their teaching, which was more successful. This model is shown in Figure 3.2 on page 65.

The model started at New Moon and participants sitting in the classroom represented observers on Earth. They had to work out where west was and were told to imagine that the Sun was setting. Based on the previous activity they then decided where the Moon would be positioned relative to themselves and the Sun. We then moved on 24 hours to the same time the next day. I held the Moon a little higher and told them this is where it would be, a little higher each day. Then we moved on 48 hours i.e. three days after New Moon. I held it high enough (on a chair) so they could see a crescent of white sticking out from where they were sitting. Now they had to imagine seven days from New Moon – the same time of the evening. I climbed onto the desk where they were sitting, keeping the white surface facing west and asked what they could see. I then moved on to show the waxing gibbous and finally full Moon rising just after sunset, which would be a total of two weeks after New Moon.

After this, I gave them a handout from the Johannesburg Planetarium's website showing current calendar dates with the phases of the Moon, so they could use it as a reference for their teaching over the next two months. The website also gave the dates of eclipses for 2006. I gave them some handouts of additional materials (HARTRAO, no date) they could use when teaching this module e.g. how the dates of Easter and Ramadan are worked out, the first Moon landing and Tswana stories about the Moon, as indigenous knowledge is also part of curriculum. I offered them more on this if they wanted, as I had quite a few resources from my previous research. We discussed that it was open as to how much extra information they wanted to use in their lessons, but the crucial concepts to be covered were the Moon's motion, phases, eclipses and an idea of the scale.

At the end of the session, the teachers spent some time discussing when they would teach it and whether they would include it in the examinations as an optional question for the classes that had done this module. They also spoke about doing an additional activity and assessing that activity rather than examining the module. They proposed to make a decision closer to the time. I agreed to make electronic copies of the activity sheets available so that the teachers could edit them as they thought appropriate for their lessons. The teachers responded very positively to the session and commented that they had really enjoyed it and that they'd learnt something.

I met with the teacher who had missed the Intervention session when she was better in order to go through everything we did in the session and give feedback from it. As the activities were intended for group work, this session didn't go into as much depth. I worked through the activities with her and explained how the other teachers suggested changing the activities, so that they were more suitable for teaching.

3.2.3.3 Classroom Observation

The design for what was going to happen in the classroom was left mostly up to the teachers. During the intervention session I provided them with enrichment activities on the topic of the Moon, which they could include in their lessons if they chose. We agreed that there would be a minimum of three lessons taught and that these would include the vital concepts covered in the intervention activities, namely scale and the Moon's motion, phases and eclipses. At this stage, I also provided the teachers with information sheets and consent forms for their classes, so that there was plenty of time to get these completed before the lessons started.

I suggested that the teachers could use my questionnaires as a pre- and post- test for their classes. The teachers would then let me know when they were teaching the module and I would arrive to observe and film the lessons and interact with the learners during the group work. Sufficient sets of models were provided to both schools for use with eight groups of learners per class. My focus during these observation sessions was to see what the teachers did with the intervention activities and models in their classrooms. In other words, I wanted to see how they used their pedagogic content knowledge to teach this section. Although I would interact with the learners, my data collection would focus on the teachers as this was the aim of my third research question (Section 1.4.2 on page 7).

3.3 Models

Models were used in the interviews and the intervention. In the interviews, the participants were external to the model i.e. they were viewing the model from a perspective outside the 'Earth'. My reasons for using models in the interview context are that they can provide more detailed explanations to the interview questions, help in finding and classifying alternative understandings, take less time during data analysis and give better interrater agreement than two-dimensional drawings (Trundle *et al.*, 2002). This is important for the reliability of the study. In their study, Parker and Heywood (1998) found that "there was an acute need (for the participants) to visualize what was happening through the use of models (1998:512). Trundle *et al.* (2002) also report that their participants seemed more relaxed and found it simpler using a three-dimensional model to describe lunar phenomena, the latter also reported by Callison and Wright (1993) and Parker and Heywood (1998). During piloting of their interviews, Trundle *et al.* (2002) also saw that some participants changed their reasoning while manoeuvring the model. This was further justification for using models in my interviews.

In the intervention, I made use of models and activities rather than worksheets and notes because of recommendations in previous research. Trundle *et al.* found that an activity incorporating a model was "particularly critical … (and) the cognitive load for the activity … is judged to be heavy" (2007:321-322). The activity they are referring to was one in which their participants were able to use the model to study the reason for lunar phases. Moreover, Stahly *et al.* (1999) challenged the methodology of only using a textbook when teaching, as they found that despite the fact that the learners in their study had made and interacted with models of the Sun, Earth and Moon, they still had alternative conceptions and so they questioned if a "textbook's approach would effectively allow the students to enhance their understanding of the lunar phase phenomenon, since it does not feature active involvement on the student's part" (1999:174). In my study, the participant was internal to the model used in Activity 3 (Appendix D on page 239) i.e. the participant viewed the model from an Earth observer's perspective.

3.4 Sample Groups

I drew up a letter inviting senior phase natural science teachers to participate in the research (Appendix F on page 255). I also included a copy of the questionnaire information sheet (Appendix E on page 243) to give a brief outline of the research. The letter was sent to 34 schools around Johannesburg, which were selected by convenience sampling where an available sample is used rather than selecting from the entire population (Brunsell & Marcks, 2005). Of these schools, 20 were private and 14 state schools. I wanted to aim for a balance between the number of state schools and private schools participating. (The number of private schools was more than state schools as there was a greater density of these within the areas I selected). A total of 23 schools indicated a willingness to participate in the study. Unfortunately, only four of these were state schools. I suspect this is due to the large numbers of learners in state schools and teachers having less time on their hands and under greater pressure than their colleagues in private schools.

Furthermore, a case study group of five teachers from two schools was selected by invitation i.e. convenience sampling. (Initially there was a possibility that the group would be in the region of 7-10 teachers, which is why I referred to two teachers as being 20% of the intended sample in Section 3.2.1 on page 56. One of the schools was an independent, all-girls' Church school (School 1) and the other an all-boys' independent Church school (School 2). I originally approached teachers from one state school and one private school to participate in the case study. These teachers were approached, as they had expressed an interest in my study during personal discussions as my research design was being formulated. Unfortunately, the teachers in the state school felt that their time constraints would be too tight in the third term, which was the only viable time to collect my data, so teachers from another private school who had also expressed an interest in being involved in the study, were approached.

3.5 Role of the Researcher

I was involved as researcher in all phases of data gathering, as teacher in the intervention session and observer when the teachers taught the Moon lessons in their classrooms. By request of one of the teachers, I taught Activity 4 to her classes, as she didn't feel confident enough to teach the concepts covered in this activity. I did the videotaping in the classroom sessions and a research assistant videotaped the intervention session. The research assistant was not affiliated to either of the case study schools.

3.6 Data Collection

Data were collected through questionnaires, interviews, an intervention and classroom observation. Questionnaires would also give me a general feel for the teachers' understandings, especially the case study group's, which would be useful in preparing activities for the intervention. Bearing the dispute between Schoultz *et al. (2001)* and Vosniadou *et al. (2005)* in mind, I needed to be very careful that my chosen theoretical framework is supported by my methodology and data collection methods. Henning (2005) points out that questionnaires are normally associated with quantitative research and interviews and observation with case study research. This justifies my choice of questionnaires for the survey part of my research and the interviews and observation for the case study. The observation and post-interviews would have been meaningless without the intervention and so this was also a necessary component of the case study. Also, the observation part of my research would give teachers an additional opportunity to utilize their knowledge and so continue with the enculturation process (Brown *et al.*, 1989).

Sufficient questionnaires for each school were packaged into envelopes, along with instruction sheets for each teacher. I then delivered these packages to the various schools. After three weeks, I contacted the participating schools and made arrangements to collect the questionnaires. Twenty of the twenty-three schools returned questionnaires, which yielded a total of 60 responses to the questionnaire. Of these 60 responses, 13 (22%) were from state school teachers. These 60 respondents therefore formed the basis of the survey sample.

The five teachers from the two case study schools were part of the sample that completed the questionnaire. Follow-up interviews were conducted with these teachers in order to provide more detail on their questionnaire answers. I then met with four of the case study teachers for a 2 ½ hour session. One of the teachers was ill on the scheduled date and I repeated the session with this teacher on another date. In the intervention, we worked through the activities and models on the Moon's motion, phases and eclipses as described in Section 3.2.3.2 on page 61. This intervention session was videotaped and field notes made.

Unfortunately, only two teachers actually taught this section of work, one of them to two different classes. The others were under too much pressure to finish teaching content to be tested in the end-of-year examinations and did not have enough time to teach the Moon module. I observed the use of the activities and models in each of the teachers' lessons. These classroom sessions were videotaped with the permission of the respective schools, the teachers and the learners (or parents where the learners were still considered to be minors).

3.7 Ethics

Ethical issues are concerned with "how people involved or touched, in any way, by a research project might be affected by their involvement" (Sikes, 2004:16). It is important to consider ethics because in educational research, one is generally researching people and they could be traumatised by the process if the researcher is not sensitive and respectful. Permission was sought and granted from the Gauteng Department of Education to conduct research in GDE schools and permission to conduct research was sought and granted from the two main research sites (Appendix H on page 258).

Sikes (2004) gives several pointers for consideration with respect to ethical issues, which are relevant to this research. The first refers to a justification of interest and the key issue here seems to be 'who benefits from the research'? If it is only the researcher, then the ethics are questionable. In the case of my own research, my intention was for the teachers involved in the case study to benefit from the research in that I hope their confidence for teaching 'Planet Earth and Beyond' will increase, given that their own pedagogical content knowledge will have increased and they will have materials and activities to use in their classrooms. Furthermore, this study will have relevance for future researchers and practitioners.

The second relates to the effects of being involved in the research. Junior teachers especially, may be afraid of exposure in front of their heads of departments, fellow colleagues or teachers from another school. It was necessary to establish good relations and an atmosphere of tolerance and working together to problem-solve rather than focusing on what the teachers didn't know. Also the use of videotaping could incite a fear of ridicule if they suspected the video would be shown to others. So it was very important to ensure confidentiality by means of an information sheet which disclosed all aspects that the research would entail, with as much detail as possible and in an understandable format, as well as a consent form for the teachers to sign, which provided assurance of confidentiality and anonymity. The information sheet stated the purpose of the research, the methods that were going to be used in the research and also provided assurance of confidentiality. Both the consent forms and information sheets were based on ones prepared by other researchers at the University.

Access is another issue. There was a danger that a junior member of department may have been coerced by the head of department or school principal to participate in the study and I made it clear in the letter of invitation (Appendix F on page 255*)* that this should not happen. With regards to social power, I had to be sensitive in that I probably had more knowledge about the Moon than my participants did. To behave in an ethical manner, I made every effort to not be derogatory in any way, but rather helpful and guiding. I hope my participants gained some valuable resources and knowledge from this research and I expressed my appreciation and gratitude to all the teachers who participated in the research, with a thank you note. I also gave each of the case study teachers a box of Astros, which they knew nothing about beforehand i.e. it was meant as a token of appreciation and not to coerce them to take part in the research.

With regards to interviews, Henning (2005) raises an important ethical issue for consideration. She points out that an interview occurs “between two … people who are unequal in power and ownership of the process” (2005:66). She contends that the ideal interview situation is for the participant to feel that she is participating in a conversation with the interviewer, rather than being tested. I made a point of steering the interview in a different direction whenever I noticed a participant becoming uncomfortable because she was unable to answer my questions. So I switched from lunar phases to eclipses (or vice versa) and sometimes it was necessary to switch to some background questions about themselves and their teaching experiences to put them at ease. Also, there had been solar and lunar eclipse shortly before the pre-interviews took place and I used these as discussion points when necessary e.g. I asked if they'd seen, heard or read about the eclipses.

Another ethical issue I had to consider, was that consent from a few of the learners and/or their guardians may not be obtained for purposes of video-recording. These learners were placed together in the same group and this group was not filmed, but the learners still participated in the lessons. The learners from both schools are familiar with group work in science and so would not find group work unusual. Information sheets and consent forms for participants were drawn up, according to the guidelines set up by the University of the Witwatersrand's ethics committee (Appendix E on page 243).

Finally, as the case study sample group was very small, it would be difficult to maintain confidentiality should the school request a copy of the final write-up. Therefore, in this write-up no referral will be made as to whether this is a teacher from School 1 or School 2. Both male and female teachers were involved in the study, but only female fictitious names used and all teachers will be referred to as 'she'. All learners will be referred to as 'he'. In this way, no distinction will be able to be made between the teachers and learners from the two schools.

3.8 From Validity and Reliability to Precision and Trustworthiness

According to Hammersley (1987:75), validity is the “extent to which an instrument measures the property it is intended to measure”. This definition is useful for measuring validity as far as the questionnaire items are concerned, as these data would be quantitative in nature. In order to evaluate the validity of the questionnaire, I needed to ensure that the questionnaire items corresponded to the first research question (Section 1.4.2 on page 7). Therefore, there needed to be questions assessing all three aspects – namely the Moon’s motion, phases and eclipses and that the answers to these questions would enable me to conclude something about natural science teachers’ understandings of these phenomena. In chapter 4, where I explain the methodology of the data analysis for the questionnaires, I give a breakdown of the questions and show exactly which questions relate to each of these three phenomena (Section 4.1 on page 82). I will also show how the responses were coded and classified, allowing me to reach conclusions about the teachers’ understandings of lunar motion, phases and eclipses (Section 4.4 on page 126).

Hammersley defines ‘reliability’ as the “ability of an instrument consistently to produce valid scores” (1987:78). With regards to the questionnaires, this would involve comparing my results to those obtained by the researchers from whom I adapted my questionnaire items. This will be discussed in chapter 4. Furthermore, someone else could code the questionnaire items and then we could check for interrater agreement. I selected ten questionnaires with classifications that ranged from no conceptual understanding to a full scientific understanding and asked a colleague to code them according to my classification scheme described in chapter 4. The outcome of this and level of interrater agreement is discussed in chapter 4 (Section 4.3 on page 126).

It is more difficult to measure validity in the case study part of this research, namely research questions 2 and 3. Scaife (2004) is of the opinion that in case study research, a more useful definition for ‘validity’ is that “validity concerns the relationship between the claim and the accompanying process of data gathering… that is used as the grounds for the claim” (2004:69). Henning (2005) explains how the terms ‘validity’ and ‘reliability’ were transferred from the natural to the social sciences, but that the original meanings of these words are not useful for qualitative research. For Henning (2005:147), “precision” is the most important criterion when claiming validity. According to Henning (2005), the implication of precision and validity in case study research is to: keep records of all data collected and procedures used; inspect for any instances of partiality or anything that could possibly have been omitted; cross-examine methods used and choices made; relate findings back to the theory; and confer with my supervisor with regards to research procedures.

Therefore, I have filed all my participants’ questionnaires according to code number. The use of codes on the questionnaires and interview transcripts helped with avoiding partiality, as I didn’t know who the questionnaire or interview transcript belonged to when working with them. I have kept all the video tapes and have numbered them in the order in which they were made. I also made digital back-ups of these tapes in case they were damaged. The digital copies were given the same numbers as the original tapes. I have also filed all field notes and summary notes made during the intervention and observation sessions. I have described the procedures used in this research in detail throughout this chapter as well as procedures for data analysis in chapters 4 and 5. I listened to the interview tapes several times to ensure the accuracy of the interview transcripts and also to watch the intervention and observation tapes several times to ensure that anything of relevance to my research questions is included. When I discuss the data analysis for lunar eclipses in Section 4.1.3 on page 89, I show how I classified the Earth blocking the Sun's light and the Earth's shadow as the same fragment. Originally, I had classified them separately, but changed this after an email discussion with the colleague who cross-checked my coding (Gundry, pers. comm.). Also in chapter 4, I explain how I had to re-think my original coding strategy for background questions 4 and 5. Both of these are evidence of cross-examining my methods and procedures. In chapters 4 and 5, I will show how I related my findings back to the theory. Throughout the writing of this thesis, I have regularly submitted drafts to my supervisor and conferred with him to ensure accuracy and quality.

Also, with regards to the case study section of my research, Scaife (2004) comments that research in the classroom doesn't necessarily lend itself to the replicable results usually advocated in definitions of reliability. Reliability is therefore not a helpful standard with which to evaluate the goodness of case study research. A more useful criterion would be the trustworthiness of the research (Scaife, 2004). This is corroborated by Mishler (1990:416) who argues that researchers conducting "inquiry-guided research have long been aware that the standard approach to validity assessment is largely irrelevant". He contends that when measuring the trustworthiness of research, the "essential criterion… is the degree to which we can rely on the concepts, methods, and inferences of a study… as the basis for our own theorizing and empirical research" (1990:419).

Sturman (1999 in Scaife, 2004) suggests numerous strategies that can be used to add to the trustworthiness of research. I will mention his suggested strategies and respond to each of them. The first is to be very thorough when explaining and describing how I collected and analysed my data. This is done throughout chapters 3 to 5 inclusively. Sturman states that the explanations and descriptions would be assisted by presenting examples of interview transcripts or dialogues that took place during the group discussions or classroom observations. Several of these are given in chapter 5 as well as Appendix C on page 229. According to Sturman, this would provide another researcher the opportunity to analyse the data and compare his or her interpretation with mine to see if they agree. It is also important that all data that I collect is reported on, even if it contradicts my proposition (Yin, 1994). For instance, I am basing this research on the proposition that the science teachers will probably have a poor astronomy understanding and regard its place in the curriculum as unimportant. I may find that this is not the case. Another strategy is that I would have to admit to any biases in my research. Here, the types of schools and teachers in the case study portion of my research could be a factor. Both are private schools, produce excellent results and are well-resourced. The teachers are well-educated and make a concerted effort to attend in-service training. I deliberately selected these schools and teachers as they are supportive of my research and open to new learning opportunities. Finally, it would also be necessary to unambiguously state any relationships that exist between the data that I collect and the inferences I make from that data. I will have field notes as well as videotape and photographic evidence to support my data and data collection techniques.

3.9 Summary

In this chapter, I have given some more detail about my chosen methodology of a survey case study. I have outlined the piloting procedures and the design of each stage of the study. I have explained how the sample groups were selected through convenience sampling and my role throughout the study. I have explained the methods of data collection and outlined the ethical and precision and trustworthiness considerations. I will discuss the methodology for data analysis together with the relevant results in chapters 4 and 5 to allow for easier reading and referral.

CHAPTER 4 SURVEY DATA ANALYSIS AND RESULTS

In this chapter, I am going to focus on the survey part of the study i.e. the questionnaire sample of 60. First, I will explain how I analyzed the questionnaire data. Then, I will present and discuss the questionnaire results, relating my findings back to the theory. Finally, I will discuss validity and reliability issues relating to the questionnaires. The case study group completed post-questionnaires. I will present the results of these in chapter 5 rather than here, as they are only relevant to the case study group and make more sense when read and analyzed in conjunction with the interview results of the case study group.

4.1 Data Analysis

I used an Excel spreadsheet as my coding sheet for the questionnaire analysis. This was beneficial in that it made tallying responses quick and easy and the option to use colour highlighting gave a clear, pictorial summary. It was also useful to be able to see all 60 responses together for comparison purposes in that I didn't need to keep paging back through questionnaires trying to remember where I'd seen a similar answer. Trundle *et al.* (2002) also used a coding sheet in their study, which speeded up their analysis process "by organizing the key points of analysis and standardizing the coding system among the 3 researchers" (2002:640).

Questions on the questionnaire were divided into four groups: those specific to the Moon's motion (questions 1 A,B,C,E), the Moon's phases (questions 1D, 3, 4 and 5), lunar eclipses (questions 6 and 7) and the background questions. Question 2 on the Moon's motion incorporates a concept that is fundamental to a scientific understanding of lunar phases, namely that the Moon orbits the Earth (Trundle *et al.*, 2002; 2007). So instead of including it with the Moon's motion, question 2 was analyzed together with the questions on the Moon phases. The coding sheet can be found in Appendix G on page 256.

4.1.1 The Moon's Motion

The questions concerning the Moon's motion were all related to observable phenomena and were closed (true/false) questions. All the respondents' codes were placed in the first column of the coding sheet and the adjacent columns labelled according to question number (1 A, B, C, E). A correct response to the true/false questions was indicated by a '1' and an incorrect response by a '0' in the respective columns, making them easy to tally.

4.1.2 Moon Phases

The questions on Moon phases included closed and open questions. Question 1D was a true/false type question and responses were indicated on the coding sheet in the same way as described for the true/false questions on the Moon's motion. For the multiple choice questions I marked each respondent's selection (A, B, C, …) with a '1' in correspondingly labelled columns. This also made it easy to tally the total number of responses to each option. For the open questions on Moon phases, I decided to use a typological approach for analysis. Hatch (2002) explains that typologies can be created from theory, everyday knowledge and research aims and that once the typologies are set up, all the data are sorted into categories according to these typologies. I chose this approach as there were specific scientific facts that I was looking for and the typologies that were set up beforehand were based on previous research findings. I allowed myself to be open to understandings which did not fit into the predetermined typologies and was prepared to add to the list of typologies if necessary. Trundle *et al.* (2002) used a similar approach and commented that their “coding sheets were used as guidelines but they were not allowed to … restrict coding. Codes that emerged during analyses were added to the coding system” (2002:640).

To set up typologies for the Moon’s phases, I used the comprehensive coding system developed by Trundle *et al.* (2002) for their study on student-teachers’ understandings of Moon phases. Their classifications were based on 13 previous studies as well as their own findings. This coding system looks for concepts essential to the understanding of Moon phases and is summarized in Table 4.1 below.

Table 4.1 Concepts essential to understanding the Moon’s Phases

Typology	Code
The Moon orbits Earth	SciOrb
Half of the Moon is illuminated; that half is facing the Sun	SciHaf
The part of the illuminated half we see determines the phase	SciSee
Relative positions of the Earth, Sun and Moon determine the part we see	SciEMS

(Trundle *et al.*, 2002:640)

I assigned the codes SciHaf and SciOrb to correct responses to questions 1D and 2 respectively. The remaining two codes were assigned if these concepts appeared in the answers to question 5. I wasn’t very strict with assigning codes for question 5. I gave the code SciEMS if there was any indication that the phases had something to do with positions – even if they only mentioned the positions of the Sun and Moon. Without interviews, it was impossible to tell if it was obvious to the respondents that the Earth's position also played a role and so didn't occur to them to mention it or if they didn't realize they had to include the position of the Earth as well. I then created four new columns on my coding sheet. Each column had a heading of SciOrb, SciHaf, SciSee and SciEMS. If I had found these codes in respondents' answers to questions 1D, 2 and 5, I indicated this with a '1' in the corresponding column on the spreadsheet.

Originally I had thought that questions 3 and 4 were not necessary to assign these codes and I included them to provide more in-depth information. Question 3 essentially tests to see if respondents can identify a position that would provide a crescent Moon shape[1]. In essence, question 3 would challenge those with a greater scientific understanding. However, the colleague who cross-checked my questionnaire coding pointed out that an answer of A or B on question 3 (see Appendix A on page 219) could imply an alternative eclipse understanding of the Moon's phases and she recommended that question 3 be looked at in conjunction with the open response to question 5 (Gundry, pers. comm.). So I went back and cross-checked all respondents who had selected option A or B on question 3 together with their response to question 5 and re-classified where necessary. Question 4 was included to test for a misconception that was prevalent in my own previous research (Kelfkens, 2005; Kelfkens & Lelliott, 2006), namely that the lunar phases are somehow linked to time and so it would be possible to see more than one phase during the night. This could also be linked to the misconception that a daily orbit of the Moon around the Earth is responsible

[1] Incidentally, the diagram in question 3 is strictly only correct for the Northern Hemisphere. In the Southern Hemisphere we would see a lateral inversion of the Moon shown in the diagram when it is at position D. However, this does not flow logically from the diagram and anybody 'working it out' from the picture would logically place the Moon at position D

for the lunar phases i.e. confusing the Moon’s motion with the Earth’s rotation.

Different codes were assigned to the types of alternative understandings, which were also categorized according to predetermined typologies based on previous research findings (Trundle *et al.,* 2002; Kelfkens & Lelliott, 2006). Table 4.2 below provides the initial set of typologies that I used as well as an example of a research paper that has reported this alternative understanding. This provided me with a comprehensive listing of classifications for possible interpretations for the phases of the Moon but again, I did not allow it to restrict me and was open to alternative explanations that were not in the predetermined typologies. Whenever I came across an alternative conception, I would create a new column adjacent to these, mark a ‘1’ in the column and give a header to the column which described the type of alternative understanding. I added a ‘comments’ column in which I added any quotation of interest from the questionnaire.

Table 4.2 Typologies for Alternative Understandings of the Moon’s Phases

Alternative Concept	Reported By
Earth’s Shadow on Moon	Trundle *et al.* (2002:649)
Earth’s rotation on its axis	Trundle *et al.* (2002:649)
Moon’s position relative to different geographic locations on Earth	Trundle *et al.* (2002:649)
Clouds	Trundle *et al.* (2002:649)

Alternative Concept	Reported By
Planet’s (other than Earth) shadow on Moon	Trundle *et al.* (2002:649)
Earth’s tilt	Trundle *et al.* (2002:649)
Sun’s shadow on Moon	Trundle *et al.* (2002:649)
Sun’s orbit of Earth and Moon	Trundle *et al.* (2002:649)
Varying amount of light from Sun to Moon	Trundle *et al.* (2002:649)
How directly the Sun shines on Earth	Trundle *et al.* (2002:649)
Varying distance between Sun and Moon	Trundle *et al.* (2002:649)
Varying distance between Earth and Moon	Trundle *et al.* (2002:649)
Time of Year/Month/Night	Kelfkens & Lelliott (2006:406)
Moon’s rotation on its axis	Kelfkens & Lelliott (2006:406)
Moon is a source of light	Kelfkens & Lelliott (2006:406)
Moon’s rotation about the Sun	Kelfkens & Lelliott (2006:406)

Finally, I colour-coded responses in the various columns. The different colours made it easy to see what conceptions were present for each respondent at a glance. I was then able to give each respondent a classification. Sometimes I gave a comment or reason for the classification if it was not straightforward and then I came back and double-checked these before settling on a final classification. I used Trundle *et al.'s* (2002) classification system as a starting point. If the respondent in Trundle *et al.'s* (2002) study obtained all of the codes given in Table 4.1 on page 84 on their questionnaire without any misconceptions, they were classified as having a 'scientific' understanding. If the respondent had all four codes together with the misconception that the "Earth's rotation on its axis contributed to causing the phases" (2002:643), they were classified as 'scientific with alternative fragment'. If only some of the above codes were given with no apparent alternative conceptions, then the respondent would be classified as 'scientific fragments'. If a definitive alternative conception was used to explain the phases, then the classification was 'alternative' understanding. By 'alternative' understanding, I mean "contrary explanations … that are in conflict with the explanation accepted by the scientific community" (Barnett & Morran, 2002:860). More than one alternative conception was coded as 'alternative fragments'. Finally, if the answers given contained too little information or were too obscure to code, they were classified as 'no conceptual understanding'. I included a 'no conceptual understanding column' on the coding sheet and likewise marked a '1' in this column if I felt that the respondent fell into this category. I returned to the questionnaires much later, when they were not as fresh in my mind and went through each questionnaire again and checked to see that I had been accurate in my data capture and whether I agreed with the classifications I had given.

While doing the final classification, I did not find the classification 'scientific with alternative fragment' particularly useful. Only one respondent had the potential to fall into this category, but had a different alternative conception together with the four scientific codes. Nobody in my previous research (Kelfkens, 2005; Kelfkens & Lelliott, 2006) had fallen into this category either. I felt that a far more useful classification would be 'scientific fragments with misconceptions', as in some cases there were between one and three scientific fragments and misconceptions present from question 4 but no definite alternative explanation. I felt there had to be a distinction between these respondents and those that had scientific fragments but with the correct answers to question 4. More detail is provided on this in the discussion of the results.

4.1.3 Lunar Eclipses

Questions 6 and 7 on lunar eclipses were open questions. Again, I used a typographical approach to analysis. The typologies were based on Barnett and Morran's (2002) study. They used a rubric for assessing understandings of solar and lunar eclipses, in which they list all the criteria on which they based their classifications. I decided to use the concepts essential to understanding lunar eclipses as given in the rubric as a basis for the typologies and generated a set of codes with the same format as those used for Moon phases. The typologies and related codes for lunar eclipses are listed in Table 4.3 below.

Table 4.3 Concepts essential to understanding Lunar Eclipses

Typology	Code
Sun, Earth and Moon must be aligned directly	SciAli
Moon is positioned in the Earth's shadow	SciSha
Moon's position during lunar eclipse (Earth between Sun and Moon)	SciPos
Indicates the difference between a full Moon and a lunar eclipse	SciDPE

[Typologies adapted from Barnett & Morran (2002)]

I read through the responses to questions 6 and 7, assigning codes as I came across the concepts in the written answers or diagrams. For instance, SciAli and SciPos were often assigned as per the diagrams drawn for question 7. SciSha was assigned if they mentioned the Earth's shadow playing a part or if they said that the Earth blocks the Sun's light. This is because a shadow is "simply the absence of light" (Gundry, pers. comm.) and so both explanations were accepted. I used the same spreadsheet as before and added four new columns, each titled with one of the codes listed in Table 4.3 on page 89. I added columns for alternative understandings, no conceptual understanding and comments. I did not have predetermined typologies for alternative understandings and so coded these as I came across them. Data were entered into the spreadsheet in the same manner as described for the questions on Moon phases. I approached the classification of understandings concerning lunar eclipses in a similar manner to lunar phases in that respondents with all four scientific fragments were classified as 'scientific', those with a subset of fragments were classified as 'scientific fragments', those with an alternative explanation as 'alternative', those with more than one alternative explanation as 'alternative fragments' and the balance as 'no conceptual understanding'. The classification 'scientific fragments with misconceptions' was not used with lunar eclipses, as it was not needed. Instead, once I started analyzing the results, I found it more useful to break down the classification 'scientific fragments' into two sub-categories: those with three fragments and those with 1-2 fragments, as there was quite a large difference in number between those with three fragments and those with 1-2 fragments.

4.1.4 Background Questions

The background questions were a mixture of open and closed questions. To analyze the open questions which related to the teachers' opinions and attitudes, an inductive approach was used as I could only guess at what sort of things the teachers might say, so it made more sense to categorize these as I came across them. Hatch (2002:161) explains that an inductive approach “is a search for patterns of meaning in data so that general statements about phenomena under investigation can be made”. This method was chosen as I suspected that categories that I would not have considered would emerge from the data. Closed background questions were analyzed in much the same way as those for the Moon’s motion. Data were added to the questionnaire coding sheet in the same manner as before.

Questions 5 and 6 asked about the confidence levels of teachers for teaching about lunar phases and eclipses, as well as how important they considered this section for inclusion in the natural sciences syllabus. They were asked to rate both of these items on a scale ranging from ‘not at all’ to ‘very confident’ or ‘very important’ respectively. In both cases, they were asked to comment on their choice.

Once questionnaire analysis was complete, I assigned fictitious names to each of the respondents. I checked carefully to ensure that none of the fictitious names selected were the same as any first names of the respondents. I had to be particularly careful with the case study group as they would be easy to identify. I made sure none of the fictitious names were similar to original names to ensure confidentiality. As the case study group included only one male teacher, I only made use of female fictitious names for this group in order to not reveal identities.

4.2 Questionnaire Results

I have used rounded values for percentages in all the sections where results are reported. A consequence of using rounded values is that the percentages given in tables don't always add up exactly to the expected total.

4.2.1 The Sample

The background questions provided some characteristics of the sample group which are presented in Figure 4.1 on page 93. The intention here is only to describe the sample group. Further information gathered from the background questions relating to teachers' attitudes towards teaching about lunar phases and eclipses are presented in Section 4.2.5 on page 106. In the graph shown in Figure 4.1 on page 93 , only the highest level of study indicated on the questionnaire is given. So for example, if a teacher indicated having previously received instruction at both school and university level, this teacher was classified as 'university'. One teacher did not give a response to this question, so n = 59 for this section of the graph.

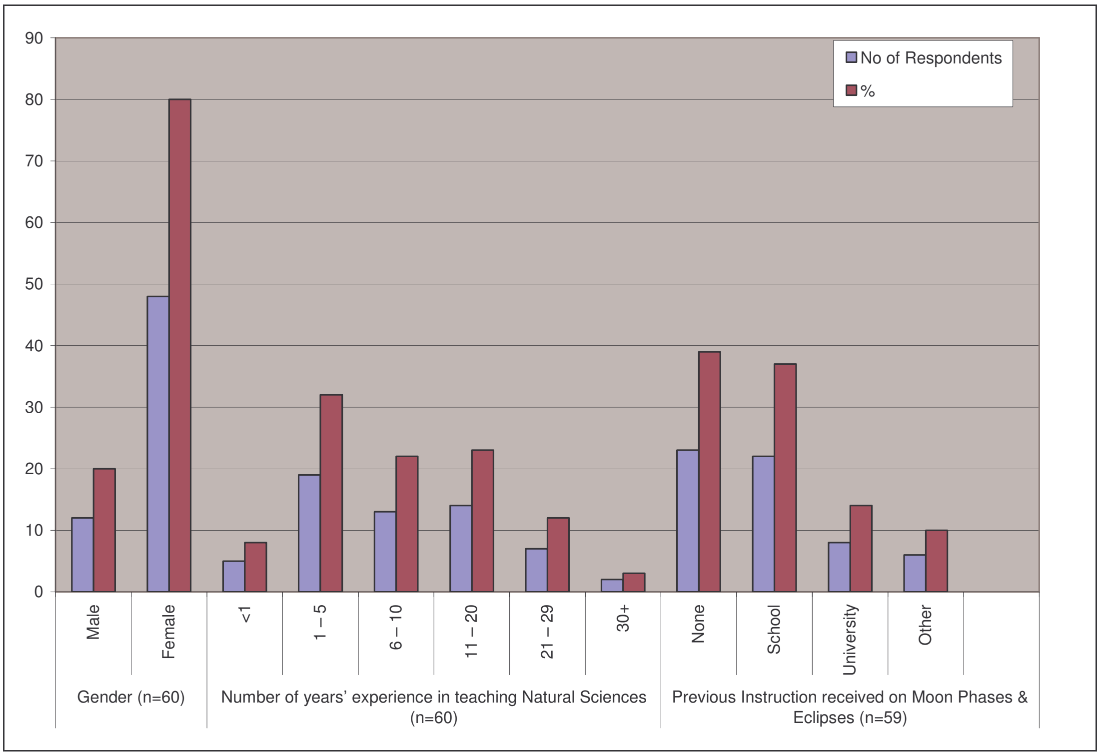


Figure 4.1 Characteristics of the Sample Group

Data collection for this study occurred 18 months after it became compulsory to teach the new curriculum. When Jenkins (2000) looked at the effect of the new curriculum in England and Wales ten years after its implementation, he removed teachers who had been teaching for ten years or less from the sample group, as he felt that these teachers would be unaware of the teaching situation before the curriculum changes took place. The same argument could be used in my study for the five teachers with less than a year's experience in teaching natural sciences. However, some of these teachers may have been teaching for longer, possibly teaching another subject. If new to teaching they would have been schooled in the old curriculum and so would have some idea of the changes and also, as will be discussed in Section 4.2.5.3 on page 115, many schools are resisting the changes and so it is very likely that these teachers are familiar with some aspects of the old South African curriculum. It was interesting to look at these five teachers and see that only one reported receiving university instruction on Moon phases and eclipses. This respondent commented that she qualified in 2005. One of the other teachers who fell into this category had just returned to teaching after 12 years, so understandably she had received no tertiary education on this subject matter. It is very concerning that the remaining three teachers (assuming they are also newly qualified), received no instruction on this content matter in the course of their teacher training.

Also of concern, is how few (14%) of the teachers had received any instruction at all on lunar phases and eclipses at university and how many (39%) have never studied anything about this subject matter at all, with a large portion of the sample group (37%) last studying this content at school. Likewise, only a very small portion (17%) of King’s (2001) sample group in the United Kingdom had received some form of earth science instruction as part of their degrees. Summers and Mant (1995) report that the 54 newly qualified teachers in their sample had not covered material within the U.K. equivalent of ‘Planet Earth and Beyond’ in their PGCE course. Teachers in my study cited family, friends, teaching overseas, popular media (books, television, newspaper articles), and a school textbook as other sources for learning about lunar phases and eclipses. Many of King’s (2001) participants (40%) used high school learner textbooks as sources for the earth science component. Two teachers in my study had attended in-service training courses and one had attended a course at the Hartebeeshoek Radio Astronomy Observatory (HARTRAO). These three teachers account for 5% of my sample as having attended some form of in-service training. Similarly, in King’s (2001) sample of teachers, 4% had attended in-service training. There are a number of possibilities as to why this percentage is so low in South Africa. Firstly, it was my own experience that much of the initial training for the preparation of Curriculum 2005 was poorly presented by officials from the Department of Education, many of whom had never taught in a classroom.

My own experience is that the situation in Johannesburg has vastly improved with some of the universities now running much of the in-service training. However, some teachers may have been put off by the earlier in-service training attempts and now don't attend the courses. Secondly, many teachers are exhausted by their workload, particularly with the additional administration involved in preparing and marking according to rubrics and outcomes and so don't attend anything extra that isn't compulsory. The final scenario, is that teachers are disinterested in attending training on 'Planet Earth and Beyond' because they believe it belongs in geography (refer to the results of background question number 6 discussed in section 4.2.5.3 on page 115).

4.2.2 The Moon's Motion

A summary of the scientific concepts and the results of the questions on the Moon's motion (except question 2) are provided in Table 4.4 on page 96.

Table 4.4 Results for Questions on the Moon's Motion

Question	**1.A.**	**1.B.**	**1.C.**	**1.E.**
Correct Concept	When the Moon is visible, it is **not** always in the same place in the sky.	The Moon moves across the sky in roughly the same path as the Sun.	The Moon does **not** rise at the same time every night.	The Moon is sometimes visible in the sky during the day.
No of correct responses (n = 60)	57	9	59	58
% Correct Responses	95%	15%	98%	97%

As can be seen, questions 1 A, C and E indicated that the teachers had a good knowledge of observable phenomena related to the motion of the Moon, with over 90% of them obtaining the correct answer for each of these questions. Parker and Heywood (1998) also commented that the majority of their participants had a good knowledge of observable phenomena related to the Moon's motion. They only performed poorly on question 1B. Initially, I suspected that this might be due to the way the question was worded and wondered if better results would have been obtained if I'd rather given the statement: 'The Moon rises in the East and sets in the West' for them to give a true/false response to. However, Summers and Mant (1995) had a similar finding with this question in their sample of 120 teachers. They report that hardly any of the teachers in their study knew that the Moon's course is approximately the same as the Sun's. They also included a true/false type question which stated that "The Moon appears to move across the sky from North to South" (1995:17) and they found that the majority of the teachers performed just as poorly on this question. Mant and Summers (1993) support this finding as well – only 10% of their sample was aware that the Moon traverses the sky in roughly the same path as the Sun. So it would seem plausible to conclude that my respondents had a poor knowledge of this fact rather than there being a problem with the wording of the question.

Another similar result obtained by Summers and Mant (1995) is that the vast majority of their participants knew that the Moon can be seen during the day. The teachers in my survey performed significantly better on question 1A than those in Summers and Mant's (1995) study where about 67% knew that the Moon does not stay in the same position in the sky, but seems to traverse it. Mant and Summers (1993) report that 80% of their primary school teacher sample knew that the Moon isn't stationary. Generally, therefore, the teachers in my sample group indicated a good knowledge of observable phenomena related to the Moon's motion, with the exception that the Moon traverses the sky from East to West.

4.2.3 Moon Phases

With regards to question 2, 45 (75%) of the teachers answered correctly that the Moon orbits the Earth and takes approximately one month to do this. Likewise, Summers and Mant (1995) and Mant and Summers (1993) found that 75% of their respective samples knew that the Moon orbits the Earth. However, only 39% of Trundle *et al.*'s (2002) pre-instruction group knew that the Moon orbits the Earth. Comparisons here and in the next paragraph are made with Trundle *et al.*'s pre-instruction group each time, as neither my respondents nor those of Summers and Mant had any instruction, so the groups would be of similar standing. In theory, any response to question 2, except for A, implies that the Moon orbits the Earth. It is my opinion that the code SciOrb in Table 4.1 on page 84 should be tightened up to include the time frame i.e. a scientific understanding should not just reflect that the Moon orbits the Earth, but that it orbits the Earth once a month. Indeed, the most common error on this question was that ten (17%) of the teachers thought that the Moon orbited the Earth on a daily basis. This could imply that they think that the daily orbit of the Moon around the Earth causes the phases, as they have confused the daily rotation of the Earth with that of the Moon's orbit.

In Trundle *et al.*'s (2002) study, 93% of the pre-instruction participants and more than 50% of Summers and Mant's (1995) sample group were unaware of the fact that half of the Moon is always lit up by the Sun (except during a lunar eclipse). In my study, 63% of the respondents were also unaware of this fact. It is very likely that the percentage of respondents in my study who didn't know this may well have been higher, since 1D was a closed question and so respondents could have guessed the answer and also, very few referred back to this fact in their open response to question 5.

Question 4 on the questionnaire came from the Introductory Astronomy Survey (CAER, 1999). This survey was used by Brunsell and Marcks (2005) to determine 142 science teachers' knowledge of astronomical phenomena. Of these 142 science teachers, 73 taught at a similar level as the natural science teachers in my study. In Brunsell and Marcks' (2005) study, 85% of these 73 teachers obtained the correct answer to this question, whereas 71% of the teachers in my study obtained the correct answer. A possible reason why the teachers in Brunsell and Marcks' study performed slightly better on this question could be because they had been exposed to their new curriculum (the National Science Education Standards) for a longer time period – since 1996 (Brunsell & Marcks, 2005). I mentioned in Section 4.1.2 on page 83 that question 4 was included because of a misconception that appeared in my previous research that the Moon phases are somehow linked to the time of night or year (Kelfkens, 2005; Kelfkens & Lelliott, 2006). This misconception only appeared once in the open response to question 5 and I suspect that this is because the vast majority of my current sample group have not been influenced by traditional African beliefs.

The final classifications for conceptual understandings of the Moon's phases are given in Figure 4.2 below, which is ordered from most scientific to least scientific understanding:

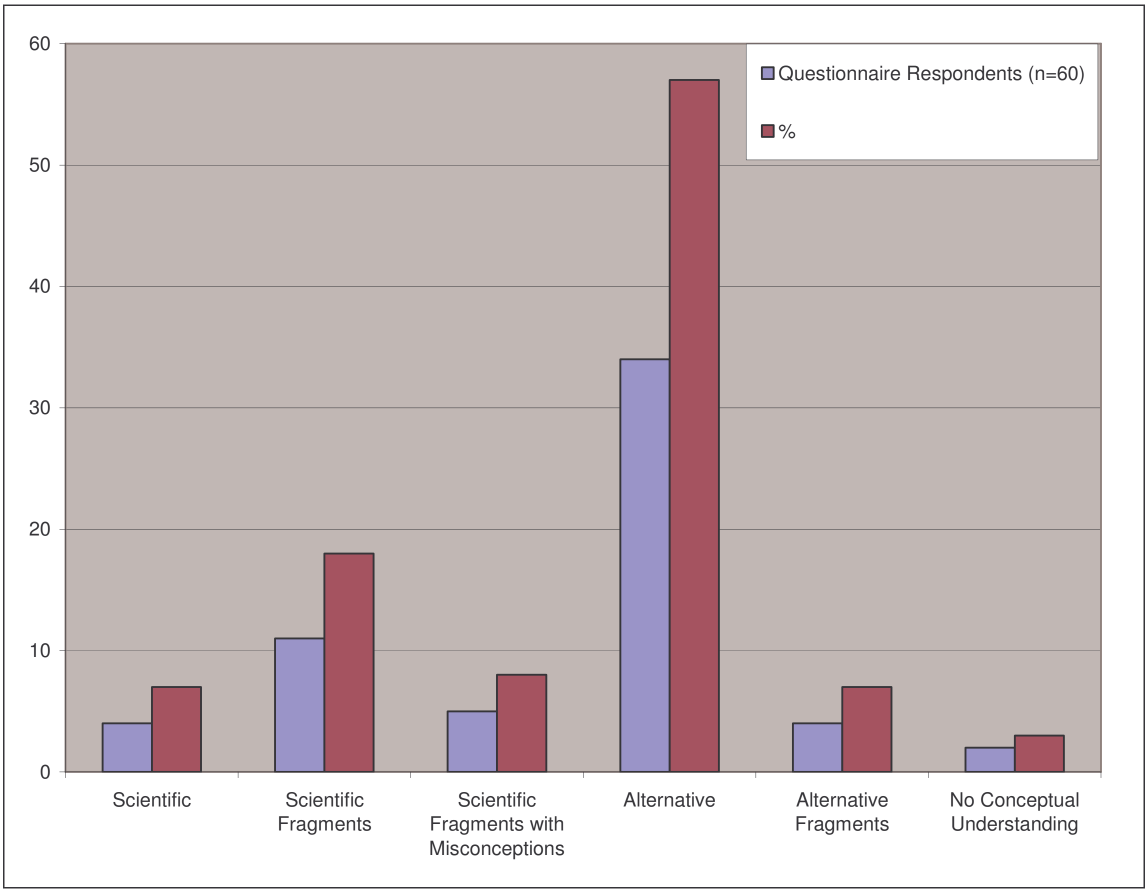


Figure 4.2 Classification of Understandings of Moon Phases

As can be seen from the graph, four (7%) of the 60 teachers were classified as having a scientific understanding. This is comparable to the number of participants classified as having a scientific understanding in several studies: 4% of Trundle *et al.'s* (2002) pre-instruction group and 10% of both Mant and Summers' (1993) and Fanetti's (2001) participants. The teachers classified as 'scientific' obtained all four codes for concepts essential to a scientific understanding and there was no evidence of an alternative understanding for the cause of Moon phases. Two of these respondents had actually answered question 1D incorrectly, which related to half the Moon being lit up by the Sun. However, both respondents contradicted themselves in question 5 and gave a full, detailed scientific explanation for the change in the Moon's shape. As question 5 was an open question, I gave these respondents the benefit of the doubt and classified them as 'scientific'.

Eleven (18%) of the teachers were classified as 'scientific fragments', which is higher than Trundle *et al.'s* (2002) study, where only one student-teacher was classified as 'scientific fragments' before instruction. The reason for this difference could be that some of the teachers in my study had already completed instruction at tertiary level and some had attended in-service training on this subject matter. With regards to the five (8%) teachers classified as 'scientific fragments with misconceptions', no comparisons can be made with Trundle *et al.'s* (2002) study, as they did not make use of this type of classification. These five teachers had given an incorrect response to question 4. An incorrect answer to question 4 is problematic as it implies that the Moon's shape changes during the course of the night and it could imply that these teachers are under the impression that the Earth's rotation or the time of night has something to do with the cause of the phases. Interestingly, question 4 provides the very misconception that Trundle *et al.* (2002) used for their 'scientific with alternative fragment' classification.

Thirty-four (57%) of the respondents were classified as having an alternative explanation for the cause of lunar phases. By comparison, 36 (63%) of Trundle *et al.'s* (2002) pre-instruction group were classified as 'alternative', so our results are similar. Figure 4.3 below lists both the type and frequency of alternative conceptions found amongst the respondents in my study in decreasing order of frequency.

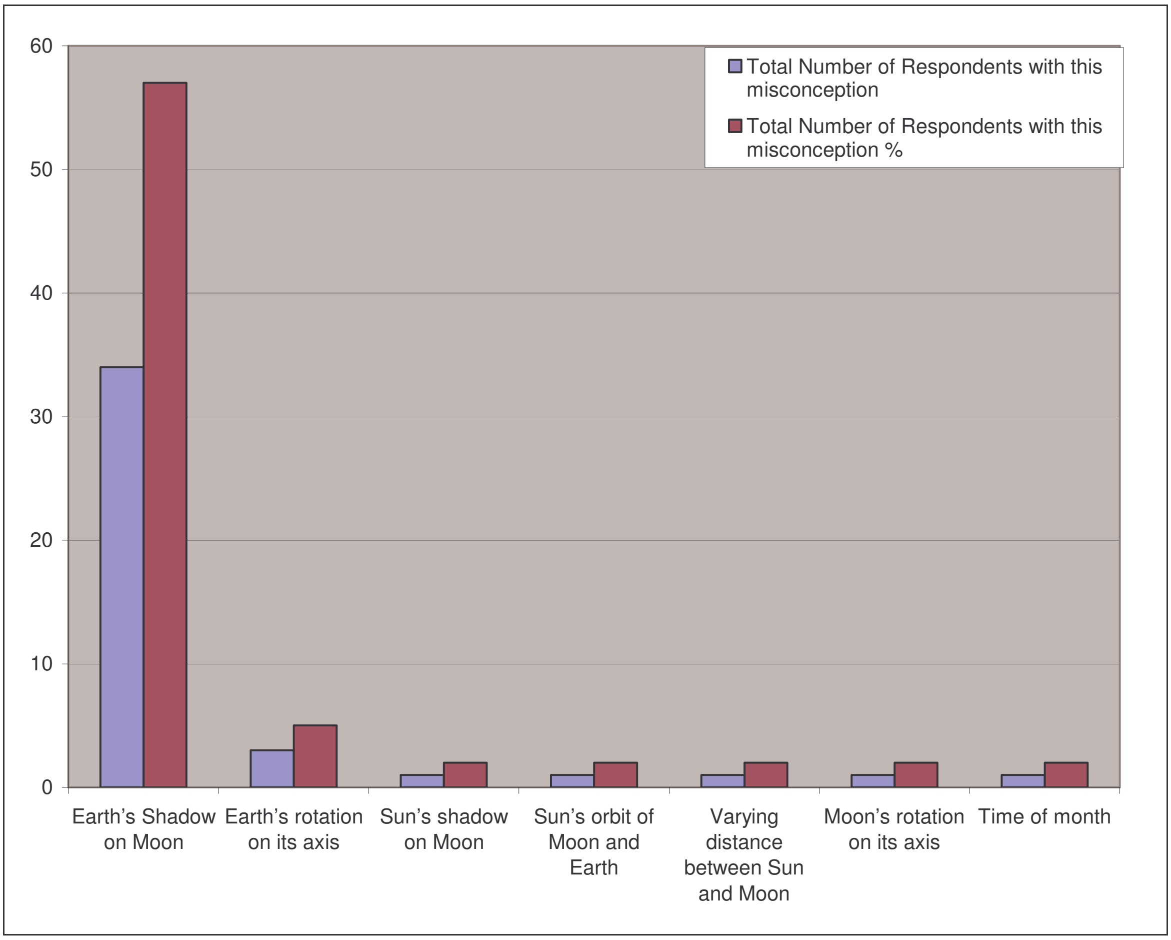


Figure 4.3 Rate of Occurrence of Alternative Conceptions

No alternative explanations were found that were previously unreported. The misconception of clouds being responsible for lunar phases was absent, something I had also found in my previous research (Kelfkens, 2005;

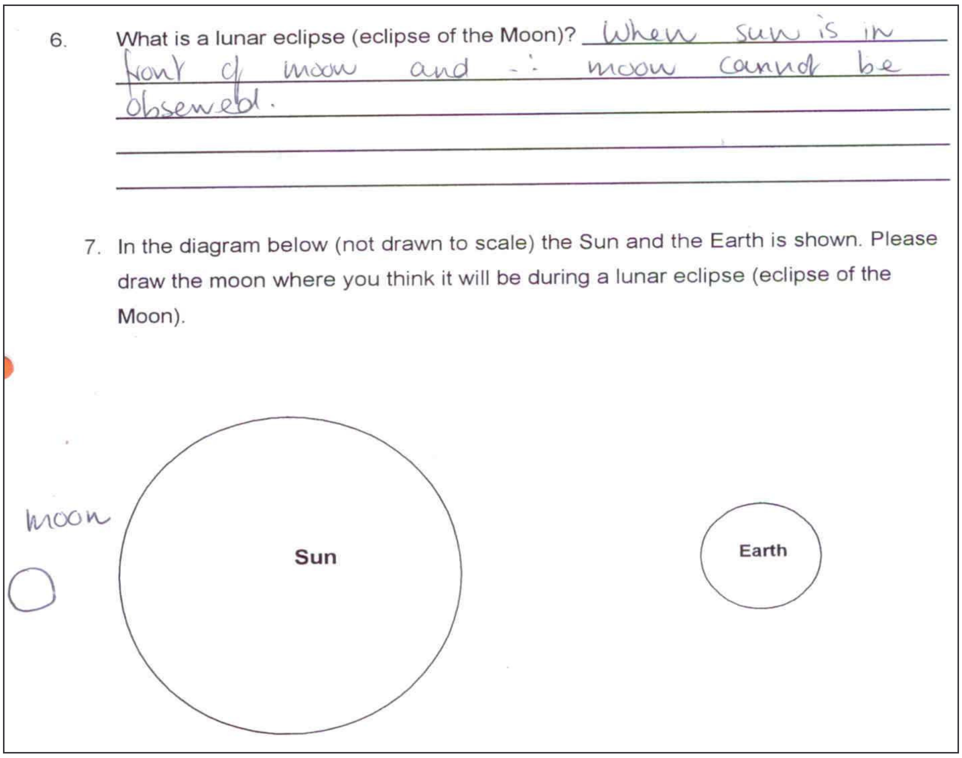
Kelfkens & Lelliott, 2006). I discussed this point in chapter 2 (Section 2.1.3 on page 16) and since this study has confirmed the results regarding clouds in my previous research (Kelfkens, 2005), I think it is very likely that this misconception is far less prevalent amongst respondents who live in areas where the night sky is generally clear. The most common alternative misconception found amongst 34 (57%) of the teachers is that the Earth's shadow on the Moon is the determinant of lunar phases. Mant and Summers (1993) report this misconception amongst 80% of their participants and Stahly *et al.* (1999) say that "the most commonly held notion for the causes of lunar phases is that the Earth casts a shadow on the Moon" (1999:160). The second most common alternative explanation was the Earth's rotation on its axis (5% of my participants). These alternative explanations (Earth's shadow and Earth's rotation) were also the two most common alternative explanations in Trundle *et al.'s* (2002) study.

One of my respondents answered that both the Earth's rotation and the Moon's rotation on their respective axes were the determining factors for lunar phases and three others gave an additional alternate fragment besides the Earth's shadow and so these four (7%) were classified as 'alternative fragments'. This is in comparison with 16 (28%) of the pre-instruction group in Trundle *et al.'s* (2002) study. In both my and Trundle *et al.'s* (2002) study, two respondents were classified as having no conceptual understanding.

4.2.4 Lunar Eclipses

The majority of respondents [54 (90%)] knew that the positions of the Sun, Earth and Moon have to be aligned when a lunar eclipse occurs and fifty (83%) were able to place the Moon at the correct position for a lunar eclipse to occur on the diagram in question 7. Forty-four (73%) knew that the Earth's shadow fell on the Moon during a lunar eclipse. Only four (7%) teachers gave an indication that there would be a full Moon if there was no eclipse. It is possible that more teachers were aware of this fact but did not articulate it in their answers. As mentioned earlier, this is one of the problems with open questions – they don't always draw out the necessary information and as I was concerned about leading the participants, it was very difficult to use another question to probe this further. However, looking at the large number of respondents with an eclipse explanation for phases, 4% is probably a fairly accurate indicator.

Two alternative explanations for a lunar eclipse were identified. One was a solar eclipse explanation. I think it is to be expected that there would be some confusion between a lunar and a solar eclipse. Barnett and Morran (2002) also found a solar eclipse explanation amongst several of the learners in their study (Section 2.1.3 on page 16). The other alternative explanation was that the Moon could not be seen during an eclipse as it was behind the Sun from the Earth implying that the Moon's orbit is not geocentric. An example of this misconception is provided in Figure 4.4 on page 104. I couldn't find this alternative conception in other research, but as mentioned in Section 2.1.2.1 on page 15, very little detailed research on lunar eclipses is available.



6. What is a lunar eclipse (eclipse of the Moon)? When sun is in front of moon and ∴ moon cannot be observed.

7. In the diagram below (not drawn to scale) the Sun and the Earth is shown. Please draw the moon where you think it will be during a lunar eclipse (eclipse of the Moon).

Figure 4.4 Lara's explanation of the cause of Lunar Phases

Figure 4.5 on page 105 provides a summary of understandings of the cause of lunar eclipses from most scientific to least scientific. Three respondents held a scientific understanding of lunar eclipses, which is slightly fewer than the four scientific understandings for lunar phases. Two of these respondents were also classified as 'scientific' on the lunar phases portion of the questionnaire. The third respondent was classified as 'alternative' on the lunar phases section, having the misconception that the Earth's shadow on the Moon is responsible for the phases. Only two participants (3%) held a full scientific understanding of both phases and eclipses. The papers I have looked at which report on both lunar phases and eclipses (Barnett *et al.*, 2000 and Barnett & Morran, 2002) don't report this kind of detail, so once again it is difficult to compare my findings to other research.

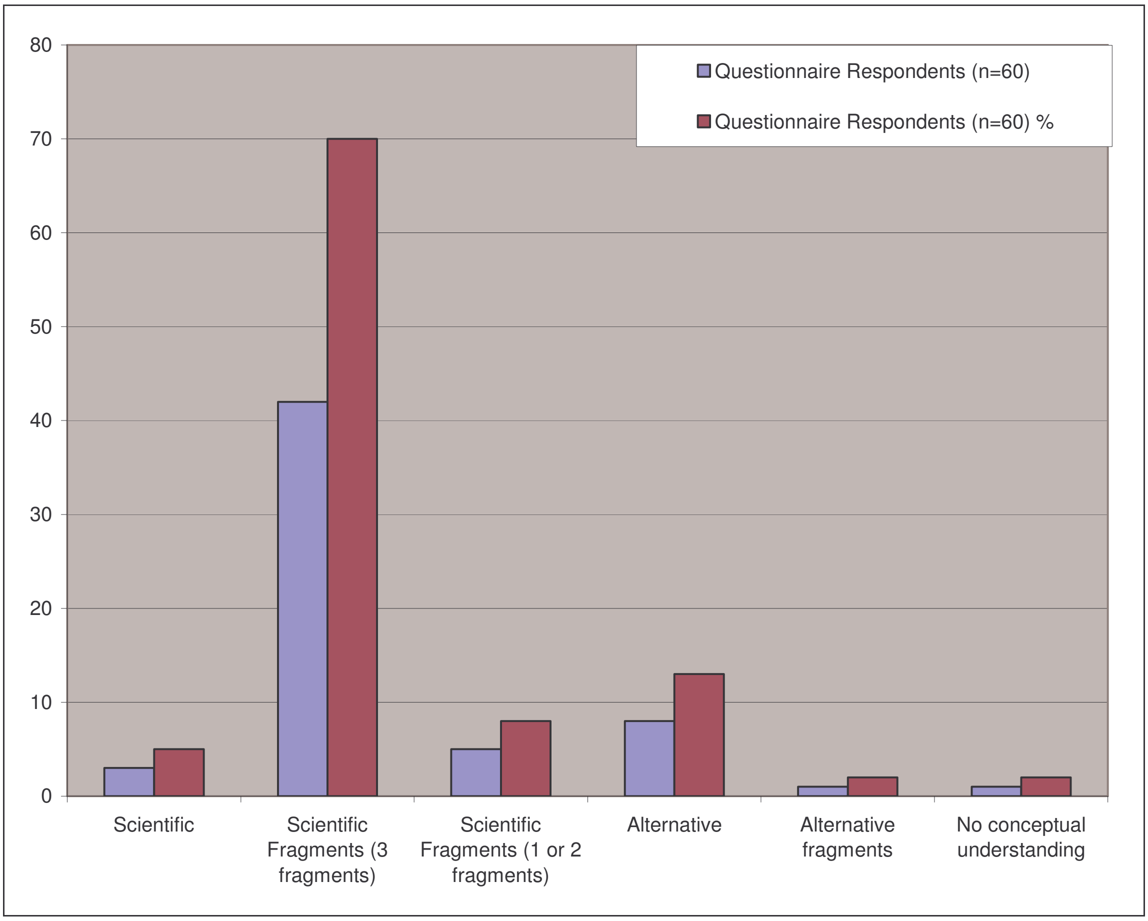


Figure 4.5 Classification of Understandings of Lunar Eclipses

I was surprised to find so many respondents classified as 'scientific fragments' [47 (78%) in total], which I broke down into two levels: those with three fragments and those with 1-2 fragments because only five of the 47 teachers had 1-2 fragments. I was surprised at this result because lunar eclipses are not a common occurrence and sometimes occur very late at night. The popular media (television and newspapers) tend to make quite a fuss when an eclipse occurs and possibly this is why so many teachers had some scientific conceptions present. With many of them being science teachers, most of them would have taught a section on 'light' at some stage and would most likely know what an eclipse would look like because of the pictorial coverage given in newspapers and on television. So knowing that the

Moon becomes dark or a shadow forms on it during an eclipse and knowing something about light and shadows, many of them were probably able to work this out.

Of the eight respondents who were classified as ‘alternative’, five confused a solar eclipse with a lunar eclipse and the remaining three thought that the Moon orbited the Sun and that an eclipse occurs when the Moon is behind the Sun and cannot be seen from Earth, as was illustrated in Figure 4.4 on page 104. One respondent exhibited both these misconceptions and was classified as ‘alternative fragments’. One respondent was classified as ‘no conceptual understanding’ and also had held a very poor understanding of lunar phases. This respondent had been classified as having the alternative understanding that the Sun’s shadow causes the lunar phases, did not answer question 4 on phases at all, thought that the Moon orbited the Earth on a daily basis and there was no presence of any scientific fragments from questions 1D, 2 and 5 for lunar phases.

4.2.5 Background Questions

4.2.5.1 Question 4

Data from question 4 of the background questions revealed that 18 months into the new curriculum, the vast majority of the teachers [43 (72%)] had not taught anything about the Moon’s motion, phases and eclipses. Only seven (12%) had taught something about the Moon’s phases and six (10%) had taught something on lunar eclipses. Similarly, in Summers and Mant’s (1995) study, only 19% of the teachers had taught lunar phases even though the majority had taught something from ‘The Earth’s Place in the Universe’ (the equivalent theme to ‘Planet Earth and Beyond’). Also, “prior to the NC implementation (primary teachers) would not have been required to include such a curriculum in their own teaching" (Parker & Heywood, 1998:503-504). Some insight into why so few teachers in my study have taught this content matter is revealed in questions 5 and 6: many teachers believe it should still be taught in geography and it would seem that this is what is happening in most schools surveyed in this study.

4.2.5.2 Question 5

The results for confidence levels (question 5) are given in Table 4.5 on page 108. One respondent did not give a rating on the scale for confidence levels and so n = 59. The sample group was quite evenly divided with regards to confidence levels with 27 (46%) expressing a lack of confidence and 23 (39.0%) expressing some degree of confidence for teaching about the Moon's motion, phases and eclipses. Several science teachers in Jenkins' (2000) study expressed that they didn't have the confidence to teach this work because it was outside their area of speciality. Nine (15%) teachers in my study expressed uncertainty about their confidence levels. All nine teachers indicated that they had filled in 'not sure' because their knowledge was currently poor and all expressed that they would feel confident to teach this content if they were to brush up on their knowledge. A typical comment is Lauren's: "Would have to study the details – Then would be fine" (LaurenQ:5:22-24).

Table 4.5 Confidence Levels for teaching about the Moon

How confident you feel teaching about the Moon's motion, phases & eclipses (n = 59)				
Not confident at all	**Not very confident**	**Not Sure**	**Confident**	**Very confident**
12 (20%)	15 (25%)	9 (15%)	19 (32%)	4 (7%)

Six categories emerged from the feedback comments given by teachers in response to question 5. These are summarized in Table 4.6 on page 109 in order of decreasing frequency. The total number of responses is given in the right hand column followed by a breakdown into confidence levels for each category. Four teachers abstained from commenting, therefore n = 56. Some teachers fell into more than one category so there is some overlap.

Table 4.6 Categories explaining confidence levels

Category	Category Explanations	Number of Respondents and Breakdown with Respect to Confidence Levels (n = 56)		%
Research	The teachers who fell into this category expressed that they would have to do some form of research e.g. ‘read’ or ‘look it up’, ‘study it’. This category included teachers who would do the research themselves from any available resources and teachers who would look to others more knowledgeable than themselves in this field.	38		68
		Not at all	4	7
		Not very	13	23
		Not sure	9	16
		Confident	10	18
		Very confident	2	4
Prior Knowledge	The teachers in the ‘Prior Knowledge’ category were placed there because they felt they already knew quite a bit about Moon phases and / or eclipses, even if they expressed shortfalls in their knowledge.	8		14
		Not at all	1	2
		Not very	2	4
		Not sure	0	0
		Confident	5	9
		Very confident	0	0

Category	Category Explanations	Number of Respondents and Breakdown with Respect to Confidence Levels (n = 56)		%
Currently teaches this content	All teachers who fell into the ‘Currently teaches this Content’ category indicated that they currently teach or had taught content matter relating to the Moon since the inception of Curriculum 2005.	5		9
		Not at all	0	0
		Not very	0	0
		Not sure	0	0
		Confident	3	5
		Very confident	2	4
Taught Elsewhere	The teachers in this category indicated that in their schools, the section on the Moon is covered by someone else. This could be either a teacher in another department or a teacher in the same department with more expertise or who teaches different grades to the respondent.	4		7
		Not at all	2	4
		Not very	0	0
		Not sure	1	2
		Confident	1	2
		Very confident	0	0

Category	Category Explanations	Number of Respondents and Breakdown with Respect to Confidence Levels (n = 56)		%
Minimal Background	The teachers who fell into the 'Minimal Background' category had very little background knowledge on this subject matter and some also expressed very little interest in it as well.	4		7
		Not at all	2	4
		Not very	2	4
		Not sure	0	0
		Confident	0	0
		Very confident	0	0
Learner Issues	The teachers who fell into the 'Learner Issues' category, expressed levels of confidence related to some learner issues. So any reason given by a respondent that dealt with learners was placed in this category.	3		5
		Not at all	1	2
		Not very	1	2
		Not sure	0	0
		Confident	1	2
		Very confident	0	0

Robyn and Joan’s comments which follow, are typical of the majority [35 (92%)] of the teachers who fell into the ‘Research’ category. These teachers expressed that it was a matter of reading it up and then they would feel confident to teach the material. Both confident and non-confident teachers fell into this group. Those that expressed confidence did so because they felt they could simply look it up and then they would be confident to teach it e.g. Robyn: “I feel that if I was to teach I have enough understanding to be able to grasp the concepts of the Moon's motion, if I researched the topic fully” (RobynQ:5:22-25). Then there were those that weren’t confident but felt they would be once they’d done some research e.g. Joan: “I know very little about it. I would have to spend some time studying this before I taught it - if I did do some studying I would be reasonably confident” (JoanQ:5:22-25). This implies that these teachers think that the Moon’s motion, phases and eclipses are easy concepts to grasp, when in actual fact, this is a complex topic. This is suggested by the results of this research and is supported by several other researchers such as Stahly *et al.* (1999), Fanetti (2001) and Callison and Wright (1993) who say that: “the concept of lunar phases, their occurrence and how they occur is a very complicated one. There are concepts within concepts” (1993:6). Some teachers mentioned the resources they would use to brush up their knowledge: 2 specifically mentioned using textbooks, but neither stated which level of textbook; one teacher specifically mentioned using the Internet. Quite a few of the teachers in my study said they would ‘read up’ or ‘study’ or ‘research’ this section of work, probably implying book-based or internet resources. Only three teachers looked towards outside help. One of these, Sandy, said: “I am sure that I will cope if I had to study the topic or ask the HSS teacher to assist me” (SandyQ:5:22-24). Sandy was one of the respondents who checked ‘not sure’ for this question and she was the only one who considered asking a geography teacher for assistance. King’s finding was that science teachers were much more likely to ask science colleagues (46% of his sample) than geography colleagues (20% of his sample) for assistance. Another, Tarryn, mentioned that “This is really an area where I would need a lot of instruction / reading up in order to be competent to teach it” (TarrynQ:5:22-25) and the third, Roxanne, suggested that “a visit to the planetarium may help” (RoxanneQ:5:22-25).

The eight teachers in the ‘Prior Knowledge’ category were placed there because they felt they already knew quite a bit about Moon phases and eclipses and expressed a mixture of confidence or lack thereof. It may sound strange that they would not feel confident if they had prior knowledge, but I think this is because they were very aware of the gaps in their knowledge. An example is Tania: “My information about the Moon's phases has been "collected" over many years. There are gaps in my knowledge and I would need to read up thoroughly to feel confident about this subject” (TaniaQ:5:22-26). Sarah’s comment is an example of a teacher who had prior knowledge and felt confident about teaching this subject matter: “I love astronomy. I download the sky map every month & when I see the Moon, I use my calendar to work out its position etc.” (SarahQ:5:23-26). All five teachers who fell into the ‘Currently teaches this Content’ category were either ‘confident’ or ‘very confident’ because they had taught the content matter relating to the Moon’s motion, phases and eclipses. Janice’s comment indicates that she has integrated the content relating to the Moon with the section on light, which is traditionally a physics section: “I just teach in conjunction with light and shadows (JaniceQ:5:24-25).

Three of the four teachers who fell into the ‘Taught Elsewhere’ category gave a reason similar to that of Michelle: “I have an agreement with the geography department to teach this component - it prevents repetition in subject contents” (MichelleQ:5:24-26) i.e. this content is taught by the geography department. Michelle was not sure how confident she felt about teaching this section. Only one of these teachers, Kelly, expressed confidence for teaching about the Moon, as she had some astronomy background in her teacher training. However, she obviously had to fit in with the decisions made by the science and geography departments at her school: “Did Geog at Wits and in NS we haven’t been required to teach much in depth. Currently this component of NS is covered by the Geog teachers at school” (KellyQ:5:23-25). In Cayley’s school it is taught in the natural sciences, but is covered in Grade 8, which she doesn’t teach. Cayley did not feel at all confident to teach this section: “Have not taught it. We teach it in Gr 8 - and I have been teaching Gr 9 classes only” (CayleyQ:5:22-24).

As can be expected, the four teachers who fell into the ‘Minimal Background’ category expressed very little confidence for teaching about the Moon’s motion, phases and eclipses as they had very little background knowledge on this subject matter. Donna’s response summarizes the sentiments of the teachers in this category: “I haven't taught it before and last did geography or phases of the Moon many years ago” (DonnaQ:5:22-24). Two of the three teachers who fell into the ‘Learner Issues’ category, expressed a lack of confidence for teaching this section of work because of the challenging questions posed by learners. This is reflected in Julia’s comment: “Can teach very basically but cannot extend children, answer challenging questions without referring to Internet or create a general interest and excitement in” (JuliaQ:5:24-27). Learners probably ask more detailed questions because this section of work interests them, which is reflected in Heather’s comment. Heather expressed confidence for teaching about the Moon, which partly had to do with the fact that she’d completed a basic astronomy course during her time at university and she had also taught this subject matter: “I … have a personal attraction to this interesting field. The main reason for this, is the way the children react to learning about it - with pure enthusiasm” (HeatherQ:5:24-27).

4.2.5.3 Question 6

The results for question 6 on importance levels are given in Table 4.7 below. A surprisingly high number of teachers in relation to what I had anticipated responded that they thought this section of work was important. Thirty-five (58%) felt it was important to very important as opposed to 15 (25%) who felt it was not very important or not important at all. The balance were unsure of its importance. King (2001) had a similar response in his survey. He says that "in view of the lack of earth science in the educational backgrounds of most of the teachers, the fact that they regard the earth science of moderate importance was a surprisingly high finding" (2001:651). However, their opinion of its importance in the natural science curriculum was lower than their self-confidence for teaching the subject matter. This is the opposite of my study where 35 (58%) have regarded it as important as opposed to 23 (39%) who felt confident about teaching this content.

Table 4.7 The Importance of 'Planet Earth and Beyond' in the Natural Sciences Curriculum

How important you think Planet Earth & Beyond is for a natural sciences curriculum (n = 60)				
Not important at all	**Not very important**	**Not Sure**	**Important**	**Very Important**
8 (13%)	7 (12%)	10 (17%)	20 (33%)	15 (25%)

Several issues were raised in the part of the question that invited comment and these are summarized in Table 4.8 on page 117. Some teachers mentioned more than one issue or benefit and so there is some overlap and two teachers refrained from commenting and so n = 58. The categories in the table appear in order of decreasing frequency. Initially, I thought I would take those that didn't think 'Planet Earth and Beyond' was important and divide them into categories and do something similar with those who thought it was important and I was hoping to also find a common thread amongst those who were unsure. However, I found that in some cases, the same categories appeared in all three groups and so had to re-think my strategy. I then decided to just divide the entire sample into the categories and indicate the breakdown with respect to importance levels in Table 4.8 on page 117. I had experienced similar problems with question 5 and so I included a breakdown of confidence levels in Table 4.6 on page 109 as well. Stahly *et al.* (1999) who used an inductive approach for their interviews mention revising the categories they developed when discrepancies arose.

Table 4.8 Categories for importance Levels for 'Planet Earth and Beyond' in the Natural Sciences Curriculum

Category	Category Explanations	Number of Respondents and Breakdown with Respect to Importance Levels (n = 58)		%
Geography	All comments which indicated that this section should be taught in geography (or HSS) were placed in this category. This ranged from teachers who were adamant that it holds no place in science to teachers who could see its value in science but still mentioned geography or HSS.	22		38
		Not at all	7	12
		Not very	5	9
		Not sure	6	10
		Important	3	5
		Very important	1	2
Integrated Teaching	Any response that indicated how 'Planet Earth and Beyond' or the section on the Moon could be integrated into natural science or even a single topic in natural science was placed in this category. This category also included more general comments concerning how biology and/or science and/or geography can be taught with an integrated approach.	18		31
		Not at all	1	2
		Not very	0	0
		Not sure	4	7
		Important	9	16
		Very important	4	7

Category	**Category Explanations**	**Number of Respondents and Breakdown with Respect to Importance Levels (n = 58)**		**%**
Learner Benefits	Any response that gave some form of learner benefit from being taught this section was placed in this category.	15		26
		Not at all	1	2
		Not very	0	0
		Not sure	2	3
		Important	5	9
		Very important	7	12
Other Benefits	There were teachers who mentioned other benefits of the inclusion of ‘Planet Earth and Beyond’ in the natural science syllabus. These comments were very general, philosophical or religious in nature. In addition, these comments were often a bit vague.	8		14
		Not at all	0	0
		Not very	0	0
		Not sure	0	0
		Important	4	7
		Very important	4	7

Category	Category Explanations	Number of Respondents and Breakdown with Respect to Importance Levels (n = 58)		%
Teachers Unprepared	Responses that indicated *in any way* that natural science teachers in general or the respondent in particular, are ill-equipped to teach this content were placed in this category.	6		10
		Not at all	2	3
		Not very	1	2
		Not sure	2	3
		Important	1	2
		Very important	0	0
Repetition	Responses in this category were generally along the lines of ‘Planet Earth and Beyond’ (or the Moon) being an important section but could be taught in the natural sciences or geography, but not in both and so be a repetition of work.	6		10
		Not at all	2	3
		Not very	0	0
		Not sure	1	2
		Important	3	5
		Very important	0	0

Category	**Category Explanations**	**Number of Respondents and Breakdown with Respect to Importance Levels (n = 58)**		**%**
Time Issue	One of the problems raised were time issues fitting this work into the syllabus. So any mention of ‘no time’ or ‘struggling to finish the syllabus was placed into this category.	2		3
		Not at all	0	0
		Not very	1	2
		Not sure	0	0
		Important	1	2
		Very important	0	0
Rote learning	Some teachers felt that ‘Planet Earth and Beyond’ was not important because it involved rote learning and no skills and therefore had no place in an OBE curriculum. These responses were placed in the ‘Rote Learning’ category.	2		3
		Not at all	0	0
		Not very	2	3
		Not sure	0	0
		Important	0	0
		Very important	0	0

Category	Category Explanations	Number of Respondents and Breakdown with Respect to Importance Levels (n = 58)		%
Not relevant	Any response that indicated that this content matter was not relevant to natural science for any reason was placed in this category.	1		2
		Not at all	1	2
		Not very	0	0
		Not sure	0	0
		Important	0	0
		Very important	0	0

Twelve (80%) of the 15 teachers who felt that ‘Planet Earth and Beyond’ held little or no importance in natural sciences fell into the Geography category i.e. they felt that this component should be returned to geography and removed from natural sciences. Aileen expressed the strongest sentiment in this regard: “I loathed Geography at school and did not take it as a subject - I certainly don't want to teach it nor do I feel remotely competent to do so. It seems bizarre to me to suddenly include it in the natural sciences unless the natural sciences are divided and taught by the teachers in the relevant disciplines i.e. Geography, Science & Biology” (AileenQ:6:8-15). A further two teachers felt that ‘Planet Earth and Beyond’ was not important because it involved rote learning and no skills and were placed in the ‘Rote Learning’ category. Sarah’s comment is an example: “We need to teach skills in NS. Skills that develop scientists, thus the content does not matter too much. This section to me is pure learning and thus not all that necessary. …It does require the ability to interpret in 3-D, which is something” (SarahQ:6:8-12 & 21-23). This view is very similar to some of those expressed in Jenkins’ (2000) study, where teachers felt that finding hands-on activities for teaching the earth science component was very difficult. The way the intervention was conducted in this study certainly did not make use of rote learning and several skills were required and/or developed through the activities. I would imagine that Sarah and Cara (the other teacher in the ‘Rote Learning’ category) have never been exposed to alternative teaching methods for this content matter. It was interesting to note that Sarah and Cara were from the same school. All three teachers from this school felt that this section was unimportant for the natural sciences. I noticed trends like this in other categories as well and will comment on them in the relevant discussions, but it points to the possibility that one teacher’s ideas and opinions can strongly influence others in the department. The remaining teacher who felt that ‘Planet Earth and Beyond’ was unimportant was the lone respondent in ‘Not

Relevant'. Jade commented: "It does not help students towards matric science" (JadeQ:6:8-10).

Those that regarded 'Planet Earth and Beyond' as unimportant accounted for 12 of the 22 teachers in the Geography category. A further seven teachers in the 'Geography' category had indicated that they were 'not sure' with regards to the importance of 'Planet Earth and Beyond' in the natural sciences but still felt it should be taught as part of geography. Incidentally, the feeling that 'Planet Earth and Beyond' should still be taught in geography is not unique to South Africa. King (2001:643) reports that "in a few schools (in the United Kingdom), the geography department has been invited to teach the earth science component". Two of the remaining three teachers who fell into the 'Geography' category felt that it was important in the natural sciences but that it shouldn't be taught in both and so be a repetition of work. These were two of the teachers in the 'Repetition' category. An example of the type of comment in the 'Repetition' category is Candice's: "These topics or sections are usually covered by the Geography (HSS) department and is often not covered in natural science / science as it is a repetition of work in different subjects (Learning Areas). Pupils often look forward to "Real Science" (Experiments etc) & appear quite bored when these topics are discussed – repeated" (CandiceQ:6:8-16). In the 'Repetition' category, there was also evidence of a trend within a particular school, as four of the six teachers in the 'Repetition' category were from the same school. The final teacher in the 'Geography' category also felt that 'Planet Earth and Beyond' was important in the natural sciences but seemed to be happy for the status quo of the geography department teaching this section to continue: "It is important but is still being taught by our geography teachers so we are under no pressure to do it in natural sciences" (JoanQ:6:8-10).

The fairly large proportion of responses in the ‘Geography’ category is indicative of the resistance to change mentioned in Section 4.2.1 on page 92. Some of the problems teachers associated with this curriculum change have been discussed. Two further problems raised by teachers concerning the inclusion of ‘Planet Earth and Beyond’ in the natural sciences curriculum, regardless of whether they thought it was important or not, were time issues and natural sciences teachers being ill-equipped to teach this section of work. Tania’s quote is an example of time problems relating to fitting this work into the syllabus: “I am concerned about time taken for this component as "Biology" and "Science" curriculum is already long” (TaniaQ:6:12-14). It is possible that time is a problem because teachers are still trying to teach some of the old curriculum work as well and so ‘Planet Earth and Beyond’ falls by the wayside. Tarryn’s comment is indicative of natural science teachers being ill-equipped, but I think it offers a bit more insight: “’Geography’ is a science just like biology and chemical / physical science - I just don't know how many teachers are prepared (on all sides) to effectively teach it as one subject” (TarrynQ:6:9-12). I think that Tarryn is hinting that not only do natural science teachers not have the background, but they don’t want to teach ‘Planet Earth and Beyond’. Later in my research, Tania experienced a change of heart about her concerns. She was my research assistant for the filming of the intervention session. I only asked her to do this after she’d completed and given me her questionnaire and she also didn’t know any of the teachers in the intervention group. After she’d observed the intervention session, she felt very enthused to teach this section and asked for a copy of the materials I had used in the intervention. The last I heard was that this section had been included in her natural science department’s planning for 2007!

Many teachers commented on the benefits of including ‘Planet Earth and Beyond’ in the natural science curriculum. These benefits fell into three broad categories: ‘Integrated Teaching’, ‘Learner Benefits’ and ‘Other Benefits’.

Claire’s comment provides an example of a teacher who could see the advantages of integrated teaching: “It gives balance to the very Science/Bio focus & it provides opportunity to link sections in each distinct field in the natural sciences” (ClaireQ:6:8-10). At 31% I was surprised and pleased that this number of teachers could see how the subjects could be integrated. In the ‘Learner Benefits’ category, three sub-categories appeared. Four (7%) teachers felt that this section was necessary for either subject or career choices. Tania’s comment is an example: “I think that 'Earth & Beyond' is a vital section as it incorporates biology and science. Many students will not have an opportunity to study this section again due to subject choice. This component contains important life skills and life knowledge” (TaniaQ:6:8-12). Another four felt it was important because, as pointed out by Natalie, learners find this section of work interesting and enjoyable: “Learners enjoy this section - they seem to know a lot & ask a lot of very intelligent questions. They are very interested in space” (NatalieQ:6:8-11). The rest of the teachers gave an array of nine different benefits to learners – Stacey’s is an example of one of these: “This generation may become space tourists - they also need to understand their place in the Universe and help contribute to better use of our natural resources. We should therefore foster a love of their planet - and stimulate interest in further exploration” (StaceyQ:6:8-14). Two teachers in the ‘Learner Benefits’ category fell into more than one sub-category, which is why n=15 and not 17 for this category. Finally, there were eight teachers who mentioned other benefits of the inclusion of ‘Planet Earth and Beyond’ in the natural science syllabus. These comments were either rather general in nature, such as Emma’s comment: “It is part of Science and our environment” (EmmaQ:6:8-9). Some of them, like Leonie’s were what I’ve termed ‘philosophical’ in nature: “Perspective, knowing about the world is vital to building a good character” (LeonieQ:6:8-9). Paul’s comment was religious in nature: “Not only does it emphasize God's omnipotence, Almightiness, but also satisfies the curiosity. Also means contribution to everyday life (ocean etc) is piece of puzzle available to us" (PaulQ:6:8-12). All the comments that fell into this category were of these three types.

4.3 Validity and Reliability

I have already mentioned several strategies in this chapter to ensure accuracy in coding the questionnaires and classifying respondents. These included: returning to those classifications which were not straightforward before settling on a final classification and returning to the questionnaires at a much later date and checking them. Furthermore, I selected ten questionnaires across the spectrum of understandings and asked a colleague to cross-check my coding and classifications. The data capture for all the closed questions (lunar motion, some lunar phases and some background) revealed 100% correlation, indicating that my data capture for the closed questions was accurate. Initially, there was a 60% interrater agreement on the coding for phases. As already mentioned in Section 4.1.2 on page 83, I re-coded the questionnaires which indicated an 'A' or 'B' response to question 3. My colleague also picked up an additional alternative explanation for one of the respondents and when I re-read the questionnaire, I agreed with her interpretation. So finally, there was a 90% agreement for the phases classifications. For eclipses, there was a 90% agreement on the coding and we agreed on 21 out of 26 codes (81%) across background questions 5 and 6. In this chapter, I have compared my results to other studies which used the same or similar questions. By and large, our results are similar, which is indicative of the validity of the questionnaire.

4.4 Summary Discussion of Survey

1. The teachers' educational backgrounds on lunar phenomena was generally poor – only 14% had covered some content on lunar

phases and eclipses at university level. There have been similar findings in the United Kingdom: 17% of King's sample and none of the 29 newly qualified teachers in Mant and Summers' (1993) study had tertiary education on this content. 5% of my sample and 4% of King's (2001) sample attended in-service training on this subject matter. So the problem of a poor background is not unique to South Africa.

2. Generally, the teachers in my study like those in Parker and Heywood's (1998) study, were knowledgeable about observable phenomena related to the Moon's motion. The exception to this in my study was knowledge of the Moon's apparent path across the sky. Only 15% knew that its path is roughly the same as that of the Sun's. This finding is corroborated by Mant and Summers (1993), who found that 10% of their sample were aware of this fact and Summers and Mant (1995), who reported that hardly any of their respondents were aware of this.
3. Both Summers and Mant (1995) and my study report that a high number of participants knew that the Moon is visible during the day – the vast majority in both cases. With regards to the fact that the Moon is not always in the same place in the sky, my finding of 95% of participants is supported by the large proportion (80%) in Mant and Summers' (1993) study who knew this.
4. In my sample group, 75% of respondents knew that the Moon orbits the Earth. Mant and Summers (1993) and Summers and Mant (1995) report the exact same percentage in their surveys. Our findings are in contrast to Trundle *et al.* (2002), who report that only 39% of their student-teachers indicated knowledge of this. Most people are unaware that half the Moon is always lit up by the Sun (except during a lunar eclipse): 93% in Trundle *et al.* (2002), more than half in Summers and Mant (1995) and 63% of my sample. The

fact that the Moon does not change its appearance during the course of the night was familiar to 71% of my sample, which is comparable to Brunsell and Marck's (2005) result of 85%.

5. Several parallels can be drawn between the phases classifications in my study and that of Trundle *et al.'s* (2002) study. There are similar percentages for those having a scientific understanding (similar to Mant and Summers' (1993) findings as well); similar percentages for those having an alternative explanation for phases and no conception of phases and the same two most frequent alternative explanations (Earth's shadow and Earth's rotation). Many research reports concur with the Earth's shadow being the most common alternative explanation. Some examples are Mant and Summers (1993), Summers and Mant (1995), Parker and Heywood (1998) and Fanetti (2001), amongst others. Trundle *et al.* (2002) found several more types of misconceptions than I did and I suspect that this is because they interviewed all their participants and as I will show in chapter 5, interviews amongst only five participants in my study, produced more and a wider variety of alternative conceptions than the equivalent five questionnaires did.

6. Generally, there is little research on lunar eclipses and what there is, has different emphases to mine. I found two alternative conceptions with regards to the cause of lunar eclipses – one is a solar eclipse explanation, also reported by Barnett and Morran (2002) and the other is that the Sun obscures the Moon from the Earth which implies that the Moon's orbit is not geocentric. While most teachers had a good idea of alignment, position and the Moon falling into the Earth's shadow during a lunar eclipse (resulting in a larger than anticipated number classified as 'scientific fragments'), very few of them articulated that this occurs at full Moon. Also, only

three respondents were able to give a full scientific explanation, two of which also gave a scientific explanation for phases.

7. A finding of mine that appears to be in contrast to Barnett and Morran's (2002) study is the difficulty level of eclipses. If a comparison is made between the number of teachers with a partially scientific understanding for eclipses (70% with three fragments) and phases (18%), the teachers in my study had a better understanding of eclipses than phases. Barnett and Morran (2002) found "five students had difficulty in determining the difference between a full Moon and lunar eclipse even if they understood the reasons for the phases of the Moon" (2002:870). The implication here is that more difficulty was experienced with eclipses than phases. As mentioned in chapter 2, very few papers touch on lunar eclipses. So more research is needed on lunar eclipses together with phases to investigate this further.
8. The background questions revealed that despite the curriculum being in place since 2005, 18 months down the line 72% of my participants have not taught anything about the Moon; 12% have taught something about phases, which is comparable to the 19% in Summers and Mant's (1995) study; and 10% have taught something about lunar eclipses.
9. Questions 5 and 6 provided some interesting insights, concerns and benefits regarding the introduction of Moon phases and eclipses into the natural science curriculum. Some degree of confidence for teaching about lunar phenomena was expressed by 39% of my participants. The vast majority (68%) stated that they would just look it up if they had to teach it. In my opinion, their confidence for being able to grasp the complex concepts embedded in lunar phases and eclipses, is misplaced. This is supported by the results of this research, as well as that of Trundle

et al. (2002), Stahly *et al.* (1999), Callison and Wright (1993) and Fanetti (2001), to name a few.

10. The finding that 58% of teachers regarded lunar phenomena as important for inclusion in the natural science curriculum was much higher than expected. King (2001) comments on a similar finding in his survey. However, my findings are in contrast with King's with regards to a comparison between confidence levels and the importance of this work. I found that more of my teachers valued its importance than expressed confidence for teaching it. In King's (2001) study, it was the other way around. More than a quarter of the teachers in my study felt that lunar phenomena should be taught by geography teachers (this was the largest category in response to background question 6), which indicates a significant resistance to the curriculum change. However, the fact that 31% of the teachers had some vision of integrated teaching, is encouraging.

CHAPTER 5 CASE STUDY DATA ANALYSIS AND RESULTS

In this chapter, I will focus on the case study. I will start by introducing the case study group and giving some background information about the participants in this group. Then I will explain how I analyzed the case study data, which incorporates an intervention, pre- and post-intervention interviews, post-intervention questionnaires and classroom observation. In order that the interview and post-questionnaire results make sense, I will also discuss pre-intervention questionnaire results specific to the case study group. The discussion of the results is within a constructivist framework. Where results relate more specifically to the situated learning and pedagogic content knowledge theories, I will address these specifically under separate headings. Finally, I will make some comments regarding the precision and trustworthiness of the case study.

5.1 The Case study Group

The case study group consisted of five teachers from two schools. They were given the fictitious names: Courtney, Danielle, Donna, Emma and Lara. The purpose of this section is to provide an introduction to the case study group by describing some of the background information given on the questionnaires. Detailed results for this group will be provided in subsequent sections.

Courtney had been away from teaching for 12 years. She had returned and had been teaching natural science for just under a year at the time of this study. She had never formally studied or taught anything about the Moon. Courtney indicated on her questionnaire that she was not at all confident about teaching on the Moon’s motion, phases and eclipses. She mentioned that she would “have to read up and prep everything I teach really well before I teach it” (CourtneyQ:5:24-26) and therefore fell into the ‘Research’ category for background question 5. However, she felt that ‘Planet Earth and Beyond’ was important for the natural science curriculum and her response fell into the ‘General Benefits’ category: “It’s different and interesting and relevant to our understanding of how things work on Earth” (CourtneyQ:6:8-10).

Danielle had been teaching natural sciences for 15 years. She had never formally studied anything about the Moon and had taught a little bit about it to Grade 9’s as part of a theme on cosmology. On the questionnaire, Danielle had indicated that she was unsure how confident she felt about teaching this content and her comment placed her in the ‘Research’ category: “I would need to do background research - am confident I could get the concepts” (DanielleQ:5:8-9). Danielle indicated ‘not sure’ again for question 6 on the questionnaire concerning the importance of ‘Planet Earth and Beyond’ for the natural sciences curriculum. Her comment was: “No single component / theme is vital - it is vital to teach across disciplines (bot;zoo;phys;chem; earth sci) whatever theme is being taught. However, it is also very important to teach in a wide variety of themes” (DanielleQ:6:8-12). I placed her in the ‘Integrated Teaching’ category.

Donna had not taught anything about the Moon during her seven years of teaching natural sciences. She had last learnt something about the Moon during her junior or intermediate grades at school. Donna ticked the ‘Not very confident’ box for question 5 and I placed her in the ‘Minimal Background’ category because of her comment: “I haven't taught it before and last did Geography or phases of the Moon many years ago” (DonnaQ:5:22-24). With regards to ‘Planet Earth and Beyond’, she felt that “It is important for an understanding but our Geography teacher includes it in her area because with Expo we lose a lot of teaching time. So we focus on what is needed for Physical Sciences / Biology for FET" (DonnaQ:6:8-13). She was of the opinion that it is not very important for inclusion in the natural sciences curriculum. Her comment placed her in two categories for question 6: 'Geography' and 'Time'.

Emma had been teaching natural sciences for three years, but had not covered the topic of 'The Moon' during this time, nor had she studied anything about this topic. She indicated that she was unsure about how confident she felt about teaching the topic but stated that: "If I have the information and I can go through it beforehand, I think I will be fine" (EmmaQ:5:22-24). She felt that 'Planet Earth and Beyond' was an important component of natural science and for questions 5 and 6 of the background questions, Emma was placed in the 'Research' and 'General Benefits' categories respectively.

Lara had been teaching for 25 years and although she had learnt something about phases and eclipses of the Moon at university, she had never taught anything on this topic. Lara stated that she was not very confident about teaching on the Moon's motion, phases and eclipses. She fell into the 'Research' category for this question as "knowledge is very rusty but could catch up if necessary" (LaraQ:5:22-24). Lara felt that 'Planet Earth and Beyond' was important for inclusion in natural sciences and stated that "Lots of articles in magazines (Discover etc.) have articles on the solar system and especially with regard to SA and SALT in Sutherland" (LaraQ:6:8-11). I got the impression from this comment that she was implying that she would use these articles in her teaching and so placed her in the 'Learner Benefits' category for question 6.

5.2 Data Analysis

5.2.1 Interviews

I transcribed the interviews verbatim, according to the guidelines given in Henning (2005). I watched the videos and wrote down what was said and what the respondent did with the model. I then typed up the transcriptions and went through each taped interview a further three times to ensure that my transcriptions were as accurate as possible. I coded them in the same way as the open questions on the questionnaire were coded and used a typographical approach to this analysis as codes for the data in the interviews had already been established during questionnaire analysis. However, I was open to any new codes that could appear from the interview data. I underlined all extracts in the transcript that were necessary for a particular code and then filled in the codes at the relevant points on the transcripts. Examples of how I did the coding are shown in Section 5.3.1 on page 136. Once I had done the coding, I classified each of the five teachers according to the same classification system used for the questionnaire analysis. Then I compared the questionnaire classifications to those given on the interviews to see if they were the same or not.

5.2.2 Intervention

When I analyzed the video recordings of the intervention session, I made detailed notes describing everything that happened in this session. I then split up these notes into 'methodology' and 'results', adding descriptions of the events that occurred during the intervention and the order in which they took place to the 'methodology' notes and my observed results to the 'results' notes. I compared the methodology notes from the video recordings to what I had previously written and added where necessary. Within the results, I had two typologies: ‘Situated Learning’ and ‘PCK’ (Pedagogic Content Knowledge). These both formed part of my theoretical framework. I looked for two main things: data that related to the group dynamics during the session, as this is relevant for my theoretical framework of situated learning; and data that related to the teachers’ responses to and criticisms of the activities, which belongs in the PCK category. These data were particularly relevant for answering research questions 2 and 3 (Section 1.4.2 on page 7).

Once I had identified what sections were relevant to the ‘situated learning’ and ‘PCK’ categories respectively, I split the notes up again into these two categories. This formed the framework. With the methodology notes having been removed, I had to fill in some descriptive notes so that the framework made sense. Within the ‘situated learning’ category, I looked for evidence of things like learning, tools, enculturation and legitimate peripheral participation and in the ‘PCK’ category, I took note of anything that was discussed with respect to how the teachers would change what we did in the intervention session for the purpose of teaching it to Grade 8’s.

5.2.3 Observation

Unfortunately, only two of the teachers, Danielle and Donna, were able to fit in the teaching of the ‘Moon’ module. Danielle taught it to one Grade 8 class and Donna to two classes. Fortunately, Donna started the Moon module about two weeks after Danielle completed her teaching and I was therefore able to observe all lessons for both teachers. I ensured that information sheets and consent forms for the learners to complete were received well before the observation sessions took place. Both teachers grouped learners together who had not returned signed consent forms and I did not make any recordings of these groups. I video-recorded all the lessons for both teachers.

There were plenty of learner data that could have been analyzed, as I spent time interacting with the groups and observing how they tackled the activities. Also, all these learners completed pre- and post-questionnaires as both Danielle and Donna thought that this would be a useful exercise for both the learners and themselves. However, these data were not used, because it is outside the scope of my research questions and using it would have made the current study too large. Also, much of the learner data were unreliable because of how the learners changed their answers. They were supposed to use a different colour pen after the teaching on the same questionnaire, but many crossed out their answers and we were unsure when they made these changes. It would have been better to use separate pre- and post-questionnaires.

I watched the tapes and specifically looked for data that pertained to my third research question, which relates to how the teachers used the materials and models in their classrooms. So I analyzed the data in such a way as to make a comparison between the way the two teachers approached the teaching with their classes and I also looked for differences in the way that Donna taught her two classes. The focus of analysis was on the teachers, as the research questions very specifically relate to the teachers and so learner data were not analyzed unless it was relevant to how the teachers managed the lessons.

5.3 Results

5.3.1 Pre-Intervention Interview Results

The interviews took place a week before the intervention session, after the questionnaires had been returned and I'd had a chance to study them to prepare thoroughly for each interview. In this section, I will provide extracts and discussions from two of the interviews conducted with the five case study teachers and a detailed discussion of the other three. (The interview extracts for the other three teachers are provided in Appendix C on page 229). The assigned codes are shown on these extracts in bold print and the portion of the response that was awarded the code is underlined. The idea to do this came from Trundle *et al.* (2002) except that they put both the response and code in bold. I found it looked clearer not placing both in bold print and decided to use underlining for the response instead. Sometimes a code was split across several responses (not necessarily consecutive). Each relevant portion was underlined and the code word assigned so that the code word may appear more than once. From these extracts with coding, it will be possible to see how I arrived at the classification of each case study teacher. I will provide a more detailed discussion of both the questionnaire and interview for each case study teacher and comparisons will be made where appropriate.

5.3.1.1 Common Features across the Interviews

A common thread across the interviews, with the exception of Danielle, was where the participants thought the full Moon would be. Courtney and Donna thought it would be at new Moon position and Lara and Emma thought it would be at first quarter. I think that the problem with placing full Moon at first quarter has to do with the participants being external to the model i.e. it didn't occur to them to picture themselves on the Earth. They were thinking what they would see from where they were sitting. Suzuki (2003) also reports that the student-teachers in his case study found it difficult to explain Moon phases from an Earth observer's perspective and Callison and Wright (1993) also comment that this was a problem for their participants. Donna's explanation for why it would be at new Moon position was:

D: O-o-oh! I would say probably directly in the view {*Places Moon in new Moon position at level below Earth i.e. on the table*} because then the full light is shining on and the Earth can see the, the Moon. That's what I would say.

(DonnaI:1:13-15)

With Lara and Emma, the problem was the same, but they were looking at it from a slightly different perspective, namely from where they were sitting. They were both seated at first quarter position and I think they thought this would be where the Moon would have the "most amount of light on it" (LaraI:2:32) as this was the position from where they could see the Sun clearly. It didn't occur to either of them that last quarter position would have the same view and just be a mirror image. Barnett and Morran (2002) found that three of the learners in their study placed the full Moon at last quarter position and gave a reason much the same as Lara's.

Another fairly common event in the interviews was that Lara, Emma and Donna all thought that at full Moon position, the Sun's rays would be unable to reach the Moon because the Earth would be blocking those rays. Danielle had the correct conception and Courtney thought the Moon was stationary so this didn't apply to them. However, I think the other three teachers provide some insight why this is such a common misconception and why scale is so important in building a scientific understanding of phases and eclipses.

The use of the words 'rotation' and 'revolution' was another common problem. This complicated matters, as the teachers were apparently unaware of the difference in meaning of these two words in astronomical terms. Fanetti (2001) defines rotation as "an object spinning on its axis" and revolution as "the motion of one object about another" (2001:35-36). This is where interviews and the model were useful as I could probe what they meant or ask them to use the model to explain what they meant. Even Danielle, who had a very good understanding of phases and eclipses, confused the two: “And that’s caused by the Moon’s rotation around the Earth every four weeks, give or take” (DanielleI:1:9). From her description, it’s obvious that she means ‘revolution’ and not ‘rotation’. When I asked Lara what causes the phases of the Moon, she explained it as the Moon’s rotation about the Earth and then used the model to support her description and demonstrated the Moon *revolving* around the Earth. In her interview, Donna used the words interchangeably. Firstly she said “because they’re both revolving *{Indicates turning motion with her hands}* (DonnaI:1:4-5). From her hand motion, I couldn’t tell whether she meant ‘rotating’ or ‘revolving’, but then she continued and said “um, on their own axis as well as around each other”, which implies both rotation and revolution. Later in her interview, she used the word ‘rotating’ instead and showed ‘revolution’ using the model. Fanetti (2001) reports a similar problem amongst the university students in her study and also found that it was impossible to tell whether the students meant ‘rotation’ or ‘revolution’ in their questionnaire responses. Stahly *et al.* (1999) also report one of their case study participants using ‘rotation’ instead of ‘revolution’ in the pre-questionnaires and Parker and Heywood (1998) report the same problem with ‘spin’ and ‘orbit’. Emma and Courtney’s pre-interviews were not problematic, as Emma used the word ‘orbiting’ instead and used it correctly and Courtney thought the Moon was stationary, but spoke about planets revolving around the Sun, again correct use of the terminology. These findings relate to the constructivist framework in which Carr *et al.* (1994) point out that words which have alternative meanings in everyday spoken language to the way they are used in science, are also a source of misconceptions.

With the exception of Lara, none of the case study teachers indicated any tertiary level of education concerning astronomy and in Lara’s case, it had been a long time ago. However, it was clear from their questionnaires and interviews, that they had constructed their own ideas about lunar phenomena despite little formal tuition. The origin of some of their ideas was from their own observations of lunar phases and eclipses and some of them had done some reading as well. Also, it was clear that their conceptions were not necessarily correct, as will be shown in the discussion of each teacher's interview.

In the extracts that follow as well as those in Appendix C on page 229, the interviewer is denoted by 'Int' and the respondent by the capital letter corresponding to the first letter of her fictitious name. If a respondent manipulated the model as part of her response, a description of this manipulation is provided in brackets { }. Other descriptions or comments are made in round brackets ( ). I have placed the discussions in alphabetical order, which is different to the order in which interviews were conducted for confidentiality purposes. I chose to include extracts in the discussions for Danielle and Lara, as they were two contrasting teachers.

5.3.1.2 Courtney

Courtney indicated a good understanding of observable phenomena relating to the Moon's motion in her questionnaire, correctly answering three of the four questions. The only one she didn't know was that the Moon follows a similar path to that of the Sun across the sky. The same was true for Danielle, Donna and Emma. With regards to Moon phases, Courtney was classified as having an alternative understanding, namely that the phases are caused by the Moon's "distance from the Sun and position relative to the Sun" (CourtneyQ:3:4-5). As can be seen, the scientific fragment SciEMS also appears in this response. Another fragment awarded to Courtney was SciHaf, as she correctly answered question 1D, namely that half the Moon is always lit up by the Sun. Several other misconceptions appeared in her questionnaire. Firstly, Courtney was under the impression that the Moon does not revolve around the Earth. Then, she thought that a crescent Moon would be seen at the position of new Moon. Finally, she thought that a full Moon would appear as a crescent Moon six hours after rising. It was evident from her questionnaire that Courtney knew very little about eclipses. She was classified as having an ‘alternative’ understanding based on her diagram (question 7) only, where she drew the position of the Moon for a solar eclipse. However, she made no attempt to give written explanations for eclipses.

In the interview, Courtney was classified as having an alternative understanding for both phases and eclipses and in both instances, the alternative explanation was different to the one she’d given in the questionnaire. Her explanation in the interview for both phases and eclipses was exactly the same, namely that they were caused by planets blocking the Sun’s light. I suspect this was because she didn’t know the difference between a phase and an eclipse. Every time I asked about phases, she would revert to eclipses. I tried to probe on this, but had to stop after a while as she was starting to become uncomfortable. I then changed tack to put her at ease again. Because phases and eclipses are quite mixed up in her transcript, I had to include the word ‘eclipses’ in the code to make it apparent that the coding applies to eclipses and not phases in the extract which appears in Appendix C on page 229. In the interview, the only scientific fragment that appeared was SciEMS. The misconception that the Moon is stationary appeared again.

5.3.1.3 Danielle

Danielle was classified as ‘scientific’ for the phases and could work out the correct position for a crescent Moon in the diagram for question 3. She also answered question 4 correctly regarding the Moon’s appearance six hours after rising. The extracts from Danielle’s interview transcript showed that she has a scientific understanding of both Moon phases and eclipses. This classification differs from the questionnaire only in the eclipses classification, which on the questionnaire had been three scientific fragments. The missing fragment was SciDPE. I explained earlier that this fragment did not always come through in the open questions and would have proved difficult to probe further without leading participants.

The extract that follows illustrates how the codes were assigned for both the phases and eclipses in Danielle's interview transcript:

Int: I'm sure you've noticed like in the diagram sheet there that the Moon doesn't always look the same. It has different shapes which we refer to as phases, and um.. what do you think causes the different phases of the Moon?

D: Um, it's the percentage of the lit side of the Moon that you can see. **(SciHaf; SciSee).**

Int: OK. Um..

D: And that's caused by the Moon's rotation around the Earth every four weeks, give or take. **(SciOrb).**

Int: Can you use the.. um model to show me say.. where.. well, where say the Moon would be for us to see a full Moon?

D: Full Moon. You would find it here. *{Places Moon at full Moon position on opposite side of Earth from Sun, roughly at level of Earth's equator}*. Ok? It obviously can't be fully in line otherwise you'd get an eclipse **(SciAli)**, but you're looking at Sun, Earth, Moon in a line, ok and then in order for us to see it you've got to be facing the Moon too. *{Moves Earth's globe so South Africa faces the Moon}*. Alright, the Moon's rising and setting is caused by us rotating {*rotates Earth globe}*. (**SciEMS).**

Int: OK. And then basically.. you're then going to get different shapes. Now you've shown me full Moon, can you show me what.. what physically happens so we see those different shapes?

D: OK. Um, that's where you see half the Moon *{shows position of last ¼ phase}*. **(SciEMS)**

Int: OK.

D: OK … (Interruption – learners knocking – D deals with learners). OK. That's.. the Moon is waning all the way *{moves Moon towards Sun around Earth anticlockwise}* and New Moon when we can see nothing {*holds at New Moon position*} and then it waxes, back to half {*1st ¼*} and then full {*back at full Moon position*}. (**SciEMS; SciOrb).**

Int: OK. Alright. Um (long pause). Ok, alright, you've already mentioned that it would take about four weeks to do that. Um, what … ok just now when you were holding the Moon in the position behind there (behind the Earth), you said well, not too close otherwise you get an eclipse. Can you elaborate a little bit on that?

D: What an eclipse is?

Int: Uhmmm.

D: Um, obviously everything casts a shadow and so the Earth is casting a shadow behind it. **(SciSha).**

Int: OK.

D: Um, but the shadow's quite complex because you get this side of the Sun .. shine, you get rays coming here {*indicates diagonal rays from one side of the Sun reaching opposite side of the Earth*}. **(SciSha).**

Int: Uhmmm Hmmm.

D: As well as from this side *{indicates rays from other side of Sun directly across to corresponding side of Earth}*, so you get quite a .. you get an area of semi-shade here and an area of semi-shade around here {*indicates two penumbra positions*} and in the middle you get a, like a cone of, of pure shadow. **(SciSha).**

Int: Uhmmm Hmmm.

D: And if the Moon when travelling past, it has to be in full Moon position **(SciDPE; SciPos)**, when it's um, if it happens to move into position where it's perfectly in that full shadow **(SciSha)**, you get a complete eclipse. If it's partial shadow you get partial eclipses **(SciSha)** and so on. Um … we don't see all eclipses either because they {*rotates Earth on its axis*} because you, you, you need to be in the perfect position. You need to be able to see the Moon when it's perfectly in position. {*Puts Moon back at eclipse facing South Africa*}. **(SciAli; SciPos).** Um, and so that's why … the reason I know that because there was one the other day.

(DanielleI:1:3–53)

As can be seen from the transcript extract, Danielle had a good knowledge of the Moon's motion, phases and eclipses. She knew the Moon's rising and setting is caused by the Earth's rotation. She knew about partial eclipses and that one's position on Earth determines whether or not one sees an eclipse. The one problem is her use of 'rotation' when it was clear that she meant 'revolution'. As Danielle was so knowledgeable, it would appear she had a strong educational background in this field. However, as I was ending off the interview, Danielle made some comments which showed that this was not the case:

D: Um, I've never ever learnt anything formally about the phases. I might have done it in Grade 9 geography, but I didn't understand it.

Int: OK.

D: So I had to think about it. So I hope I got the stuff right.

Int: (Laughs). It's, it's interesting that you say that you never learnt about it because … um … you know, it's.. if you say you sat and thought about it you obviously had to try and work out where it would be.

D: Because a number of years ago I sat down, I was confused, a number of years ago I sat down and thought about it. And I didn't look at any texts or anything. I just sort of, kind of worked it out.

(DanielleI:3:65-74)

So her knowledge was driven by a strong interest and desire to understand how the phases and eclipses work. This also links to the constructivist theory which states that people construct their own understanding of concepts through everyday occurrences, even though they have never received formal teaching on these concepts (Driver *et al.,* 1985).

5.3.1.4 Donna

Donna correctly answered most of the closed questions on phases in her questionnaire – she didn't know that half the Moon is always lit up by the Sun. This was the only scientific fragment she didn't obtain. SciEMS and SciSee were awarded for her response to question 5, which asked for the change in the Moon's appearance after several nights: "The angle at which it (the Moon) is relative to the Earth's motion. We only see a reflection or a portion of this" (DonnaQ:3:3-5). In the interview, only SciEMS and SciOrb came through, but the alternative conception that the Earth blocking the Sun's light also appeared in the interview. Therefore Donna was classified as 'alternative' for phases.

Donna had some idea of what an eclipse is and was classified as 'Scientific fragments (3 fragments)' on her questionnaire. However, it came through from her interview that she thought that whenever the Moon was at full Moon position, an eclipse would occur. She didn't think that a phase would be observed here at all and didn't seem to be aware of the new Moon phase either. Although Stahly *et al.'s* (1999) study specifically concerns phases, they mention that a discussion about lunar eclipses arose during one of the case study participant's interviews. This participant, like Donna, "struggled with the occurrence of an eclipse and how it was different to the Moon phases (and) later incorporated the occurrence of an eclipse with his explanation by giving it the new Moon label" (1999:165-166). Donna was aware that there wasn't an eclipse every month, but she explained that this exact position for an eclipse to occur wouldn't happen every month because of the relative positions of the Earth, Moon and Sun and because the Sun and Earth 'rotate' at a different rate to the Moon. Her classification for eclipses was still scientific fragments, but changed from 3 fragments to 1-2 fragments. The fragment SciAli changed because of where she held the Moon during the interview - below the Earth and not in alignment with the Earth and Sun. She also kept it at this level when revolving the Moon around the Earth, as shown in Figure 5.1 below.

Figure 5.1 Donna revolving the Moon below the level of the Earth

5.3.1.5 Emma

From the questionnaire responses, Emma had been classified as 'scientific fragments' for Moon phases, these fragments being 'SciOrb' and 'SciEMS' i.e.

she knew the Moon orbited the Earth roughly once a month and that the phases of the Moon had something to do with “The Moon’s position with regards to the Sun” (EmmaQ:3:3-4). She had been unable to work out the position of the Moon in order to see a crescent Moon (question 3) and had selected ‘E’, which was New Moon position. The same fragments appeared in her interview, as well as the additional fragment ‘SciSee’. However, like Donna, an alternative conception appeared in the interview, namely ‘Earth blocks Sun’s light’. An interesting thing Emma did in the interview was place full Moon at first quarter, which was discussed in detail in Section 5.3.1.1 on page 137.

For lunar eclipses, Emma had shown evidence of only one fragment, SciPos in her diagrammatic response to question 7 on the questionnaire. She was classified as ‘scientific fragments (1-2 fragments)’.Her written responses indicated that she had very little understanding of lunar eclipses. This came through on her interview as well and her classification on the interview was ‘alternative’, although the codes ‘SciPos’ and ‘SciSha’ were awarded on her interview responses. The reason for the ‘alternative’ classification is shown in the portion of transcript that follows:

Int: (Laughs). OK. So you don’t know what an eclipse is at all?

E: <u>No, not .. I know it’s when partly when the Sun blocks the Moon or the Moon blocks the Sun or something like that, but more than that, no</u>. **(Alt: Sun blocks Moon or Moon blocks Sun).**

(EmmaI:4:105-108)

Emma knew that there isn’t a lunar eclipse every month, but was unable to give an explanation. She considered changing her mind about the Moon’s position at the time of an eclipse, as she figured it couldn’t be possible for it to be new Moon (she’d placed new Moon at full Moon position) and then view an eclipse at the same position, but she was unable to give an explanation or suggest any other alternatives.

5.3.1.6 Lara

Lara was the only case study teacher who correctly answered all four questions about the Moon's motion on her questionnaire. With regards to phases, she was unable to correctly locate the position of the crescent Moon in question 3 and so was classified as 'alternative' even though she had the codes SciEMS, SciOrb and SciHaf. The same three fragments appeared in her interview transcript as well as the alternative understanding that the Earth blocks the Sun's light. An additional alternative understanding, namely that the Sun revolves around the Earth, also appeared in the interview:

Int: So starting off then, on the sheet that you have in front of you, you see the various ah, shapes or phases that the Moon can take on. What do you understand or what do you think causes the different phases of the Moon?

L: Well its rotation.

Int: Uhmmm hmmm.

L: <u>Or change of position of the Moon in relation to the Sun</u>. **(SciEMS)**

Int: Can you use the model to show me um, what you mean by that?

L: {*Picks up Moon*}. <u>Because this rotates around the Earth {*shows revolving*}</u>. **(SciOrb)**

Int: OK.

L: <u>And then obviously when it's, it's going to be … the Sun's going to shine on different angles</u>. **(SciEMS)**

Int: OK.

L: And that's when there's no shining {*indicates full Moon position*} (**Alt: Earth blocks Sun's light)** and then it's coming back again {*moves towards last ¼ and waning crescent*} … waxing and waning.

(LaraI:1:1-14)

Int: OK. And then where would you (coughs) place the Moon to see a full Moon? Which position would it be in?

L: With the most amount of Sun on it. {*Holds Moon at first ¼*}. <u>I've just read somewhere that this, this..</u> (Interruption: bell goes) <u>one side of the Moon is always in sunlight</u>. **(SciHaf)** (Laughs). I've just read that in Discover magazine. (Laughs).

(LaraI:1:24-28).

L: Full Moon is where there's most amount of light on it {*shows 1st quarter*}. (Looks questioningly at Int).

Int: OK.

L: Oe! (Looks very unsure).

Int: That's fine. It's what you think.

L: Ja, because here {*waxing crescent*}, then it's .. because it's going to be shining on this side {*indicates side facing Sun and Earth from first ¼ position*} and not on this side *{Side opposite to Sun and Earth at first ¼}.*

Int: OK.

L: Unless it's up out here {*full Moon position*}. (Laughs). I don't know the position of that … when it's full Moon. Obviously it's when the most amount of Sun is on it.

Int: OK, that's fine.

L: <u>But the Sun is also moving … around the Earth {*indicates anti-clockwise revolution of Sun around Earth*}</u>. **(Alt: Sun revolves around Earth).**

Int: OK.

L: I have no idea where full Moon would be (mumbles a little, trying to figure it out). *{Now holds Moon at full Moon position}.*

Int: When you say the Sun is moving around the Earth, would it move .. do you think it would move in the same direction as the Moon or would it move differently?

L: It moves differently because this *{indicates the Sun)* is once every 24 hours **(Alt: Sun revolves around Earth)** and this {*the Moon*} is … I think it's 28 days **(SciOrb)**. Or .. it changes! It doesn't change (mumbles as she thinks about it). The different .. ah, the phases .. the different .. the full Moon is a, a different .. not at the same day of the month every year of every month. Ja. (Pause). Like Ramadan, I know that, because that always changes.

(LaraI:2:32-55)

L: Oh so, if you're talking about .. ok, from South Africa, if you're talking about from the point of view of South Africa, when do we see full Moon? Wouldn't the Sun be on it the most? {*Moves Sun to above the Earth and Moon to new Moon*} … It would be in this position. {*Revolves Sun around Earth, but at level above Earth*} **(Alt: Sun revolves around Earth)**. Ja, I must remember this. That's what I've forgotten. This also moves.

(LaraI:2:60-64)

Figure 5.2 on page 151 illustrates Lara's thoughts in the final portion of the preceding section of interview transcript.

Figure 5.2 The Sun Revolving above the Earth

In the questionnaire section on eclipses, Lara only obtained one fragment, which was ‘SciAli’. However, she was classified as ‘Alternative’. The reason for this classification is shown in Figure 4.4 on page 104. Here, it appeared that she thought that the Moon revolved around the Sun. Initially, in the interview, Lara was quite confused about eclipses, but towards the end became much clearer so that I ended up classifying her understanding as ‘scientific’. She never stated clearly that it’s the Earth blocking the Sun’s light, but she finally set the model up in the correct position:

Int: Um, in terms of, of an eclipse of the Moon, what do you understand that to be?

L: That's when you're not s-s-s … when you're not seeing it at all. But it goes into an eclipse. So you see the Moon … you see the Moon and then it goes into the eclipse. That's what I can't work out if it's the Sun … when I answered that question .. (lots of background noise … L goes to ask learners to move away from outside of room). I couldn't work that out. I've been worried about that, because obviously I know you see the Moon and then <u>I think it's normally when its full Moon and then it goes into the eclipse</u> **(SciDPE)** and you just see the light around it.

(LaraI:4:113-121)

Int: Um.. so… what, what would actually be causing the eclipse then? Is it something blocking the light?

L: <u>Ja, blocking the light</u>. **(SciSha)**

Int: Do you know what would block the light?

L: That's what I've been trying to work out.

Int: And um, do you know where the Moon would be relative to the Earth and the Sun, for an eclipse to happen?

L: {*Moves model Sun and Moon around*}. I'm just going to leave that there (referring to the Earth's globe). {*Places Sun at level above Earth and Moon at waxing crescent. Then moves Sun to opposite side of Moon from the Earth*}. I'm trying to think about it. (Laughs).

(LaraI:4-5:125-134)

L: <u>I know it's when something's lined up</u> **(SciAli)** (pause) <u>but how it's lined up I don't know. Which way .. if it's, if it's the Earth, the Moon, the Sun?</u>

Int: OK.

L: <u>It has to be in that order. It stays in that order</u> **(SciPos)**. (Pause). Because this {*the Moon*} goes round and this {*the Sun*} is going round … both of them, because this doesn't go. I, I, I thought this, this went {*indicates Moon revolving around Sun*}. It doesn't go round this way.

(Pause). This (the Moon) goes around this way {*indicates Moon revolving around Earth*} **(SciOrb)**. Ja. (Pause). So it's definitely when a lunar eclipse is {*Earth, Moon inbetween, Sun*}. **(SciPos)**

(LaraI:5:138-146)

During the course of the interview, Lara made some comments about using the models, which she found extremely helpful. I suspect that manipulating the model in the interview helped her to figure out how eclipses work.

L: It is difficult but you definitely have to have a model like this *{Indicates Earth's globe}*. You can't do this 2-D.

Int: Ja. And what .. what I find with 2-D is that often the pictures are misleading.

L: Ja. Definitely 3-D (Digresses to talk about using models to teach other areas). So this is wonderful. So we'd actually have to, when we teach this, we'd have to source … {*indicates models*} .. source that. (Interruption by learner and then digression on where to purchase models). Because that's important. It's actually crucial to this section to have visuals in three-D.

(LaraI:3:73-79)

5.3.2 Intervention Results

5.3.2.1 Situated Learning

In keeping with my theoretical framework of situated learning, I planned the intervention in such a way that learning would occur through activities. Cobb and Bowers (1999:5) claim that "a primary metaphor in the situated learning perspective is that of knowing as an activity that is situated with regard to an individual's position in a world of social affairs", which concurs with Brown *et* *al.*'s (1989) definition given in Section 2.2.3 on page 48. The models were intended to be the tools the teachers would use to build their knowledge and the group was the culture in which the learning would take place through social interaction. Brown *et al.* (1989) contend that knowledge can be equated with tools because both need to be utilized in order to be fully appreciated. In the paragraphs that follow, instances from the various activities will be discussed which exemplify how this happened and there are clear instances, particularly with Courtney and Lara that demonstrate legitimate peripheral participation and how these two teachers gradually participated more and more, becoming enculturated in the practice. This is consistent with Lave's (1996) explanation of legitimate peripheral participation in which she says that learning is evident as learners gradually participate more and more and take more responsibility for task completion. Danielle was extremely knowledgeable and often took the role of the specialist from whom the 'apprentices' in the group were learning. Brown *et al.* (1989) explain that the role of the specialist is to make their implied knowledge clear or demonstrate their tactics in genuine activity. I only became involved if I was asked a question, to re-affirm something or to guide them if they were going completely off track. Otherwise I tried to let them figure it out, even if it took a while. The idea was that each teacher would eventually be able to complete the activities on her own and so be ready to teach the work.

When the teachers started working on Activity 1, although I had asked them to tackle it together, it was obviously something they were not used to doing. This could possibly be due to the time constraints of everyday teaching where teachers aren't able to sit and plan lessons and discuss problems together. At best, one teacher may plan and do a worksheet for a topic and share these worksheets with her colleagues. They started working out the scale, chatting as they went along, but not about the activity. Danielle went to collect several rulers and sheets of blank paper and I provided a calculator for the teachers to use if needed. Although chatting, they continued to work individually. At this stage, I intervened and reiterated that they must discuss the activity and work out the scale together. This only happened very gradually through this activity and again in Activity 3, but eventually in both activities, the whole group became involved.

The information given was the radii of the Earth, Moon and Sun and they needed to work out the diameter of each to obtain its size. Courtney pointed out that diameter = two x radius. Of all the participants in the group she had expressed the least amount of confidence with this work and became visibly stressed in the pre-interview. So this boosted her self-confidence, which was evident in the way her participation in the group increased and she began to voice her thoughts more often. Courtney's formula for diameter was helpful to Lara, who had been unsure how to calculate this, as her background was in biology and the life sciences and not physical science and mathematics. Courtney explained to Lara that in a circle, the radius is from the outside to the centre of the circle and the diameter would then continue on to the opposite side of the circle. She looked for confirmation and Danielle provided this. Courtney was happy that she knew this, as she felt she was out of her depth with the Moon content.

Emma and Danielle continued to work on their own, Emma on the calculator and Danielle in her head. Lara and Courtney now started working together, but seemed to be struggling a little with the conversions. Emma overheard and became involved in the discussion. She recommended some ratio and proportion techniques and seemed confident how to work out the scale. She went back to her own calculating and Lara and Courtney continued working together. After spending 2 ½ minutes working on the activity, Danielle announced that she thought she had the answers. Danielle said that the diameter of the Sun would be 140 mm. Lara asked how she'd calculated that value and Danielle answered that a radius of 6.95×10^8 became 70 mm. The others looked confused. This was the basis of why she'd been so quick – she'd rounded all the numbers up to whole numbers and added a zero to do the conversion. So 6.95 became 7 and then she added a zero to get the 70 mm. Then 2 x 70mm = 140 mm, which was the diameter of the Sun. Courtney was impressed and exclaimed "Oh, okay!" (Tape 2; 29:32). So it was obvious she had followed. Emma then showed how she did the calculation using ratio and proportion. She explained that she had doubled 6.95×10^8 (the Sun's radius) to obtain 1.39×10^9 and then showed how she had used ratio and proportion methods to convert to mm, but Courtney said that Emma had lost her. Lara was also struggling with this explanation. Emma turned her page around so they could see. They didn't understand where the '1.39' came from. She explained again that it was the radius x two. I had also used Emma's method originally (ratio and proportion) to work out the scale before the session. Likewise, in the catch-up session, Donna was quite comfortable with calculating the scale, as she had a strong mathematical background and also worked it out using ratio and proportion.

Lara and Courtney then followed this part of Emma's calculation, but still didn't seem that comfortable using her method as Lara then wanted to see Danielle's method again. So it was unlikely that she had followed Danielle's explanation the first time around. Danielle explained that she had rounded the Sun's radius up to 7×10^8 and then divided by 10^7 to convert to mm. That gave her 7x10, which she doubled to convert to a diameter of 140 mm. Danielle continued to explain how she'd worked out the diameter for the Earth and the other teachers calculated together with her as she went along. Before she went too far, she checked her answers with me. She was very excited they were all correct. Lara complained that Danielle had gone through it too quickly and Courtney added that she'd lost them completely. Danielle repeated that they must just divide everything by 10^7 because that converts everything straight to mm. Courtney then asked what Danielle's answer was for the Moon's diameter. Lara answered that it was 0.34 mm, so it was obvious she had subsequently understood Danielle's method. Danielle was pleased and complimented her: "You're a fast learner!" (Tape 2; 32:47). This was evidence of Lara's learning.

Courtney couldn't understand why it was necessary to convert the orbit radius to metres, when it was given in metres. In the catch-up session, Donna asked the same question. I explained that when putting together the model, it would be quite challenging to try and measure out 1.49×10^{11} metres and so that is why we have a scale – using a smaller measurement, but also in metres. This was followed by some discussion, during which the comment was made to just divide by 10^7 again. Courtney pointed out that this would convert to mm. So she said that to get metres, you would actually need to divide by 10^{10}. Danielle confirmed she was right. This was further evidence of Courtney's increased participation in the group.

At this stage of the activity, Danielle had cut a 'Sun' out from a sheet of paper and made an 'Earth' from a blob of Prestik. Lara asked Danielle why her Earth was so small. "Because it is (small)", Danielle replied. "That's how small it is – 1.3mm" (Tape 2; 36:54). Danielle got up and started pacing out the length of the laboratory. Then she demonstrated to the rest of us what she'd been doing. She stuck her paper 'Sun' on the board at the front. She moved back across to the other end of the laboratory and we then realized she'd been pacing out 15m (the Earth's orbit radius on the scale), which was roughly the length of the lab. She stuck her 1.3mm Earth on the back wall. This visual demonstration had quite an impact on the rest of the group. Fanetti (2001), who used an activity similar to Activity 2 to demonstrate the same thing, reports that when shown the scale model "the students were impressed; the demonstration appeared to give them a more concrete understanding of how far away the Moon truly was" (2001:27).

I asked them why the Sun wasn't given an orbit radius in the activity question to challenge the misconception that the Sun moves. Courtney replied that it was because the Sun isn't moving. She was participating more and more in the discussion. Danielle added it's because the Sun isn't moving in the solar system i.e. the Sun is stationary relative to other objects in the solar system. She pointed out that the galaxies are whizzing around and also added that our solar system is heliocentric. Lara looked confused and Danielle explained to her the meaning: 'helio' – the Sun and 'centric' – the centre. I stated that the Earth revolves around the Sun and then asked them what the Moon does. Courtney answered that the Moon moves around the Earth and the combination goes around the Sun. This was a change from her pre-questionnaire and pre-interview, so learning was definitely taking place. I quickly demonstrated this to the group by balling my fist to represent the Earth. I used a finger from the other hand to show Moon revolving around Earth and revolved both around the 'Sun' - a coffee cup on the table. I pointed out that both the Moon and Earth rotate on their axes as well and tried to emphasize the difference between 'rotate' and 'revolve', as these two words were used interchangeably by several of the teachers in the group. I explained that they have very specific meanings in astronomy.

There was nothing of relevance to situated learning in Activity 2. With Activity 3, the teachers first spent some time reading through this activity on their own and glancing at the resource material. A similar pattern emerged in the group work as once they were finished reading, Emma and Danielle worked alone. However, this time Lara and Courtney immediately started discussing and figuring out some of the diagrams on the resource notes. Lara then queried one of the diagrams that showed a clockwise revolution of the Moon, drawing

Danielle into the discussion. Danielle explained that it was shown like that because it was for the Northern hemisphere and so the waxing (and waning) is on the opposite side as we'd see it. This issue had also been raised by Claire in the pre-questionnaires. She had commented that "I am not super confident because it is confusing work based on texts from the Northern hemisphere which have a different perspective" (ClaireQ:5:23-25). I hadn't expected the teachers to know enough to spot this and had deliberately not focussed on the inversion from Northern to Southern hemisphere because it's rather abstract and very complicated to understand or even visualize.

Danielle then raised the question, "Why is half the Moon called the quarter?" (Tape 3; 04:42). She commented that when you see 'half' the Moon, it's called the first quarter and then when you see 'half' the Moon again, it's now called the third quarter. Emma explained that it has to do with where the Moon is on its revolution path. Danielle actually knew the answer, but wanted to see if the others knew this. Emma then asked why at first quarter we are only seeing half the Moon, when the Moon is getting more of the Sun's rays than at full Moon position. This ties in with her explanation of phases in her pre-interview. She stated that at full Moon position, the Earth is totally blocking the Sun's rays. Lara pointed out that it was probably because the scale was incorrect, again evidence of Lara's learning and increased participation in the group. I nodded in agreement and explained that it was for this very reason that I started off with the scale activity. Danielle held up a picture and said that looking at the size of the Earth and Moon in the diagram, the Moon should be about three times further out, which highlighted problem with two-dimensional diagrams not to scale. She added that this was typical of the diagrams shown in books. Danielle added that a further problem is that the picture is two-dimensional, but the rotation (meaning revolution) is three-D. She explained to Emma that the revolution of the Moon is often a little above or below the mid-line of the Earth and so you would be able to see the

Moon. Once again, the whole group eventually became involved in the discussion.

Then they tried out the model. They switched the lights off and the classroom had blinds, so it was nice and dark. They switched on the overhead projector to represent the Sun and adjusted the visor so that the beam projected straight ahead. Lara was the first to hold a ‘Moon’. Emma held a blue ‘Earth’ ball and placed it on the overhead projector. I reminded her that the projector was the Sun and she then placed the Earth between the Sun and the Moon and shifted it backwards and forwards. Emma and Lara decided on a position, but Danielle reminded them about scale and commented that the Moon needed to be about ten times further away from the Earth than they had it. They had the Moon positioned at full Moon position. I asked them if they were sitting on the Earth, what phase they would be seeing. Danielle said full Moon but I suspect this was because she knew it ought to be. Emma and Lara were better positioned to ‘see’ it, but looked confused and not really convinced. I then suggested the Moon orbit the Earth, so Lara moved the Moon to last quarter position. The phase was unclear. Danielle told them they needed to be further away from the Sun. This is why scale is so very important in this activity. Lara and Emma moved and tried again. Emma could now see ‘half’ the Moon i.e. the last quarter phase. Lara moved again and I stopped her at new Moon position and asked what would be seen there. Lara stated it would be New Moon. Danielle then picked up they could demonstrate a solar eclipse. She asked Lara to move the Moon closer to Earth and we could all clearly see the Moon’s shadow falling on the Earth.

Danielle encouraged the group to move around while Lara was revolving the Moon, as she pointed out that they were seeing the same view all the time. I added that they needed to view it from the Earth’s perspective. This is where it’s much better for the person’s head to rather represent the Earth and I pointed out this fact to them. They were confused as to how this was supposed to work. We switched on the lights and I showed them how to stand and hold the Moon and to turn around slowly on the spot. I deliberately did this in the light so as not to spoil the effect for them. We spoke about which way to move the Moon so that the phases would be visible as for the Southern hemisphere and switched the lights off again. Now their heads were representing the Moon and this was a ‘Eureka’ moment for them. There were several exclamations and excitement as to how clear this was. Danielle agreed that this way was much better than doing the activity with an ‘Earth’ ball. Courtney also thought it was much nicer because you could see the phases much more clearly. Courtney really enjoyed trying it out and being able to ‘see’ the phases. They could then clearly demonstrate full Moon and a lunar eclipse.

When we moved on to the final activity, we started by discussing question 1, which asks where one would see the Moon rising just after sunset. Lara answered that the Moon rises in the East. Courtney suggested that the Sun rises in the East and sets in the West, so maybe the Moon would do the opposite. Emma said that she could never remember where it rises and sets. Danielle explained the Moon’s rising and setting is actually due to the Earth’s rotation and so it would also rise in the East and set in the West. This explanation covered questions 2, 3 and 4 as well. Then they looked at question 5 which asked for the positions of the Sun, Earth and Moon at new Moon. They found ‘west’ in the room and imagined the Sun to be setting there and they were Earth observers. They realized that at new Moon, the Moon would need to be placed between the Sun and themselves, with the blackened side facing them. At the end of the demonstration as described in Section 3.2.3.2 on page 61, Lara wanted to know if I’d rotated the ‘Moon’ around, as I moved across the classroom from west to east. I showed again how I kept one side, the white side, always facing the Sun on the western horizon. I possibly should have probed more here, as in retrospect, I don't think she really understood what was happening here. In this final activity, I was more involved and took the role of specialist by demonstrating, asking questions and explaining my own knowledge, which Brown *et al.* (1989) suggest to be the role of an educator in a situated learning context.

5.3.2.2 Pedagogic Content Knowledge

The other theoretical framework I focussed on is pedagogic content knowledge (PCK). As the teachers constructed their knowledge in this section, they talked about how best to transform the content in the activities to make it more accessible for the learners, what Shulman (1986:9) calls "the ways of representing and formulating the subject that make it comprehensible to others". They were aware that the learners would have prior knowledge, as they made reference to the learners being interested in the Conspiracy Theory[2] during one of the activities. Awareness of learners' prior knowledge is something that van Driel *et al.* (1998) contend is an essential part of PCK. Mulhall *et al.* (2003) argue that experienced teachers who haven't previously taught a particular topic probably have minimal PCK in that subject area. One area of shared PCK that arose during the intervention was that the teachers unanimously agreed that the exponents used in Activity 1 would be too difficult for Grade 8 learners. Mulhall *et al.* (2003) contend that one of the criteria for developing a CoRe (Section 2.2.4 on page 50) is not just how to present material to learners but to bear the group in mind that the content is to be presented to, which in my study would be Grade 8 learners. More detail on the discussion of the use of exponents in Activity 1 is given later in this section. In the paragraphs that follow, I will discuss all the issues relating to PCK that were raised during each activity.

[2] "Claims that some or all elements of the Apollo Moon landings were faked by NASA and possibly members of other involved organizations" (Wikipedia, 2008:1)

The first activity presented several issues, one of which was the use of exponents. I had already anticipated this would be problematic (Section 3.2.3.2 on page 61), but felt this activity was imperative for the teachers to do. Once they had completed the activity, the teachers started discussing the problems with the activity and how to adapt it for their learners. This is evidence of their PCK in that it revealed an awareness of the level of the capabilities of their learners and how to adapt teaching material to make it more suitable for a particular group of learners. Van Driel *et al.* (1998) contend that PCK involves altering content "in the context of facilitating student learning. Notably, PCK encompasses understandings of common learning difficulties … of students" (1998:673). In the rest of this section, I will discuss some of their concerns with the activity and their proposals for altering it. Danielle echoed my feeling that the exponents (e.g. 10^8) in this activity would be too difficult for the Grade 8's and felt that the learners may cope with the scale activity (Activity 1) if the numbers were written out in full instead of using exponents. Lara and Danielle agreed that the scale activity would take the longest, but was definitely worth it. Another problem raised by Danielle was that having an orbit radius in metres for the Moon was not really useful and it would be more appropriate to request it in mm or cm. Danielle emphasized the importance of scale several times. She gave an example of a science project model she had recently seen which had been a beautiful model of the solar system, but the Moon was half-way between the Earth and the nearest planet and if one looked at the orbit radius they'd worked out in the activity, the problem with that model was obvious.

The teachers discussed ways in which they could adapt the activity for the learners. Lara felt that this activity was far too difficult for the learners. In her session, Donna also expressed concern as to how learners were going to work out the scale. Lara felt that it would be necessary to go through the activity with the learners one step at a time and also suggested adding more explanatory steps to the activity sheet. A further suggestion Lara made was that the teachers could make the model to scale beforehand and show it to the learners and then give the scale problem to challenge the brighter learners if they asked about it. A proposal was made that they could use metre sticks to get the learners to measure out the 15m orbit radius of the Earth around the Sun in the school grounds. They also speculated whether it was possible to double the size of the Moon, so it wouldn't be so difficult to make (d = 0.3mm) and agreed that as long as everything else was doubled, it wouldn't be a problem.

Danielle wasn't convinced and was keen for the learners to use the scale activity with some minor changes. She suggested that for example, the number 1.49×10^{11}m on the activity could rather be given as 150 million km. She felt that the learners could handle the idea of 150 million. They could then simply divide by 10 000 to convert to mm as per the scale. Danielle felt strongly that this activity was so important because the calculated results are surprising. She stated emphatically that the learners know it's big, but not *how* big. Emma agreed that *some* of the learners would get it, but she was still doubtful. Emma still wanted to just give the worked-out values. Danielle felt that calculating was more powerful. She maintained that even if someone couldn't do the calculations, one of their friends calculating the values would be more believable to a teenager than the teacher just telling them. I emphasized the idea of the learners working in a group just like they currently were doing and supported Danielle's assertion that they can learn from each other. Even if the other teachers didn't agree with Danielle's stance on Activity 1, at this point they had several strategies for dealing with this activity, which Shulman (1986) deems a very necessary part of teachers' PCK.

We didn't do Activity 2 but discussed it, as it was an alternative to teaching the concept of scale without using the big numbers. From Activity 1, the teachers already knew what the approximate sizes and distances should be. They were not *that* keen on this activity because they felt that the learners wouldn't be able to have a good guess where the Earth would go, not really knowing how large the Sun in the scale model is. This is because the Sun in this model is represented by an overhead projector lamp. They decided that this was a shortcoming of this model. Again, this is evidence of their PCK as they knew what their learners were capable of. They all preferred Activity 1, but Emma, Lara and Courtney were worried about learners that wouldn't cope with the mathematics. They liked the idea of giving them worked out values and letting them still make the models and set them up. They briefly discussed some ideas such as where outside their classrooms they could go for the learners to measure the distances. Danielle again tried to convince them otherwise and said that if the learners were working in groups just like they were in the Intervention session, the learners could help each other. So Danielle recognized the value of the situated learning context. She emphasized that the way to do it was to convert the activity values to numbers that were "not easy for them, but accessible" (Tape 2; 51:19). Danielle stressed again that it wasn't necessary to be picky with the exact numbers. Rounded off values would be simpler to work with and would give the learners a 'feeling' of the scale of things, which was the most important thing.

The first issue that appeared in Activity 3 related to problems they would encounter if they used resources or simulations produced in the Northern hemisphere, as there is an inversion of the Moon from the Northern to the Southern hemisphere. Some of my Internet resources illustrated this, but the notes with diagrams I had given them were all South African and showed the Moon as we would see it. It was actually just as well this had come up, as

Northern hemisphere resources would have presented problems in the teaching of this material. I elaborated a little on what the waxing crescent would look like in South Africa and how it would look in the Northern hemisphere. We agreed that they would try and avoid this in their lessons, as it would be too difficult for the learners to conceptualize and visualize. The emphasis for this activity would rather be to get the order of the phases correct and to understand what causes the phases. Once again, this is evidence of their PCK – in this case, the teachers choosing to omit something they felt would be too challenging for their learners.

A further issue that came to the fore in the discussion of Activity 3 related to the names of the phases. Danielle felt that the naming of the phases made use of "terrible terminology" (Tape 3; 05:14). Lara and Danielle felt that the terms 'first quarter' and 'third quarter' would confuse the learners. They thought it better to just use New Moon and Full Moon and then describe the Moon's appearance after x number of days e.g. instead of first quarter, they would talk about the Moon's appearance seven days after New Moon. The teachers decided this would be a more sensible approach. As mentioned in the discussion of situated learning, I spent some time explaining the difference between 'revolve' and 'rotate' and used the models to demonstrate the difference. Lara asked if they should explain the difference to the learners and I said yes, because they are important astronomical terms with specific meanings and these are often used incorrectly. Danielle felt it was not something they should fuss about with Grade 8's, but that the teachers had to ensure the terms were used correctly in the classroom. She also suggested using the word 'orbit' instead of 'revolve' as it is very confusing that 'rotate' and 'revolve' have similar meanings in the English language.

A demonstration of a solar eclipse was not originally part of Activity 3. However, as this model could demonstrate the solar eclipse so well, the teachers decided it would be worthwhile to include it. After this session, I adjusted the activity to include the solar eclipse on the worksheet and emailed everyone the updated version. This final version is what appears in Activity 3 in Appendix D on page 239. Lara suggested that one could extend the activity to ask why a particular country would or wouldn't see an eclipse. This is evidence of the teachers' PCK again as it shows the ideas they had for extending the activity in ways they felt would interest their learners.

During the presentation of Activity 4, the teachers didn't make any suggestions for change, so I can't make any comments with reference to PCK. Here, I will focus on some resources that we discussed that could be helpful for teaching Activity 4 and further resources for the Moon unit as a whole. Resources are important for PCK as they can provide hints and examples for the analogies and illustrations that Shulman (1986) considers an essential part of PCK. After we completed Activity 4, Courtney asked if there was a video to help give the learners a clearer picture. I commented that several Internet sites have simulations, as does Microsoft Encarta. The only problem with all of these is that they're for the Northern hemisphere. I had tried to find a simulation for the Southern hemisphere before this session but only found diagrams. The school where we held the intervention session was one of the case study schools and they had Microsoft Encarta loaded on the school network, so all teachers could access it. Emma didn't have a computer in her classroom, but they agreed they would make a plan. Danielle found the Microsoft Encarta simulation of the phases and projected it onto the board so everyone could see. Courtney felt it was worth showing the learners this simulation, even though it was for the Northern hemisphere. The simulation could be used at the end of Activity 4 so they could see what happens after full Moon, as it is impossible to demonstrate this part, a limitation of the model. The simulation shows the Sun's rays as parallel lines from the right hand side of the picture with one side of the Moon always lit up.

It shows the Earth rotating and the Moon revolving. There is a picture at the bottom right of the screen showing how the Moon would appear when viewed from the Earth as it moves around. The teachers liked the simulation.

With regards to the additional resources, one of the case study schools had more of a racial mix of learners and were keen on the indigenous knowledge worksheet about Tswana beliefs (HARTRAO, no date). The teachers at the other school felt that the activity on Easter and Ramadan (HARTRAO, no date) would satisfy 'indigenous knowledge' for this unit. The teachers all liked the 'First Moon Landing' worksheet (HARTRAO, no date) and thought it would be nice to introduce the section with this worksheet. They were keen on this one because the learners were knowledgeable about and interested in the Conspiracy Theory. Emma also commented that the learners love doing this type of thing. I concluded that the teachers *must* do the core activities, but it was open as to what supplementary material they would like to do with their classes. Emma commented that the choice of activity would also depend on the class. This relates to Mulhall *et al.*'s (2004) description of a CoRe in that a teacher's PCK not only indicates an awareness of content for a group i.e. Grade 8, but even for a particular class in that group. Emma appeared doubtful that all learners in her class would cope with what Danielle was proposing. Also, I emphasized that scale is fundamental to the whole unit: learners are not going to gain a full appreciation of phases and eclipses if they don't appreciate sizes and distances.

5.3.2.3 Feedback on the Intervention Session

At the end of the post-interviews, I asked the three teachers who had not done the teaching for some feedback on the activities we had done in the intervention session, as I had not had the opportunity to interact with them and observe them teaching this work to their classes. All three teachers responded very positively: “Yes! That’s nice. All that stuff is interesting to me. I actually like it a lot” (EmmaPI:4:25); “It was wonderful. All of your examples” (LaraPI:4:26); “They were great, but I obviously needed to do a lot more studying and reading and prepping in order to teach it” (CourtneyPI:3:6-7). Emma also particularly commented on the first activity on scale and said how much she’d enjoyed it and Lara particularly commented on Activity 3 and said the use of the model in this activity was “very powerful” (LaraPI:4:16) as well as the simplicity of the models – easy to source and make: “I thought that was fabulous” (LaraPI:4:31). Danielle made a similar comment while we were talking about how the teaching went in the post-interview: “But your models were nice because they were easy … relatively, to put together” (DaniellePI:4:14). Following this, I asked Danielle:

Int: Ok. And, and do you think the models were effective … more effective than say … worksheets or some other methods?

D: Yes. Every time.

Int: Ok.

D: It’s the most hands-on they could get.

(DaniellePI:3:29-33).

The last statement made by Danielle in the above dialogue is also of relevance to the situated learning theoretical framework. In this framework, learners become enculturated “into authentic practices through activity and social interaction” (Brown *et al.,* 1989:37) and as Danielle observes, it’s practically impossible to try and see how lunar motion, phases and eclipses work in a real-life context, so using models is a good alternative to what Brown *et al.* refer to as engaging learners in genuine activity.

Courtney also responded positively when I asked her if she thought the use of models was valuable: “Yes! I’ve always thought that hands-on stuff is always more useful” (CourtneyPI:3:10) and she added that the group work was always more helpful to work things out rather than doing it individually, which supports my choice of situated learning as the theoretical framework for this study. Barnett and Morran (2002) also made use of activities with models in small groups and commented that the activities had played a vital role in developing the learners' understandings.

5.3.3 Post-Intervention Questionnaire Results

There was no difference in the way I analysed the post-intervention questionnaires compared with the pre-questionnaires and I entered the data on the same coding sheet as used previously. A summary of the comparison of classifications for pre- and post-questionnaires as well as pre-interviews is given in Table 5.1 on page 184 and Table 5.2 on page 186. With regards to the four questions on the Moon's motion (1 A, B, C and E), Emma and Courtney didn't change, obtaining the same three correct answers as on the pre-questionnaires out of a possible four. The question they answered incorrectly was the one relating to the Moon's path across the sky. Lara also had the same three questions correct, but this was a deterioration as she had answered all four questions correctly on the pre-questionnaire. She could have guessed the answer on the pre-questionnaire or it could have been that Activity 4, which addressed this concept in the intervention, was problematic for her. She seemed to struggle with the concepts in this activity and so it may have been more harmful than helpful. Activity 4 also seemed to have made no impact on Emma and Courtney's understandings. However, both Danielle and Donna improved on this section and answered all four questions correctly. It is possible that they grasped this concept because they taught the module on the Moon's motion, phases and eclipses and so interacted with the materials beyond the intervention. This relates to Carr *et al.*'s (1994) idea of connectedness, where they argue that a change in comprehension requires more than some solitary encounters and time is needed to consider new ideas and link them back to existing ones. The extra time these teachers spent interacting with the activities and concepts could have provided this. Therefore the concepts in this activity would have had another opportunity for reinforcement, even though neither teacher actually taught Activity 4. Danielle opted out altogether but based on the intervention, I think she had quite a good grasp of this activity and Donna asked me to do this activity with her classes, which gave her the opportunity to observe it on a further two occasions. Donna specifically commented on this activity after the teaching - she thought it had gone over the learners' heads. So it is probable that the teachers found it difficult and confusing as well.

Three of the five teachers retained their classifications for understandings of Moon phases from the pre-questionnaires. Danielle had been classified as 'scientific' before on both pre-questionnaire and interview and she remained so and answered all the closed questions correctly again. Danielle's response to question 5 actually yields all four codes, which are shown in bold and in brackets in the extract that follows: "The Moon moved around the Earth **(SciOrb)** to a small extent, so less of the lit side **(SciHaf)** was visible **(SciSee)** from Earth" **(SciEMS)** (DaniellePQ:3:4-5). Question 5 was an open question, requesting a reason for the change in the Moon's appearance after several nights. Although Emma and Donna remained classified as 'scientific fragments', each showed some form of improvement. Emma went from two fragments to three, adding the code 'SciHaf' to the fragments she'd obtained on the pre-questionnaires ('SciOrb' and 'SciEMS') and Donna remained at three fragments, but she obtained the code 'SciHaf' instead of 'SciEMS' on the post-questionnaire. An improvement on Donna's pre-questionnaire was that she answered question 1D correctly, which was why she'd been given the code SciHaf. Based on her pre-interview, she did know that the phases had something to do with the relative positions of the Earth, Sun and Moon, but this didn't come out in her open response to question 5 in the post-questionnaire. As mentioned before, this is a problem with open questions –

they don’t always yield the desired information. However, the pre-intervention interviews had shown that Emma and Donna actually had an alternative understanding for the cause of Moon phases. This alternative understanding was absent in their post-questionnaires and so the improvement is actually more significant when the pre-interview result is considered.

Courtney and Lara both showed an improvement. On the pre-questionnaire and interview, Courtney had been classified as having an alternative understanding. On the post-questionnaires, she was classified as ‘scientific with misconceptions’, meaning there was no definitive alternative conception present. She obtained the fragment ‘SciOrb’ but answered question 4 incorrectly, which related to the full Moon’s appearance six hours after rising. She had answered this incorrectly on the pre-questionnaire as well. She was also able to work out the correct position of the crescent Moon in question 3, which she’d been unable to do on the pre-questionnaire. Lara was classified as having an alternative understanding on the pre-questionnaire and the appearance of a second alternative conception in the pre-interview meant she was classified as ‘alternative fragments’. There was no evidence of these alternative fragments on her post-questionnaire. She obtained three scientific fragments and was therefore classified as ‘scientific fragments’, a significant improvement.

Something very interesting was that Lara gave almost the identical response to question 5 on the post-questionnaire as the pre-questionnaire. On the pre-questionnaire, she had said: "Diagram 2 - Moon is moving away from Sun, so less illuminated" (LaraQ:3:3-4) and on the post-questionnaire she said: “The Moon was moving away from the Sun so less illuminated by Sun's rays” (LaraPQ:3:4-5). There is a misconception here, as the change is from last quarter to a waning crescent and so the Moon is actually moving towards the Sun. Moreover, it contradicts her answer to 1D, where she answered that half the Moon is always lit up by the Sun. Her answers to question 5 imply that the amount of illumination does change, rather than the amount of the illuminated half of the Moon that we can see from Earth. This finding supports Driver *et al.*'s (1985) proposal that misconceptions are persistent, despite being taught and having these misconceptions challenged. Driver *et al.* suggest that learners either "ignore counter-evidence, or interpret it in terms of their prior ideas" (1985:3). This finding is also similar to that of Stahly *et al.* (1999), where in the post-interviews, one of their respondents reverted back to his original idea expressed in the pre-interview, despite giving a correct answer on the post-questionnaires. Likewise, Trundle *et al.* (2007) report three of their student-teachers reverting to their pre-instruction classifications on the delayed post-interviews despite exhibiting more scientific explanations of the post-interviews immediately after instruction.

As far as the classification for eclipses is concerned, two of the teachers retained their pre-intervention classifications on the post-questionnaire: Emma remained as 'scientific fragments (1-2 fragments)' and Danielle as 'scientific fragments (3 fragments)'. For Emma, there was still an improvement, as she had obtained two fragments on the post-questionnaire ('SciAli' and 'SciPos') as opposed to only 'SciPos' on the pre-questionnaires. Once again, there is a vast change from the pre-interview though, where it had been revealed that she had an alternative understanding of eclipses. On the pre-interview, it had been clear that Danielle had a fully scientific understanding of eclipses. I don't think Danielle's understanding had regressed, but rather that she hadn't given enough detail in her response to the open questions. All three other teachers improved in their post-questionnaire classifications. Donna changed from 'scientific fragments' to a full scientific understanding of eclipses. Lara and Courtney had both held had an alternative view of eclipses on the pre-questionnaires. However, on the pre-interview, although Lara had started off with an alternative understanding, she corrected herself and ended up being classified as ‘scientific’. On the post-questionnaire, she was classified as ‘scientific fragments’ – she had two fragments, two fewer fragments than the pre-interview. The missing fragments on the post-questionnaire could once again be the open questions not yielding sufficient detail. Courtney had also been classified as ‘alternative’ on the pre-interview and once again showed a significant improvement in understanding on the post-questionnaire. She was classified as ‘scientific’ and her answer to question 6 concerning the cause of a lunar eclipse, was: “At full Moon, **(SciDPE)** the Moon passes through the Earth’s shadow **(SciSha)**” (CourtneyPQ:3:9-10). The remaining two codes were given in her diagrammatic response to question 7, where she drew the Moon in the correct position and the Sun, Earth and Moon in direct alignment with one another.

Danielle didn’t answer background questions 5 and 6 on the post-questionnaires and Lara didn’t answer question 6, so it is difficult to make a thorough comparison. Three of the four teachers still expressed a lack of confidence for teaching this section despite the improvement in their knowledge and Courtney indicated that she was ‘not sure’. This continued lack of confidence is probably because they were more aware of the gaps in their knowledge. This assumption is based on the pre-questionnaire findings where some teachers indicated a lack of confidence despite being fairly knowledgeable (refer to Tania’s comment in Section 4.2.5.2 on page 107). All four of them felt that they still needed to do much research and preparation before teaching this section. On question 6, the one significant change was Donna’s. On the pre-questionnaires she had indicated that ‘Planet Earth and Beyond’ was not very important for the natural science syllabus, but changed this to ‘important’ on the post-questionnaires. She commented: “Important for learners to know about their planet & life around them” (DonnaPQ:6:8-9).

5.3.4 Post-Intervention Interview Results

In this section, I will discuss each of the interviewees' responses to the questions and subsequent classifications in the same order as previously. The coding and classification was done in the same way as the pre-interviews and since this was illustrated in detail in Section 5.3.1 on page 136, I will not provide lengthy transcript extracts in this discussion, but I will include quotes of relevance to the discussion. The same questions were used in both pre- and post-interviews, but at the end of the post-interviews I asked the teachers for some comments on the intervention and the teaching of the Moon module. I have commented on the interview feedback from Danielle and Donna in Section 5.3.5 on page 189 and will discuss their PCK in that section as well.

5.3.4.1 Problems Encountered

It emerged during the post-interviews that despite my efforts in the intervention session to explain that 'rotate' and 'revolve' have very specific meanings, three of the teachers (Donna, Emma and Lara) continued to use the word 'rotate' instead of 'revolve' in the post-interviews. I was able to deduce this because they would speak about rotating, but would demonstrate a revolving motion using the model. When I asked Emma to explain phases using the model, this is what she said:

E: Alright. Let's see. The Moon rotates, so here it will be full Moon I think. *{Holds Moon at new Moon position and then starts revolving the Moon, not rotating it}* **(SciOrb)**. I think if it's there *{stops at first quarter}*, it's half Moon. If it's here *{moves Moon on to full Moon position}*.. if it's here then it's full Moon. No! Then it's an eclipse or something **(SciPos)**. Then here *{orbits Moon to last quarter}* it's half Moon again and then *{moves Moon* *back to new Moon position}*, and so it goes around. *{Does another revolution with the Moon}.* **(SciOrb)**

(EmmaPI:2:1-6)

Similarly, Lara used the word ‘rotating’ but demonstrated ‘revolving’ as she manipulated the model:

L: As this, because this is, this is also rotating *{revolves Moon around Earth}*, it’s also going to be .. *{orbits Moon round and around Earth}* .. it’s not set.

(LaraPI:2:12-14)

When Donna used the term ‘rotating’, she didn’t manipulate the model, but in her explanation she refers to a change in the Moon’s position around the Earth and so I took this to mean ‘revolving’:

D: Um, just as the Earth is rotating *{shows rotating motion with hands next to the Earth’s globe}*, obviously the Moon is also rotating *{shows rotating motion with hands next to the Moon}* and so what we see on the Moon .. um, is the .. just depending on where its position around the Earth is..

(DonnaPI:1:14-17)

In Chapter 2 (on page 46), Carr *et al.* (1994) noted that the different use of words in everyday language causes alternative conceptions and Driver *et al.* (1985) pointed out that misconceptions don’t necessarily change through tuition and the teacher’s explanation can either be ignored or assimilated into their existing ideas.

A further problem with the post-interviews is that with the exception of Donna, these were conducted during the marking of the end-of-year examinations. This was unfortunate, but unavoidable. I had supplied the post-questionnaires immediately after the intervention, but I had to wait until the teachers returned the questionnaire before I arranged the interview. I sent regular reminders to the teachers to return the questionnaires but I also couldn't be too pushy about this. Regrettably, four of the post-questionnaires were only returned during the examination period and I then worked through these as quickly as possible to see where probing would be necessary during the interviews. When I then arranged the interviews, it was decided that the easiest solution would be for me to come in on a day when all four teachers would be marking and they would take a break to come and be interviewed. This also meant that there had been a considerable time-lag between the intervention and the interviews. This seemed particularly problematic for the teachers who hadn't done the teaching of the Moon module. At the end of the phases questions, Courtney exclaimed: "I can't remember! … It's just been too long" (CourtneyPI:2:22&24). Emma also commented that she felt more confident about the material soon after the intervention session and would have been comfortable to attempt to teach it then. At the time of the post-interviews, she no longer felt as confident. It is possible that closer to the time of the intervention they remembered more. From my observations in the intervention, it was certainly my impression that their knowledge was better than appeared in the post-questionnaires and interviews. Perhaps, Like Trundle *et al.'s* (2007) group, at the time of the intervention, the scientific explanation was more prominent, but about two months later this was no longer the case. Also, if they had taught the material, they would have had more time to compare their prior concepts to those learnt in the intervention, link those ideas and possibly modify them, what Carr *et al.* (1994) call 'connectedness'.

5.3.4.2 Courtney

Courtney's post-interview was the most problematic. It was evident that she still felt very uncertain about her understanding of the Moon's motion, phases and eclipses and besides the stress of examination marking, she was also upset and stressed as the intruder alarm had been activated at her home and she was waiting for further news from the security company. I told her she was welcome to answer her cell phone in the interview and if it meant we needed to terminate the interview, it was not a problem. This was not necessary, but it did mean that she froze up in the interview and was unable to answer questions that she probably knew the answers to (based on her responses to the post-questionnaire) if the circumstances had been different.

For phases, Courtney obtained the codes ‘SciOrb’ and ‘SciEMS’. However, she was classified as ‘alternative’, because she also gave the Earth’s shadow falling on the Moon as a reason for the phases. The addition of ‘SciOrb’ was an improvement from her pre- results, where she had thought that the Moon is stationary. The misconception of something blocking the Sun’s light was also present before, but her thoughts had changed from a planet blocking the light to now specifically the Earth blocking the Sun’s light. This alternative conception had not appeared on her post-questionnaire, but although she had been classified as ‘scientific with misconceptions’, she had only obtained one scientific fragment (‘SciOrb’) and as I found with the pre-interviews, probing extracts far more detail of a participant’s understanding. So her result on the post-interview is not significantly worse than the post-questionnaire and Courtney’s personal circumstances could have played a part.

In the early part of the interview, Courtney confirmed that it takes the Moon about a month to orbit the Earth, which ties in with her responses on the post-questionnaire. However, when I probed about how we would see the Moon moving across the sky in the night, she changed the period of the orbit to 24 hours, as she confused the Earth’s rotation as the cause of the Moon’s rising and setting with the actual orbiting motion of the Moon. Courtney became very upset when she couldn’t clearly remember how to explain the phases and froze up when I asked her about the eclipses to the extent that I was forced to classify her as 'no conceptual understanding' for eclipses on the post-interview. I believe that her understanding was much better as she'd been classified as 'scientific' on the post-questionnaire, but her stress levels had obviously interfered with her ability to think clearly by the time we reached the eclipses questions in the interview. I did not push her on the eclipses, as I was reluctant to stress her out even further.

5.3.4.3 Danielle

Danielle retained her 'scientific' classifications for both phases and eclipses on the post-interview. She was confident of her knowledge and this meant that she was able to give concise, correct explanations with ease. Besides being able to explain the cause of the phases, she could quickly point out the position of any of the phases accurately. She was also able to give much more detail on eclipses than the other teachers – a bit more than we'd covered in the intervention session, which implied that she'd either had a prior knowledge of this or had learnt more about eclipses during the teaching:

D: Ok, um and then <u>the full eclipse is caused by the Moon falling in the Earth's umbral or full shadow</u> **(SciSha)** and then the Moon is in full shadow there.

Int: And if you had to look at the Moon .. if you had to look at a lunar eclipse, what would you see?

D: <u>It would be a .. a full Moon</u>. **(SciDPE)**

Int: Uhmmm Hmmm.

D: With um … and then a shadow passing across it. I think it passes from left to right.

Int: And would it cover the whole Moon?

D: If you're very lucky. But very seldom.

Int: Ok. And … you mentioned that it would need to be when the Moon was at full Moon position. Um, would this mean .. why wouldn't we always see an eclipse when we have full Moon?

D: Because the Moon is often above or below the Earth's shadow {*holds Moon at full Moon position and moves it up and down*}. (**SciAli implied)**

(DaniellePI:2:17-30)

Danielle's interview left me with the impression that this work held much interest for her and was clearly a section of work that she liked and had enjoyed teaching.

5.3.4.4 Donna

Donna retained the same three scientific fragments for phases from her pre-questionnaire, which was one fragment more than the pre-interview. These fragments were 'SciEMS', 'SciOrb' and 'SciSee'. This was also a significant improvement on her pre-interview, where her understanding had been classified as 'alternative'. She no longer orbited the Moon in the model below the level of the Earth as she had done in the pre-interview. She was also able to correctly identify the positions of all the phases. Donna retained the 'scientific' classification for eclipses that she'd obtained on the post-questionnaires. This indicated that her improvement in eclipses was stable. Her classification pre-intervention had been 'scientific fragments'. Although Donna had a good understanding of the cause of lunar phases, she wasn't aware of partial eclipses and was under the impression that the whole visible part of the Moon would be blacked out in every eclipse.

5.3.4.5 Emma

As in the post-questionnaire, Emma obtained three scientific fragments for her understanding of phases. However, the misconception that the Earth's rotation also plays a role in the cause of phases appeared here, so this led me to wonder if one of the activities (most likely Activity 4) was responsible for causing this misconception in Emma. I say Activity 4 because this activity explores the relationship between the Moon's apparent motion i.e. rising and setting as caused by the Earth's rotation and the phases that we'd see just after sunset throughout the Moon's revolution. I have commented previously that this activity seemed to be problematic for Lara. So I think its use in the intervention was premature. The concepts of the Moon's phases and eclipses needed greater reinforcement and I think that this type of activity should only be introduced at a more advanced stage.

Another idea that crept into Emma's mind during this activity related to where one would see the rising and setting of the Moon. When I had asked this question in the intervention, Emma said she couldn't remember where it rose and set, but Courtney had said that the Sun rises in the East and sets in the West so the Moon probably does the opposite. This was exactly what Emma stated in her post-interview and Courtney repeated her previous explanation in her post-interview as well. So I had not been successful in challenging this misconception with Courtney and Emma. This is similar to Fanetti's (2001) finding with the use of the word 'shadow' in the additional activity, where the scale model was set up and participants asked to identify where they saw shadows. This was done for them to see that with the correct scale model, the Earth's shadow doesn't fall on the Moon. Fanetti (2001) proposed that the emphasis on shadows may have resulted in the increase post-instruction, of the misconception that the Earth's shadow is the cause of lunar phases.

When I asked Emma if she could show me how the phases work using the model, she started at new Moon position and said it would be full Moon there. At full Moon position, she again said the Moon was full and that it would also be the eclipse. She correctly positioned the phases in-between new and full Moon positions. As she had shown two positions for full Moon, I asked her to confirm for me where full Moon would be seen:

E: I remember, it didn't make sense according to my .. how I saw it, so let me just think about it. If it's here {*holds Moon at new Moon position*}, I thought it would be a full Moon. No. Ja, full Moon. Ok, but it's actually here. *{Moves Moon to full Moon position and holds it there}.*

(EmmaPI:2:8-11)

So the probing and manipulation of the model helped her re-think her ideas and she remembered that the full Moon was on the opposite side of the Earth. She had actually asked about this during the intervention and commented then as well that it didn't make sense to her. I asked her if she knew why the Sun's rays were able to reach the Moon at full Moon position. Emma's answer indicated that scale and alignment both played a part:

E: I can't remember. I know, the reason why it didn't make sense for me is because here (full Moon position) the Sun's rays doesn't actually get to it, but it's because it's not in an exact line.

Int: Ok.

E: And the Moon is .. the Sun is bigger, so it does get actually the light. It gets all the rays.

(EmmaPI:2:13-17)

Barnett and Morran (2002) also noted that one of the benefits of interviews was that the use of probing questions led to the learners reconstructing their ideas there and then. Furthermore, interviews themselves are a context for situated learning.

Before Emma had reconfigured her ideas about phases, she had correctly identified the position of an eclipse at full Moon position and was awarded the fragments SciPos and SciAli, which were the same two fragments she'd obtained on her post-questionnaire. However, once she'd re-arranged her phases in the correct positions, she decided that the eclipse must be at new Moon position and not full Moon position. So her classification remained as 'Scientific fragments (1-2 fragments)' but she only had the fragment 'SciAli' in the end. Although her understanding of eclipses on the post-interview was still very shaky, it was an improvement from her pre-interview ideas that the Sun was blocking the Moon or the Moon was blocking the Sun. She was aware of the existence of partial eclipses but couldn't give any detail of these.

5.3.4.6 Lara

Lara was classified as 'scientific fragments' for phases, which was the same classification she'd had on the post-questionnaire with the same fragments. This was an improvement on her pre-interview which showed that she had alternative conceptions of the Sun revolving around the Earth and the Earth blocking the Sun's light. She was able to correctly identify the positions of all the phases. Lara demonstrated a full scientific understanding of eclipses in the post-interview, which was the same classification as the pre-interview. She had dropped two scientific fragments in the post-questionnaires which was probably because she didn't give a full enough explanation in her responses to the open questions, but she obtained all four fragments on the post-interview. She also knew that partial eclipses are possible.

5.3.4.7 A Comparison across Pre- and Post- Questionnaires and Interviews

Table 5.1 and Table 5.2 that follow, provide a summary of the classifications for questionnaires and interviews pre- and post-intervention. A comparison between the questionnaires and interviews almost always shows a different classification. This is because the interviews reveal more information through the manipulation of the model and through the probing that can be done. This is supported by Schoultz *et al.* (2001) who found that during their interviews, their participants' related their statements to the physical interview model (the Earth's globe). This was their criticism of Vosniadou's earlier work, as mental models rather than physical models were used in her interview context. I think that the interview classification is more accurate as one can obtain a fuller picture of understandings than a questionnaire can give. To ascertain the effectiveness of the intervention, I therefore looked more closely at the difference in the interview results rather than the questionnaire results. The only exception I would make to this statement is in Courtney's case. Due to the stressful circumstances of her post-interview, I think her post-questionnaire gives a better idea of her post-intervention understandings as there is a far larger negative difference between her post-questionnaire and post-interview when compared with the others.

Table 5.1 Comparison of Case study Teachers' Classifications for Phases

	Classification for Phases			
	Pre-Questionnaire	**Pre-Interview**	**Post-Questionnaire**	**Post-Interview**
Courtney	Alternative (Sun's distance to the Moon)	Alternative (Planet blocks Sun's light) [1 scientific	Scientific with Misconceptions	Alternative (Earth blocks Sun's light) [two scientific fragments]

	Classification for Phases			
	Pre-Questionnaire	**Pre-Interview**	**Post-Questionnaire**	**Post-Interview**
		fragment]		
Danielle	Scientific	Scientific	Scientific	Scientific
Donna	Scientific fragments	Alternative (Earth blocks Sun's light)	Scientific Fragments	Scientific fragments
Emma	Scientific fragments	Alternative (Earth blocks Sun's light)	Scientific Fragments	Alternative (Earth's rotation)
Lara	Alternative (Earth blocks Sun's light)	Alternative fragments	Scientific Fragments	Scientific fragments

For phases, the table shows that although Courtney remained classified as 'alternative' there is an additional scientific fragment to her pre-interview. Donna and Lara both showed an improvement from alternative and alternative fragments respectively, to partially scientific understandings with Donna obtaining three scientific fragments and Lara, two. Danielle remained the same. This indicates that her scientific understanding was stable. Emma had the same three scientific fragments in her post-interview and exchanged one alternative understanding for another. However, a vast improvement in her understanding was that she was able to correctly identify all positions for the phases and she understood why the Earth would not block the Sun's rays when the Moon was full.

Table 5.2 Comparison of Case study Teachers' Classifications for Eclipses

	Classification for Eclipses			
	Pre-Questionnaire	**Pre-Interview**	**Post-Questionnaire**	**Post-Interview**
Courtney	Alternative (Solar eclipse)	Alternative (Planets block Sun's light)	Scientific	No conceptual understanding
Danielle	Scientific fragments (3 fragments)	Scientific	Scientific fragments (3 fragments)	Scientific
Donna	Scientific fragments (3 fragments)	Scientific fragments (1-2 fragments)	Scientific	Scientific
Emma	Scientific fragments (1-2 fragments)	Alternative (Sun blocks Moon or Moon blocks Sun)	Scientific fragments (1-2 fragments)	Scientific fragments (1-2 fragments)
Lara	Alternative (Sun blocks Moon)	Scientific	Scientific fragments (1-2 fragments)	Scientific

Comparing the pre-interview and post-interview results for eclipses, Danielle and Lara remained 'scientific'. Courtney's post-questionnaire indicates a vast improvement from her pre-intervention classifications and I think it is a more accurate reflection of her final understanding of eclipses than the post-interview result. The other two teachers all showed an improvement in their understanding of eclipses. So, looking at both the phases and eclipses results, the intervention had a positive effect on the overall knowledge of these five teachers. Carr *et al.* (Chapter 2 on page 46) contend that our feelings concerning the subject matter we learn influences our learning of this content. This could have influenced the construction of knowledge amongst the teachers in my study. Although Courtney and Emma expressed enthusiasm for learning about the Moon and its phases and eclipses, they expressed the least amount of confidence concerning this subject matter during the interviews and they showed the least amount of change in their conceptions as indicated in the previous two tables.

Generally, both Table 5.1 on page 184 and Table 5.2 on page 186 show that the case study teachers had their own ideas about the Moon's phases and eclipses before the intervention. There are changes from pre-intervention to post-intervention in most instances which shows that each teacher constructed her own knowledge during the intervention and in the case of Donna and Danielle, some of the construction may have occurred during the teaching of the content as well. It has also been noted that not all of the alternative explanations changed as a result of the intervention, which is in line with Driver *er al.'s* (1985) discussion of constructivism, in which they comment that learners may ignore the educator's explanation. Carr *et. al.* (1994) add that time and more than solitary encounters are necessary for a change in understandings.

5.3.4.8 Benefits of Interviewing

As I was coding the interview transcripts and classifying the respondents, the benefits of interviewing became apparent, as although some respondents retained the same classifications as for the questionnaires, there were slight differences in others. These differences were revealed due to the probing that can be done in interview situations. Barnett and Morran (2002) also commented that interviews provided richer data and that probing was beneficial in that it caused the learners to reconstruct their ideas during the interview. So for instance, Danielle had a better understanding of eclipses than her pre- and post-questionnaires indicated, and Emma, Lara and Courtney had alternative understandings of Moon phases, which either hadn't appeared in their pre-questionnaires at all or were different from the questionnaire. Finally, the interview itself can be a forum for situated learning.

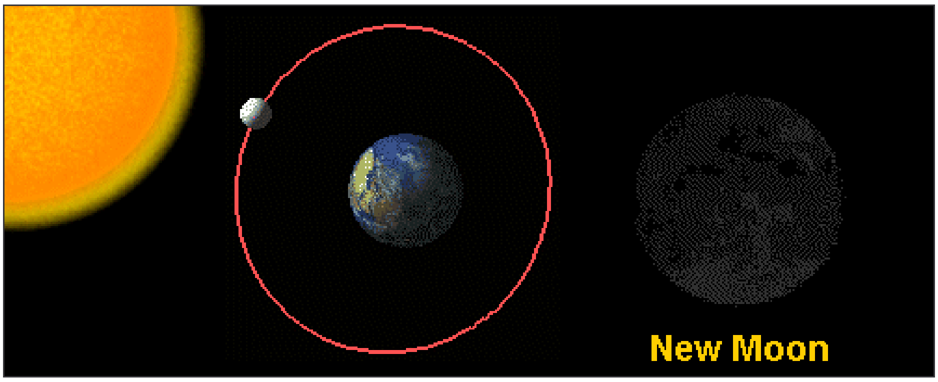
Furthermore, the manipulation of the model in the interview context was beneficial for Lara and her understanding of eclipses was more scientific than it had been on her pre-questionnaire and earlier in her pre-interview. The manipulation of the model had a similar effect in Emma's post-interview. Schoultz *et al.* (2001) also observed this in their research and comment that during discussion with their participants, the model (the Earth's globe) enabled reflection and acted as a prosthetic tool for reasoning and producing knowledge. Another interesting thing to note is that two of the alternative understandings for phases had not appeared in any of the 60 questionnaire responses. However, both a planet blocking the Sun's light and the Sun's revolution about the Moon and Earth have been previously reported (Trundle *et al.*, 2002). The implication of these findings amongst just five of the larger questionnaire sample implies that more of the total sample may have had alternative understandings and a wider variety of alternative understandings may be present than indicated in the questionnaires. Callison and Wright (1992) corroborate this finding and say that interviews gave greater detail about the way participants thought and that "it was through the interview process that the more unique notions surfaced" (1993:6).

5.3.5 Observation Results

It was only after the intervention that I came up with the idea that the case study teachers could use my questionnaires with their classes as a pre-test and post-test. I emailed them about this idea and attached a blank questionnaire that they could use for photocopying if they wished. Both Danielle and Donna, the only teachers who managed to fit in the teaching, thought that this was a good idea and used it at the beginning and end of their lessons. Danielle proposed that her class use the same questionnaire afterwards and rewrite the answers they wanted to change from the pre-test in a different colour. I mentioned this to Donna and she used the same method. Many learners did this as requested, but as mentioned in the data analysis section, several of them used the same pen or pencil and so it was difficult to tell if they'd made a mistake and changed the answer or if this was a pre-test to post-test change.

Neither teacher used any of the bonus worksheets I gave them. In the feedback session though, Donna mentioned that when she taught this section again, she would like to do some of the material covering Easter, Ramadan and the traditional African beliefs. Both elected to do Activity 1 rather than Activity 2 on scale and neither of them taught Activity 4. Danielle simply omitted it and Donna asked me to teach it to her classes. I don't think she felt confident enough to teach it. The two teachers had different styles of approach to the lessons. As Danielle had more general knowledge than Donna, she talked freely about other aspects of astronomy with her classes. For instance, in her first lesson, one of the learners asked how the mass of the Earth was determined (these data were given in the table in Activity 1), which Danielle was able to explain most satisfactorily. In the same lesson, they also spent some time discussing why the Moon shines. In both instances, a lively question-answer session ensued. I observed Danielle transforming her knowledge of rather complex calculations e.g. working out the Sun's mass, to a level her learners appeared to understand.

During one of her lessons, Danielle also spent quite a bit of time illustrating the problem with diagrams not being to scale. One of the learners had done some research on the internet for Activity 3 during the lesson and asked Danielle some questions about a diagram he had found. As the learners had already done the scale activity, Danielle used this diagram and asked the learners what the problem with it was. They figured out fairly quickly that it was not to scale. The fact that Danielle's learners were able to identify the problem with the scale on the diagram and that the groups I observed managed to do the scale activity (Activity 1) with the changes Danielle had suggested in the intervention gives some indication that her PCK methods were successful. Danielle asked the learners to be aware of this whenever they looked at textbook and internet diagrams. Fanetti (2001) picks up on this problem too. She criticizes textbooks not only for including diagrams that are not to scale, but also for excluding a caption that states the diagram is not to scale. "The textbooks do not appear to place an emphasis on scale in conjunction with lunar phases. Most of these diagrams use very distorted distance scales placing the Earth and Moon very close" (2001:20). Figure 5.3 on page 191 shows an example of an internet diagram I downloaded, which is very clearly not to scale. The Sun is too small and too close to the Earth-Moon combination and even the Moon is too big and too close to the Earth. From diagrams like this, it is easy to see why misconceptions occur.



(Cooley, 2001)

Figure 5.3 Internet diagram showing Moon Phases

Donna also spent time in discussion with the entire class, but she tended to focus more on what was required of them in the activity and giving the learners hints, whereas Danielle didn't spend much time discussing the activities, but left it up to the learners to figure them out. She relied on the activities to do the teaching unlike Danielle who freely engaged with her learners on the concepts covered in the activities. So there wasn't as much evidence of Donna's PCK during the lesson. I suspect this was because Donna was not as confident in her content knowledge as Danielle. Both teachers were very good with circulating amongst groups and responding to their queries with probing and guiding questions rather than just answering their questions. Both teachers used the group work as intended, so that the context was right for situated learning. In the post-interviews, Danielle specifically commented on the group work: "So they learnt a fair bit and the fact that it was group-centred, I think more of them understood it". (DaniellePI:3:25-26). Donna tended to move through her lessons at a slower, more thorough pace. She allowed time for all the groups to report-back, so they learnt from each other in this way as well. Danielle tended to allow the groups to complete the activity and then used one group to demonstrate the activity while she did a summary of the activity. During the summary she would explain and ask the learners questions as well. Perhaps this strategy was better for her class, though, as they became restless very quickly.

Both teachers actively encouraged research as part of their lessons. Danielle had computers in her classroom linked to the Internet, so the learners could use these during the lesson. The first lesson sparked an interest in the learners, as Danielle commented after the 2nd lesson that it had been obvious during the second lesson from the answers the learners were giving and the questions they were asking, that they had gone and done some research of their own accord. Donna was in the fortunate position that she also took the same two classes for technology and so she used one of her technology lessons with each class to allow them to do some research in preparation for Activity 3.

The teachers had very different approaches to Activity 1. Danielle modified the activity sheet so that it asked them to use a scale of 1mm:10 000 km. She also took the numbers out of scientific notation and gave them in kilometres instead of metres and rounded the values off. This is what she had proposed with this activity in the intervention and is evidence of her PCK in that she was aware of the difficulties that the Grade 8 learners would experience with this activity and had transformed the activity into a version she felt they would cope with. The activity went well during the lesson and the learners managed with the scale. At the end of the post-intervention interviews, I asked Danielle for some feedback on the teaching. Her immediate response was:

D: Um, the first activity on the scale was brilliant.

(DaniellePI:3:1)

She went on to say that she was keen to use it as an example when she taught classes how to do scaling, so not just in the context of teaching about the Moon. Donna's response to the first activity was not as enthusiastic. She had decided to use the other strategy discussed in the intervention, namely to give the learners the calculated values and let them build models from these values. She found the worksheet difficult to work with and felt her learners were not at the stage where they could cope with the scale conversions and they were also dissatisfied with just being given the worked-out values. She had not attempted to alter the activity as Danielle had done. She gave her one class the worked-out values together with a sheet showing how all the calculations were done. This caused much confusion and with her other class she decided to just give the worked-out values. This was some evidence of Donna's PCK: she realized when a strategy didn't work and attempted something different with her other class. Danielle's technique was therefore more powerful and successful. However, building the model was valuable for all the classes concerned. I noticed this as I was moving around the groups. Without fail, the learners were struck by the large distance from the Sun to the Earth and how small and insignificant the Earth and Moon appeared when compared with the Sun. The activity sparked considerable interest amongst them based on the questions I was asked in these groups. So I think that this activity was extremely valuable from the learners' perspective, but would recommend that it be taught as per Danielle's method.

Donna and Danielle did Activity 3 as per the worksheet and the methods shown in the intervention. Both their classes had done phases and eclipses in geography lessons earlier in the year. Danielle felt that therefore this activity was not "as wow for them" (DaniellePI:3:19) as the first activity was. She had her learners use balls as well as their heads to represent the Earth in this activity. I was surprised as she had commented in the intervention that the model using the head to represent the Earth was much more powerful. Danielle commented that she would have to re-think this as the switch from the balls to their heads had caused quite a bit of confusion. She noticed the same problems amongst the groups as I noticed with the teachers when they were external to the model i.e. using the ball. She kept on having to remind them to look at it as if they were on the Earth. Donna's classes had a different geography teacher and she didn't think that they'd used these types of models, if any, for this section for geography. Her classes only used their heads to represent the Earth and it worked well. She felt that this activity had been very useful for her learners and she'd noticed a vast improvement in their knowledge from when she'd walked around listening to the discussions in the groups and when they finally presented their explanations in their groups. As mentioned previously, she was much more thorough. She had organized an additional classroom for this activity so that the groups had more overhead projectors available and more space to work in. Having all the groups present rather than just one as Danielle did, had the added advantage that we could pick up on any misconceptions and if there were incorrect ideas in the presentations, the other learners in the class picked these up and challenged them. Donna commented: "I think that was a very useful activity" (DonnaPI:4:26). Parker and Heywood (1998) also found that groups presenting to one another with models a fruitful exercise. In this activity, there was some evidence of PCK. With Danielle, it was the realization that using the balls to represent the Earth and then substituting to heads representing the Earth had caused confusion and would be something she would do differently in the future. With Donna, it was the way she organized the lesson in that the learners had the space and resources to explore the phases comprehensively and that she listened to every group's explanation and used the opportunity to pick up on misconceptions and discuss these with the class.

As mentioned earlier, Danielle omitted Activity 4 and I taught this activity to Donna's classes. Donna gave this feedback to me regarding this activity: "Um .. I'm not sure that the elevation of the Moon was particularly … it seemed to confuse more than .. than clarify the issue" (DonnaPI:4:30-31). I agreed with her as I had noticed this while teaching the classes. It would appear that this activity had generally been problematic for both the learners and teachers and seemed to be more harmful than helpful. It conveys important concepts but requires quite a sophisticated level of understanding and the ability to visualize in three dimensions.

Both teachers gave me the impression that they had enjoyed the teaching and that they would teach the module in future, but both of them felt that they didn't want to repeat it if the learners had already done the work in geography. Donna thought that it was possible to teach it together with the geography teacher, but she would focus on different aspects or explore certain ideas in more depth. Overall, I can't comment much on their PCK. It was more obvious in the intervention session, where I could see how the teachers proposed to change the activities with Grade 8 learners and their own individual classes in mind, which relates to Mulhall *et al.*'s (2003) representation of PCK in the form of CoRes. The few things I observed here were the teachers' awareness of concepts that were too difficult for their learners, one of the criteria of a teacher's PCK (van Driel *et al.*, 1998) and altering a chosen teaching strategy which was not working well. I can't comment on their change in PCK at all. In retrospect, I would have needed to observe some teachers teaching the content, then doing the intervention and observe them teaching the same content the following year or with different classes in the same year in order to see the change in PCK. Although Danielle and Donna used the same activities and models, they taught their lessons very differently which concurs with Mousley's (2003) finding, where the teachers had planned their lessons together and had the same access to resources, but taught their lessons differently (Section 2.2.4 on page 50).

5.4 Precision and Trustworthiness

In chapter 3 (Section 3.8 on page 77), I outlined several strategies to address precision and trustworthiness in a case study. I responded to some of the strategies in chapter 3 and in chapter 5, I have provided examples of coding in the interview transcripts and further examples can be found in Appendix C on page 229. After the initial transcription of interviews, I went through the tapes a further three times, therefore four times in total to ensure accuracy. I changed tack during interviews when respondents were unable to answer questions and became uncomfortable. An example of how I did this is given in the extract which follows, from Courtney's post-interview.

C: I can't remember!
Int: That's fine.
C: It's just been too long.
Int: It's not a problem. Um … ok. Let's .. let's talk about something else then. Um, what do you understand a lunar eclipse as being?
C: (Sighs). Um (laughs). I've gone blank.
Int: Completely?
C: I've really gone blank. I'm sorry.
Int: Would you know what one would look like if you had to see it?
C: (Sighs). Uhmmm uhmmm.
Int: Not? Ok. And then, ok, let's talk about … I'm not going to … I can see this is stressing you more and with all the marking-
C: It's not that. It's actually all this stuff at home.
Int: You're not..
C: Ja. My mind's just not on it I'm afraid. I'm sorry.
Int: Let's .. if I can just talk briefly just about the activities we did that afternoon. How did you find them?

(CourtneyPI:2-3:22-38)

I have provided further support with photographs and quotes from the research tapes as well as extracts from the interview transcripts throughout this chapter. Furthermore, as a result of the coding change in the questionnaires which resulted from the coding cross-check, I went back and looked at the interview coding again. This resulted in two classification changes for phases on the pre-interviews. Also, throughout chapters 4 and 5, I have attempted to relate my findings to the theory as far as possible. In this way, I have shown that with a few exceptions, my findings largely correspond to other findings.

5.5 Summary Discussion of Case Study

1. A key issue in the interview related to the observers being external to the model. They looked at the Sun-Earth-Moon system from what Callison and Wright call the “astronaut” (1993:1) perspective. It didn’t even occur to them that they were not looking at the model from an Earth observer’s perspective. Suzuki (2003), Barnett and Morran (2002) and Callison and Wright (1993) all comment on this problem. Barnett and Morran (2002) also share the finding of respondents placing the full Moon at 1st quarter position. I have speculated that this was where the respondents in my study were sitting relative to the model and so it was from where they could see the Sun most clearly and so concluded that this was where the Moon would get the most light to reflect back to Earth.
2. The interchangeable use of ‘rotation’ and ‘revolution’ makes coding difficult and respondents are unaware that they have very different meanings in astronomical terms, a finding shared by Fanetti (2001) and Parker and Heywood (1998), amongst others. The intervention had little effect in addressing this as post-interviews revealed the

persistence of this problem. These findings are supported by the constructivist framework in which the use of words in science that differ from the way they are used in the English language cause alternative conceptions (Carr *et al.,* 1994) and that these alternative conceptions don't change even if contradictory to the educator's explanation (Driver *et al.*, 1985).

3. Related to point 2 is that interviews and models are beneficial at resolving the problem with 'rotation' and 'revolution' as probing questions can extract the meaning or the participant can be asked to use the model to illustrate what she means. Another benefit of interviews is that they provide richer data. Barnett and Morran (2002) also comment on the value of probing questions and the richer data that interviews provide. The richer data are evident when the questionnaire and interview classifications for my study are compared. The richer data provided by the interviews revealed a greater number and variety of alternative conceptions amongst the five case study teachers, a finding supported by Callison and Wright (1993). The implications of this finding are that the number and variety of alternative conceptions may be much larger for the broader survey sample group.
4. Models also have value in teaching. Lara voiced that it was "crucial" to have three-dimensional models to teach this section of work. Several of the teachers gave positive feedback about the models used in the intervention and teaching and comments ranged from their ease of use to their effectiveness when compared with worksheets. Barnett and Morran (2002) found that activities with models played a vital role in developing learners' understandings. Also, the visual impact of the models was significant, from the teachers' reaction to Danielle's scale model and their experience of being the 'Earth' in Activity 3 in the intervention.

5. A third important finding with regards to models was that their manipulation in the interview context helped Lara and Emma reconstruct their ideas towards a more scientific explanation for eclipses and phases respectively. Schoultz *et al.* (2001) noted a similar finding and Trundle *et al.* (2002) noticed this during piloting of their instrument.

6. The post-questionnaire and interview results indicated a shift towards a more scientific understanding amongst all five teachers, in line with the constructivist theory. As noted in this chapter, one's feelings about subject matter can influence how we learn it (Carr *et al.*, 1994) and this could have affected Emma and Courtney's results in particular. Situated learning through activities with the assistance of other group members in the intervention, which is how Cobb and Bowers (1999) and Brown *et al.* (1989) explain knowledge production, was able to develop a more scientific understanding of lunar phenomena amongst all five case study teachers. Throughout the intervention, there was evidence of legitimate peripheral participation, which is where a group member gradually participates more in group discussions and activities as she becomes more confident in her knowledge (Lave, 1996). This was particularly evident with Courtney and Lara. An example of this is Courtney's initial lack of confidence regarding the content in the intervention and her increased participation as the intervention session progressed. With Lara, it was evident in that she initially was unable to do the scale calculations and then started volunteering the answers once she understood. Teachers commented on the value of group work both in the intervention and in the teaching context.

7. Some PCK was in evidence during the intervention, particularly in Activity 1, where the teachers grappled with a variety of ideas in

order to make the activity manageable (Shulman, 1986) for Grade 8's. For instance, they discussed giving whole, rounded off values instead of numbers in scientific notation. They were very aware of the capabilities of the group they were aiming the content at and there were also comments made regarding the capabilities of particular classes of Grade 8 learners, one of the prerequisites for PCK according to Mulhall *et al.* (2003). Shulman (1986) also contends that teachers ought to be aware of learners' prior knowledge and have a variety of strategies available when teaching any topic. This was also obvious in the teachers' discussions of the activities. Little PCK was evident in the observation sessions and the design of this study would need some alterations to determine how the PCK of the teachers changed and how successful it was.

8. The importance of scale for understanding lunar phases and eclipses was in evidence on several occasions. When Emma commented in the intervention that she couldn't understand why the Moon would get all the Sun's rays at full Moon position, Lara and Danielle used scale to explain it to her. Scale was emphasized by Danielle again in Activity 3, when Lara and Emma were unable to clearly see the phases using the model. Very importantly, Emma referred to scale when she corrected her explanation for phases in the post-interview. I am unable to support my findings on the relevance of scale with theory, as Callison and Wright (1993) only provide recommendations and not findings with regards to scale and Fanetti (2001) was not able to provide any conclusive findings on scale.

9. The post-questionnaires and interviews indicated a general trend towards a more scientific understanding. The post-questionnaires also indicated an attitude change for Donna regarding the importance of Moon content in the natural science curriculum. The

implication of the attitude change and improvement from pre- to post- intervention implies that an intervention with models can be effective at improving teachers' knowledge and self-confidence for teaching about lunar phenomena.

10. The time lag between the intervention and post-interviews seemed to be particularly problematic for Courtney and Emma, as both commented on it. Based on Trundle *et al.*'s (2007) findings, I proposed that it was very likely that their understanding of the scientific explanation was better closer to the intervention and it would have been interesting to see if there was a difference if another set of interviews had been done straight after the intervention.

CHAPTER 6 CONCLUSIONS, REFLECTIONS AND IMPLICATIONS

6.1 Introduction

In this chapter, I want to firstly respond to the research problem and questions and draw conclusions based on the findings presented in chapters 4 and 5. I will also reflect on these findings as well as some of the issues raised during the research. Then I will identify the limitations of this study and finally, I will look at areas that require further research.

6.2 Research Problems and Questions

6.2.1 The Research Problem

In chapter 1, I hypothesized that South African natural science teachers would not have had any formal education on the Moon's motion, phases and eclipses, that they would hold alternative conceptions about this subject matter and view it as unimportant and the domain of the geography department. The research problem concerned how capable teachers are of teaching the new curriculum material on the Moon's motion, phases and eclipses should my hypothesis be correct. The results revealed that the teachers in this study had little formal education on the Moon's motion, phases and eclipses with 39% having never studied this material and only 14% receiving instruction at university level. Also, 37% last studied this material at school and only 5% had attended any form of in-service training. The majority of them held an alternative understanding for the cause of Moon phases and only two of the 60 teachers held a scientific understanding for both lunar phases and eclipses. However, the group had a better understanding of eclipses than I had anticipated, with 70% holding three scientific fragments. Another finding that I had not anticipated was that more than half of the teachers viewed this work as important for inclusion in the natural science syllabus. However, the results also revealed that despite this, 38% of them believed that it should be taught in geography and the reality is that geography teachers are still teaching this section of work in the vast majority of schools represented in this study. The implication of this is that the Department of Education will either need to rethink its place in the natural science curriculum or address the problems of teachers who don't have the necessary background to teach this section and who have the conviction that it belongs in the geography syllabus. Personally, the latter option is preferable and is discussed in 'Recommendations' (Section 6.6 on page 214).

6.2.2 The First Research Question

My first research question asked 'What are senior phase natural science teachers' understandings of the Moon's motion, phases and eclipses?' The teachers held a good understanding of observable phenomena concerning the Moon's motion, with the exception that its path across the sky would be from East to West. The largest classification group for phases, was the grouping for teachers with an alternative understanding for the cause of phases (57%). Overall, there were misconceptions present or no understanding of lunar phases amongst 40 (47%) of the sample group. I found that only four (7%) of the sample group held a full scientific understanding of the lunar phases with the remainder (18%) holding some scientific fragments. Based on these results, I would say that the understanding of phases is poor, given that the teachers need to be in a position to accurately cultivate knowledge of lunar phases amongst their learners. The teachers' understandings of eclipses was generally good, with only ten teachers (17%) having an alternative or no conceptual understanding. However, only three held a fully scientific understanding and as mentioned previously, only two of the three held a scientific understanding for phases as well. This number clearly needs to be much higher if teachers are to adequately teach this content matter.

I think that the better understanding of eclipses stems from the large number of teachers who held an eclipse model for phases. From teaching light and shadows in science, it may seem obvious that for a shadow to fall on the Moon, something must be blocking the light and since most (75%) knew that the Moon orbits the Earth, the Earth is the likely object blocking the Sun's light. So the concepts needed to understand eclipses are possibly more accessible to science teachers. Some of them may know that eclipses occur at full Moon if they've observed an eclipse, but I would guess that the majority of them wouldn't expect this to be the case, as only four (7%) of the teachers obtained this fragment. This is because the teachers are not familiar with the scale of the Sun-Earth-Moon system and are unlikely to know that the Moon's orbit is seldom on the plane of the Earth's orbit. An understanding of the phases is complicated by a three-dimensional visualization of the relative positions of the Earth, Sun and Moon and knowing that the relative positions determine how much of the lit half of the Moon is seen from Earth.

6.2.3 The Second Research Question

The second research question was 'What are selected senior phase natural science teachers' understandings of the Moon's motion, phases and eclipses after an intervention with activities and models?' Generally, the case study groups' knowledge benefited from the intervention, with three of the five teachers achieving a scientific or partially scientific understanding of phases. Before the intervention, only one had a scientific understanding, three an alternative understanding and one was classified as 'alternative fragments'. The results for their understanding of eclipses were also positive, where they all finally held a scientific understanding (definitely three out of the five) or scientific fragments. I am basing this statement on Courtney's final questionnaire result, rather than her post-interview, as I mentioned in chapter 5 that the interview circumstances were problematic. Two of the teachers felt that the time lapse between the intervention session and the post-questionnaires and interviews had played a part in not achieving the level of understanding they had hoped for.

6.2.4 The Third Research Question

The final question was 'How are activities and models on the Moon's motion, phases and eclipses used in the science classroom by a small group of secondary science teachers?' The materials and models from the intervention were enjoyed by the learners and the two teachers who taught the module on the Moon's motion, phases and eclipses. Danielle's strategy for Activity 1 worked well with her learners, but it would need to be trialled with more classes together with pre- and post-tests with the learners to gauge how successful this strategy is. Donna used a different strategy and found this activity problematic for her learners. Neither of the teachers considered using the alternative scale activity (Activity 2) and it wasn't popular amongst the other teachers who took part in the intervention either. So Activity 1 seems preferable for teaching scale, but with rounded values, scientific notation removed and the values given in kilometres, so that the numbers aren't as long as they would be if given in metres. The learners all enjoyed Activity 3 where they used the models to explain lunar phases and eclipses. Based on the group report-back sessions during the lessons, they seemed to have developed good understandings of these concepts. Again, pre- and post-tests with the learners are needed to gauge how effective these activities are.

Activity 4 was problematic in that it was too complex for the teachers, never mind the learners and while it develops important concepts, it should not have been included in the teaching for this level of learner.

More research would be needed to provide a more complete answer to the third research questions as I was unable to sufficiently measure how effective the teachers' PCK and the activities and models were with the learners. Also, it was unfortunate that only two of the case study teachers taught the Moon module and an extra set of interviews between the intervention and the teaching would also have been helpful as I would have been able to see if the teachers' content knowledge was better closer to the intervention and also whether the teaching made a difference to their understanding of lunar phenomena.

6.3 Conclusions

1. Natural science teachers are not adequately prepared for teaching the section on the Moon's motion, phases and eclipses. This is evident in both the results for their understandings of lunar phases and eclipses as well as the lack of formal education on this topic amongst the sample group. This view is supported by Summers and Mant (1995), who contend that for "teachers adequately to teach the science National Curriculum, they need a scientific understanding of … the concepts involved in them" (1995:11). This conclusion can only be made for the educators that participated in this study and cannot be generalised to all South African educators.

2. An intervention with models can be successful at improving understandings of lunar motion, phases and eclipses, but it needs to be more intensive. By this I mean more sessions, so that more time

can be spent exploring and thereby reinforcing the essential concepts. I think that a combination of an intervention with teaching is more successful than just the intervention, as it forces the teacher to grapple more with the material and concepts. I say this because Donna and Danielle were the only two teachers to correctly answer all the questions on the Moon's motion in the post-questionnaires. They also obtained the highest classifications for understandings of lunar phases. Danielle was classified as 'scientific' and although Lara was also classified as 'scientific fragments' for phases, Donna had an extra fragment. Donna and Danielle were also deemed to have a complete scientific understanding of lunar eclipses on the post-interviews.

3. In all the lessons I observed, I witnessed that the activities sparked much interest and enthusiasm amongst the learners, which gave some indication of the benefits of the teaching and the activities. Pre- and post-tests are needed to measure this more effectively. Parker and Heywood (1998) found that models were absolutely essential for their participants to form an image of how lunar phases occur and Trundle *et al.* (2007) report that an activity incorporating a model was "particularly critical … (and) the cognitive load for the activity … is judged to be heavy" (2007:321-322).

4. The use of models in both the interviews and intervention was invaluable. In the interviews, the model helped both Lara and Emma reorganize their thoughts in such a way that they were able to give improved explanations of the phases (Emma) and eclipses (Lara). During the pre-interviews, Lara stated emphatically that this section could not be taught without three-dimensional models. Several teachers commented on the value of the models in the intervention session during the feedback in the post-interviews. They felt that the

use of models was much more valuable than any other strategy for understanding and teaching this material.

5. An appreciation of the scale of the Sun-Earth-Moon system is vital for developing a scientific understanding of Moon phases and eclipses. Summers and Mant (1995) say that phases and eclipses are “complex, and real understanding involves crucial considerations of the scale of the solar system” (1995:13). This was clearly demonstrated in Activity 3 where the teachers were unable to ‘see’ a full Moon if they used the incorrect scale for their model. There were many teachers with the alternative understanding that the Earth blocking the Sun’s light causes the phases. A better understanding of scale and the Moon’s orbital path would help to address this misconception, as they would then, like Emma in her post-interview, understand why the Sun’s light can reach the Moon on the opposite side of the Earth. It is essential to explain why we don’t always see eclipses at full Moon position.

6. Also in Activity 3, using the participant’s head to represent the Earth was much more powerful than using a ball, as being internal to the model, it forced the participant to view the phases from the Earth’s perspective. Several models require the observer to be external to the model and even when looking at two-dimensional diagrams the observer tends to view it from a space perspective. This problem is also reported in several other research papers, e.g. Parker and Heywood (1998), Callison and Wright (1993) and Suzuki (2003). So models and diagrams need to force viewers to look from an Earth-perspective. Once they have mastered this, they can be placed external to the model and look and think about it from other perspectives.

7. The interviews were invaluable in that they revealed far richer data than the questionnaires. Barnett and Morran (2002) also note the value of probing questions in interviews which can result in a participant rethinking their ideas on the spot. A critical finding from the interviews was that there were more alternative understandings than had appeared in the questionnaires and a wider variety of alternative conceptions.

6.4 Reflections

There is a need to explore the Moon's motion at a simple level before even getting to phases. Participants (and learners) need to know that the Moon orbits the Earth and how it does so, otherwise it is very difficult to measure their knowledge of phases accurately. This would also make the follow-on activities more meaningful. They would therefore need to know that its orbit is only very slightly elliptical and they can approximate it to a circle and that the orbit varies about five degrees above and below the plane of the Earth's orbit. To this end, an introductory activity on the fact that the Moon orbits the Earth and how it orbits would have been helpful, as one teacher in the case study group was not aware that the Moon orbits the Earth and most were unaware that the orbit would occur at a small angle (5°) to the plane of the Earth's orbit. One even thought that the orbit was below the level of the Earth (Section 5.3.1.4 on page 145). It could also be worth looking at the shape of the orbit, as some of the teachers knew the orbit was elliptical, but demonstrated this as more exaggerated than it should be. In other words, they were unaware that the orbit was only very slightly elliptical and that a circular orbit is a good approximation. In retrospect, the absence of this type of activity was a shortcoming of this study, as an understanding of the phases relies on an understanding of the Moon's orbit.

Phases needed to be dealt with much more intensively in the intervention. The teachers appeared to understand phases during the activity when they were working with the model, but less of this knowledge was in evidence in the post-interviews. So the activity possibly needs to be broken up into smaller segments and more time spent on it. During teaching, Donna asked one of her classes to go and do research on the phases and eclipses before they did the activity. Both she and I noticed a difference between this class and her other class who did the research after using the model but before presenting it to the class. So it may have been beneficial to ask the teachers to first do some of their own research and then to attempt the model. Some probing questions could be asked to start off the activity, which could then serve as a guide for a research portion of the activity and then the final part of the activity would involve manipulating the model so that they can see how the phases and eclipses work.

Activity 4 was generally problematic. It conveys important concepts, but it needs a firm foundation and a certain level of intellectual development. One of the problems with this activity is that it requires an understanding of the motion of the Moon, namely that the Moon’s orbit is only slightly elliptical and that its path does not lie on the plane of the ecliptic. As pointed out earlier in this section, an activity looking at the Moon’s motion is necessary before moving on to the phases of the Moon. It is too complex to grasp when learning about phases for the first time as it requires too much abstract visualisation, particularly for learners. However, I think it is still important for both the participants and their learners to realize that the Moon’s rising and setting is caused by the Earth’s rotation. With regards to the Moon observation chart, it would be useful to include a question on where in the sky the Moon was observed (N, S, E, W) at the time of observing. This would lay some foundation for an activity on elevation to follow on a later stage.

From the post-intervention results, the theoretical framework of situated learning led towards a more scientific understanding of lunar phenomena. The feedback from the teachers included a comment from Courtney that the use of group work as a learning environment is always helpful; and from Danielle, that in her opinion, the use of a situated learning context in the classroom resulted in better learning than another strategy would have. In the intervention, the use of group work in a situated learning context meant that certain topics e.g. the calculation of scale were covered several times and through observing the interaction, I was able to see how Lara, through legitimate peripheral participation, was eventually able to calculate the scale values quickly and easily. The use of models as tools for enculturation was well received by the teachers, with all of them giving positive feedback on this at various stages.

Although models are extremely valuable, it is very problematic when the participant is external to the model, which was the case in the interview model. An important finding in this study was that the case study teachers tended to 'look in' as an outside observer and didn't picture how an observer *on* the Earth would view the Moon. I think it would have been more valuable to use a similar model to Activity 3 in the interview context, where the participant's head represents the Earth, because it forces them to view the situation from an Earth-observer's perspective. I think in the post-interviews it would have been valuable for those that couldn't remember how the phases worked to have rather used the activity model. In future research, I think it would be absolutely fundamental to use phases and/or eclipses models where the participant is forced to view the model from an Earth-observer's perspective. Only once this foundation is firmly established and a firm understanding reached, should participants then look at models from other perspectives. Callison and Wright (1993:11) contend that "an externally viewed model increases the complexity rather than providing a simple forum for explanation”. Barnett *et al.* (2000) found that their virtual reality modelling software seemed to be successful at addressing this problem and another possible solution is suggested by Suzuki’s (2003) students, who used the scope of a video camera as the ‘eye’ of a doll placed on the Earth in their model.

6.5 Research Limitations

The questionnaires made use of closed questions, which can be leading (Opie, 2004) and also limit responses thereby not always revealing all misconceptions (Stahly *et al.*, 1999). It is very likely that this skewed the questionnaire results, as the interviews revealed misconceptions amongst the case study group that hadn’t been present in the questionnaires and also misconceptions that hadn’t appeared in any other questionnaires in the larger sample group. The implication of this was that in the larger sample group there were probably more participants that held misconceptions and a wider variety of misconceptions. However, open questions also have their limitations in that they don’t always reveal sufficient information. A participant may have a better understanding than she reveals in a questionnaire. For instance, both in the pre-and post-questionnaire, Danielle was classified as scientific fragments for eclipses but in both pre-and post-interviews, she was classified as scientific. It wasn’t that her understanding was any different - she simply had put insufficient detail in her questionnaires. I had also found this problem in my previous research (Kelfkens, 2005) and this is why I chose a combination of closed and open questions for the questionnaires to try and find a balance between these two problems.

The sample size and type of teacher limits this research. With regards to the questionnaires, the participants were mostly from private schools and not all private schools in Johannesburg are represented in this study. So the results can only be generalized up to this point. Stake (1995) comments that: "case study seems a poor basis for generalization. Only a single case or just a few cases will be studied at length. Certain activities and problems will come up again and again. Thus, for (the case), certain generalizations will be drawn" (1995:7). However, I feel that the results would give some indication of what can be expected from a larger sample group representative of more schools. There were only five teachers in the case study portion of this research. This amount is too small for any results to be generalized, but this research has revealed some important findings as well, a critical one being that a participant needs to view a model from an earth observer's perspective. Other important findings relate to the value of models and the essential role that scale plays in understanding phases in particular. As the body of reported research on lunar eclipses is rather limited, as pointed out in chapter 2, my results on lunar eclipses have value in supplementing this body of research.

Also, much like King (2001), I relied on the science heads of department at the schools to distribute and collect questionnaires and the willingness of teachers to complete the questionnaire. So it could be deduced that the teachers who did this had an interest in the research, which may bias the results. However, since several schools were represented in this study, the data still provide some insight to teachers' feelings (King, 2001) and understandings.

The post-results for the case study teachers may have been limited by the gap of several weeks between the intervention and the post-instruments. Two of the teachers commented in the post interviews that they couldn't remember because it had been too long. This was not a problem for the teachers who taught the material as this had been more recent and had allowed further interaction with the materials and more time to work through the concepts. The gap in time also meant that some of the teachers lost their confidence and ran out of time to teach this work and so the results are also limited by the fact that only two teachers taught this material.

6.6 Recommendations emanating from the Study

In this section, I will discuss some recommendations that arise from the findings of and reflections upon my study. Some issues for further research are also suggested.

I would suggest in-service training which follows a similar format to that used in the intervention as a procedure for addressing natural science teachers' misconceptions regarding the Moon's motion, phases and eclipses. I am suggesting in-service training because of the positive results of the three teachers in the questionnaire sample that had attended in-service training. Although not a big enough group to generalize, the in-service training must have been beneficial as none of these three teachers had received any university tuition on astronomy and yet two of them had a scientific understanding of phases and for eclipses, two of them held three scientific fragments and one a scientific understanding. Having said this, it must be borne in mind how few teachers attend in-service training – only 5% of my sample which was comparable to King's (2001) finding in the United Kingdom. The GDE (Gauteng Department of Education) would need to take a proactive approach to providing in-service training and more teachers may attend if the training took place in the cluster groups which already exist amongst neighbouring schools. This would mean smaller groups and a hands-on approach, which is what these activities require. King (2001) supports the use of in-service training with small groups as an effective method for professional development. Appleton (1995:366) in his study on whether an increased amount of knowledge is essential for greater self-confidence for teaching science, agrees that in "in-service courses … the teaching strategies which have proved effective in generating positive changes in self-perception tend to be time consuming, and need to be conducted in small-group settings rather than large lectures". King (2001) gives a thorough strategy for best principles for tackling new content matter in in-service training scenarios, which would be useful for anyone wanting to implement training. The ideal would be for in-service courses to be repeated regularly. I am basing this on Trundle *et al.*'s (2007) finding that not all participants' understandings were persistent several months after the completion of their physics course. Trundle *et al.* suggested a smaller set of activities later in the year to reinforce the student-teachers' learning. Driver *et al.* (1985) claim that conceptual change involves more than just noticing that one's ideas are contradictory to those presented. It also needs time and the right conditions. So regular in-service training would provide additional opportunities for conceptual change. However, I realize that this is not practically feasible and so would encourage teachers to be more engaged with their own professional development.

I think that this kind of exposure could have further reaching benefits i.e. if teachers see the type of activities that can be done on this topic and improve their own knowledge, they may change their minds about teaching the topic. I say this bearing in mind Tania's pre-questionnaire response regarding the place of this work in the natural sciences curriculum and her subsequent change of heart as a result of observing the intervention. Also, all the case study teachers were very positive about this section of work and the way it was explored in the intervention session. Donna also had a change of heart. Initially, she was the only case study teacher who felt this work was unimportant for the natural science curriculum and she indicated the opposite viewpoint in the post-questionnaire. This would certainly also challenge those teachers who think that this work can only be taught in a rote-learning manner.

A useful tool for teaching phases and eclipses are computer-generated simulations. The case study teachers appreciated the Microsoft Encarta one that I showed them and a simulation like this could be used by schools with access to computers. However, there is a need for simulations for the Southern Hemisphere. At the time I conducted my research, I was unable to find any computer-generated simulations specific to the Southern Hemisphere. It is also important that any simulation used should give a correct sense of scale so as not to produce or reinforce other misconceptions. Summers and Mant (1995:13) agree that “many of the existing resources for teaching and learning in this whole area are themselves sources of misconceptions”

This study looked particularly at teachers, even the observation section, so an obvious continuation of this research would be to look at the impact on learners now that the activities have been tested. Activities 1 and 3 could remain with the changes suggested in Sections 5.3.5 and 6.4 on page 189 and on page 209 respectively. Activities 2 and 4 would be removed and replaced with an introductory activity on the Moon’s motion as suggested in Section 6.4 on page 209. As mentioned previously, the learners could do pre- and post-tests, but separate copies of the questionnaires would need to be used as I found that several of the learners did not want to admit they had the ‘wrong’ idea before teaching and so changed their answers in the same colour pen as they’d used initially. The pre- and post-tests could also be used to give an indication of the effectiveness of the activities.

In chapter 1, I mentioned the dearth of astronomy education research in South Africa. None of the published studies I found had looked at the impact of the new content in the curriculum. I have only looked at a small section of the new content, but based on the answers to the background questions in the questionnaires, it is not just the astronomy content that is being ignored by natural science teachers, but the ‘Planet Earth and Beyond’ section in general. So more astronomy education research is needed in South Africa in general and on curriculum content in particular. Furthermore, much of the general astronomy research seems to measure understandings, have instruction and then measure again. This is often focussed on pre-service teachers because of the difficulty of conducting such a study with in-service teachers. Should small-group in-service training be provided on the astronomy content matter, this would provide the vehicle for this type of research to continue and with a much larger participant group. However, this is just more of the pre-test / post-test type study and so it shouldn’t stop at the post-test stage. What the teachers do with their newfound knowledge in the classroom is an area that hasn’t been reported on much in general publications and I haven’t found any such previous studies in South Africa. As a result of observing the use of the activities in the classroom, the teachers were able to come up with some best practises for presenting the activities.

There also needs to be more research on lunar eclipses and the value of scale in understanding phases and eclipses. Very few research papers focus on either scale or eclipses, which meant that I could not find much to compare my own results to. Moreover, I focussed on how lunar eclipses occur but didn’t really look at the differentiation between full and partial lunar eclipses, which provides another potential extension of the current research.

6.7 Conclusion

In this study, I set out to establish in-service teachers’ understandings of some new curriculum content, namely the Moon’s motion, phases and eclipses as well as their feelings about this new content in order to ascertain whether they have an adequate knowledge base for teaching this content.

While their knowledge was better than expected in some areas, the overall level of understanding is insufficient to teach this content to learners. I have suggested in-service training with small groups together with activities and models as a means to address the gaps in their knowledge.

Although teachers were more positive than expected about the place of this material in the natural science curriculum, most are happy to leave it to the geography department to teach. It is possible that teachers may become more enthusiastic about teaching it themselves if they are able to take part in activities such as those presented in this research and if they feel confident about their knowledge. This was certainly the case for my research assistant and the teachers who participated in the case study. The activities would first need to be amended according to the recommendations given in this chapter. With greater knowledge, I hope that South African natural science teachers will have the confidence introduce the Moon to their science classes.

I will end as I began, with a quote from David Whitehouse:

"At last, I have learnt that you can gather all the facts about the Moon but the facts will never give you the full picture or tell you the complete story. You cannot strip it of its myth and mystery and say it is just a ball of rock. It is far more precious than that. It has a unique place in people's hearts – just look at what they have done to discover it".

(Whitehouse, 2001:304).

APPENDIX A

Code [ ]

Questionnaire

The Moon's Motion, Phases and Eclipses

One of the aims of my research is to study your understanding of the Moon's motion, phases and eclipses. I am interested in your current understanding and would not like you to look up answers or discuss the questions with anyone. All answers will be treated with the strictest confidentiality.

1. *Read statements A - E below. Please write **TRUE** or **FALSE** in the space provided below each statement.*

   A. When the Moon is visible, it is always in the same place in the sky.

   ____

   B. The Moon moves across the sky in the same path as the Sun.

   ____

   C. The Moon rises at the same time every night.

   ____

   D. Half of the Moon is always lit up by the Sun.

   ____

   E. The Moon is sometimes visible in the sky during the day.

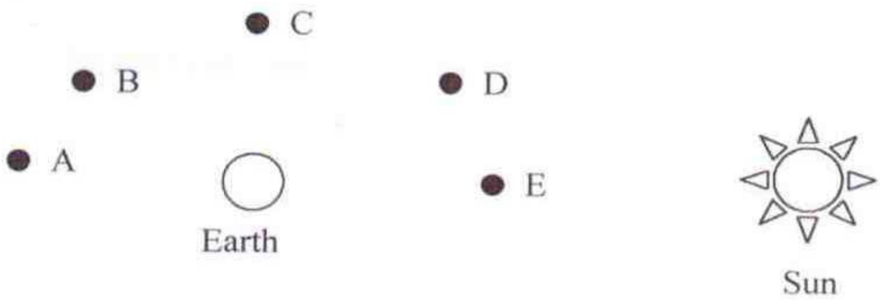
   ____

[Adapted from Summers & Mant (1995) and Comins, N.F. (no date)]

2. *Please draw a circle around the letter (A, B, C, D, E or F) corresponding to the correct answer:*
Approximately how long does it take for the Moon to move around the Earth?

A The Moon does not move around the Earth.
B 1 hour
C 1 day
D 1 week
E 1 month
F 1 year [Adapted from Trumper (2001)]

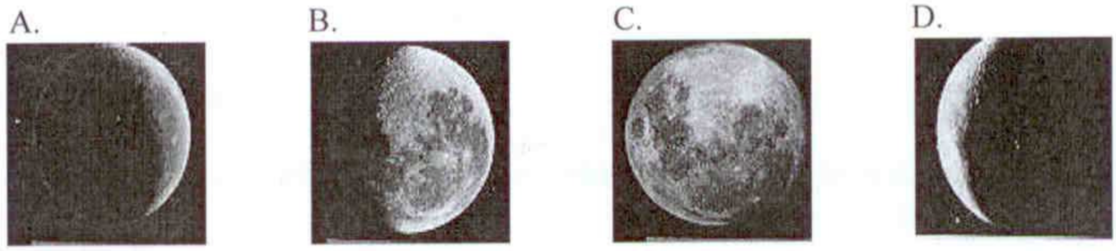
3. The diagram below shows the Earth and Sun as well as five different possible positions for the Moon. Please circle the position of the Moon (A, B, C, D or E) that would cause it to appear like the picture shown on the right.



[CAER 1999:4]

4. *Please draw a circle around the letter (A, B, C, or D) corresponding to the correct answer:*

You observe a ***full*** Moon rising in the East. How will it appear in six hours?



(CAER, 1999:4)

A **B**

5. The diagrams above show how the Moon appeared one night (Diagram **A**) and then how it appeared a few nights later (Diagram **B**). What do you think the reason is for the change in the Moon's appearance? _________

____

____

____

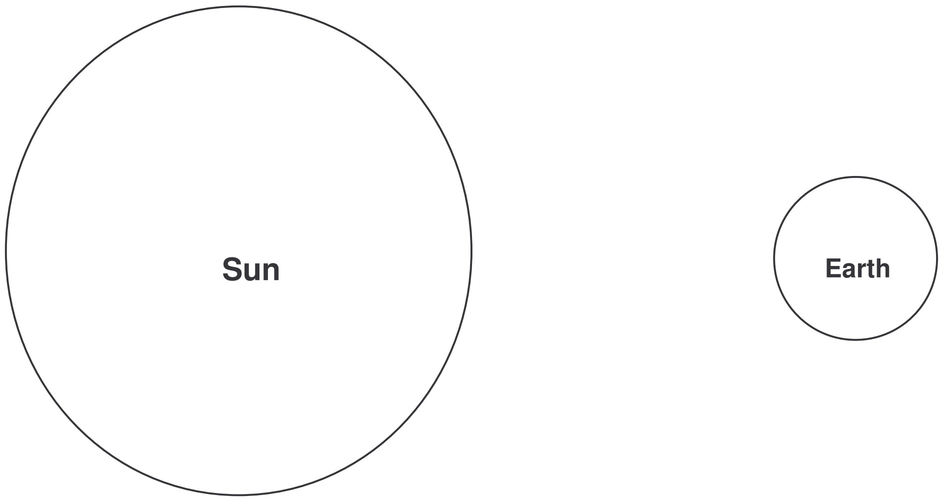
____

____

(Trumper, 2001)

6. What do you think causes a lunar eclipse (eclipse of the Moon)? ________

7. In the diagram below (not drawn to scale) the Sun and the Earth is shown. Please draw the Moon where you think it will be during a lunar eclipse (eclipse of the Moon).



Explain why you put the Moon in that position (in the previous diagram).

[Adapted from Barnett & Morran (2002)]

Background Questions

The questions below are for you to tell me a little bit about yourself.

1. Please place a cross **X** next to the correct option.

   Gender: Male ______ Female ______

2. How many years have you taught natural sciences?

   ____

3. ***Please indicate your answer with an X in the space provided.***

   Have you ever studied anything about the phases of the Moon?

   No _______ ***Please go to question 4.***

   Yes_______

   I learnt about it from:

   School _______

   University _______

   Family _______

   Friends _______

   None of the above, I learnt about it from

   ____

   ____

   ____

4. ***Please indicate your answer with an X in the space provided.***

Since the implementation of Curriculum 2005, have you ever taught anything about the Moon?

No ________ ***Please go to question 5.***

Yes ________

*Please **X** whichever options are applicable.*

I have taught about the Moon's:

Motion ________

Phases ________

Eclipses ________

Other ________ Please specify:

____

____

____

____

[Adapted from Summers & Mant (1995)]

5. Please place an ***X*** in the box that best describes how confident you feel teaching about the Moon's motion, phases and eclipses.

Not confident at all. ☐

Not very confident ☐

Not Sure ☐

Confident ☐

Very confident ☐

Please comment on your choice above: ______________________________

____

____

____

____

____

[Adapted from King (2001)]

6. How important do you think the 'Planet Earth and Beyond' component is for a natural sciences curriculum?

Not important at all. ☐

Not very important ☐

Not Sure ☐

Important ☐

Very important ☐

Please comment on your choice above: ______________________________

____

____

____

____

____

[Adapted from King (2001)]

Thank you for taking the time to complete this questionnaire.

APPENDIX B

Code [ ]

Interview

{Good morning/afternoon/evening _________. My name is Lesley Kelfkens. Thank you for allowing me to interview you. Are you comfortable with me videotaping this interview?

In front of you, you see a model: this large yellow ball represents the Sun. It's resting on a base just to stop it rolling over the table. Here is a torch / lamp which you can also use as the Sun if you want to simulate the Sun shining. This globe represents the Earth and the small white ball represents the Moon.

The model is not to scale for practical reasons.

1. You probably have noticed that the Moon does not always look the same. It changes shape and the different shapes we see are called the phases of the Moon. For example, sometimes we see what we call a "full Moon" and at other times the Moon is not full. What do you think causes the phases of the Moon?

   (Trundle, Atwood & Christopher, 2002).

   {Probe for understandings of: half the Moon is always lit up by the Sun; has to do with relative positions of the Earth, Sun and Moon; amount of illuminated portion of Moon we see determines the phase}.

2. Can you use the model to show me how the phases work? Can you show me for example, where would the Moon be for us to see a New/Full/Crescent/1st quarter/last quarter Moon? *[Use a diagram sheet to assist with terminology].*

(Trundle, Atwood & Christopher, 2002).

3. Use the model to show me what happens as the Moon goes through one complete cycle of phases. Explain what would be seen. You may use the diagram sheet to assist your explanation.

(Trundle, Atwood & Christopher, 2002).

4. *{Only ask this question if they moved the 'Moon' sphere}*
How long would it take the Moon to move through the cycle of phases as you showed me?

(Own question)

5. What do you think causes a lunar eclipse?

(Own question)

6. Can you use the model to show me the position of the Sun, Earth and Moon for a lunar eclipse to occur?

(Barnett & Morran, 2002)

7. *{If the position shown is the same as for one of the phases, ask about this}*: Since this is the same as you showed for the ______ phase, would we always see a lunar eclipse if the Moon is in this phase? Why/ why not? *{Probe}*

(Own Question).

Diagram Sheet : Phases of the Moon

1 2 3 4

5 6 7 8

APPENDIX C

Extract from Courtney's Pre-Intervention Interview

Int: Ok, um.. having a look at the diagram sheet there, it shows you various different shapes or phases the, the, the Moon can take. Um, what do you think would cause those different shapes?

C: Well, it's obviously the orientation of the Sun, the Earth and the Moon. (**SciEMS)**

Int: Uhmmm hmmm.

C: This is what I couldn't figure out on the questionnaire, where I really got stuck because then I know that everything revolves around the Sun, doesn't it? *{Shows revolving motion with her hands around the model Sun}.* I don't know. I don't know (laughs). Do the planets revolve around the? … No,because … I don't know. That's where I got stuck so I don't know. So I know it's got something to do with the light from the Sun being blocked and therefore you only see various parts of the Moon. That's what I thought ..

Int: Ok and then what-

C: (overlapping) An eclipse of the Moon is but then I got completely stuck so I don't know. **(Sun's light blocked – eclipses).**

Int: OK and, and for the pha.., is for the phases, is light from the Sun being blocked in that case as well?

C: … I'm assuming. **(Alt: something blocking Sun's rays).**

Int: And what would block the light rays?

C: Well the other planets .. getting in the way. I don't know (laughs) **Alt (Planets blocking Sun's light)**. As I said, I don't know. I've got no geography background so I have absolutely no idea.

(CourtneyI:1:1-21).

Int: OK. Could you .. when, when we see a Full Moon like as in picture number six (on the diagram sheet) where would you place, using the model, where would you place the Moon? (Long pause) Where do you think the Moon would be (C picks up the Moon, smiles, shakes her head), or where would the Earth be for us to see the Full Moon?

C: Well, it would have to be directly in front {*holds Moon between Earth and Sun*} of the Earth. I mean if … I don't know {*rotates globe around on its axis until Africa faces Moon and Sun*} … I suppose something like that. There you're seeing the full Moon. I don't know. You can't help me and tell me what an eclipse is? (Laughter). 'Cos that might, might help me just get my, my thoughts in order, but I really don't know.

Int: That's the point of next Monday's session-

(CourtneyI:1-2:28-37)

Int: OK, well that's fine. And.. um .. so you say.. you said on your questionnaire that the Moon doesn't move so would you say if you put it here {*New Moon position*} to say 'full' Moon (as this is where C put the Moon for full Moon) does it stay here and then other things move in the way and block it?

C: (Long pause). <u>I know all the planets move (pause) and they all move around the Sun *{shows revolving motion again around the Sun with her hands}*. That's my understanding. I'm not sure about the Moon</u>. **(No SciOrb)**

(CourtneyI:2:47-53)

Int: OK. That's fine. And (long pause) do you know what the difference is between a normal Moon phase and an eclipse?

C: I always understood that for an eclipse there was something was getting in the way and so you didn't see the Moon then illuminated properly. **(Alt: Planet blocks Sun's light - eclipses)**

Int: OK.

C: That's what I always understood an eclipse to be.

Int: And that something is?

C: Well, a planet. Planets, as far as I understand, all orbit … {*indicates them moving around with her hands*} … and then obviously that's when they're sort of lined up in a certain way that, that would block **(Alt: Planet blocks Sun's light - eclipses).** I could be wrong (smiles). (Laughter).

(CourtneyI:2-3:56-67)

Extract from Donna's Pre-Intervention Interview

Int: OK. Um … so firstly, starting with the phases, if you look at the, the diagram sheet there, it shows some of the different shapes or phases of the Moon. Um, what do you understand causes the phases of the Moon?

D: Well I would say the, the angle, the different, because they're both revolving *{Indicates turning motion with her hands}* um, on their own axis as well as around each other, that, because of the, the Sun, the light shining um, at different angles **(SciEMS)**, you'll be able to see.. because if for example, this (the Moon) is, you know, not quite in line with all the others *{Moves Moon slightly out of direct alignment with Sun and Earth – Moon between Sun and Earth}*, because of it's different positions *{Indicates turning motion with her hands}*, it will reflect differently **(SciEMS)** and so, as a viewer from the Earth, you're going to see different um, perspectives depending on the reflections**.** **(SciSee)**

Int: OK. And then where would you place the M-o-o-n.. um, in order for us to see a full Moon?

D: O-o-oh! I would say probably directly in the view {*Places Moon in new Moon position at level below Earth i.e. on the table*} because then the full light is shining on and the Earth can see the, the Moon. That's what I would say.

Int: OK. And then um, if … basically, um you mentioned that it would be the different angles and the position of the Moon that would determine the phase, so (coughs) starting then from the full Moon, can you show me how the, um you said in your questionnaire that the Moon takes roughly a month to go..

D: Uhmmm.

Int: Around the Earth. So could you show me it's path roughly over that month and, and what we would more or less see at the different positions?

D: Well, I would imagine, and my knowledge of phases of the Moon is uh, not up to date, but I would imagine that it would be moving that way {*moves Moon anti-clockwise around Earth* (**SciOrb)** *but at level well below Earth*}.

Int: OK.

D: I'm not really sure about this. Um obviously over here {*full Moon position*} because there's no light reflecting from the Sun, um so the Moon is behind the Earth **(Alt: Earth blocks Sun's light)** then we would, that would be kind of your eclipse type of thing (**SciPos)**, I would imagine, like your seven (referring to diagram 7 – New Moon - on diagram sheet) where .. just like blackness. So it would go around and come back in the month **(SciOrb)**.

(Donnal:1:1-31)

Int: … you've mentioned, you've mentioned that an eclipse would happen ok, round the, the back there. What do you understand as causes a, a lunar eclipse?

D: I would just say that the, the light um, because now it's, it's right behind the Earth there's nothing reflecting from where the Sun is to the Earth, there's nothing there {*indicates space between Earth and Sun*} in terms of the Moon.

Int: OK.

D: <u>So um, because it's behind we're not getting any kind of reflection from the Sun, and so it will appear as if there is no Moon.</u>

Int: OK, so basically what, what would be blocking the Sun's light that we wouldn't see ..?

D: <u>Well, I'd say the Earth.</u> **(Earth blocks – eclipses)**

Int: The Earth. Ok. And um, … ok you've shown me where it would be. Um, would … ok you've said it goes around the Earth on a monthly basis and at the back there you get … would you get an eclipse every time it goes around the back on a monthly basis?

D: Probably not every time, um because maybe there's, because the Earth and the Sun are also rotating so they … and, and because they rotate at a different rate to the Moon, it's, it's going to be quite seldom that it's in exactly the same position, they're both in exactly the same positions relative to the Sun.

Int: OK.

D: So I would say no, um.. probably.. maybe once a year. I don't really know, but um because of, of them rotating *{shows revolving}* at the same time it's going to be very difficult to repeat that, that regularly.

Int: OK. And um (pause).

D: I vaguely have in the back of my mind some diagrams of .. um prenumbras and goodness knows what else, but what, what ah .. I'd have to look that up to remind myself. (Laughter).

(DonnaI:2-3:42-66)

Extract from Emma's Pre-Intervention Interview

Int: Ok, um, I'm sure you've noticed the different shapes of the Moon that's shown on the diagram sheet-

E: (overlapping) Uhmm hmmm.

Int: Which we call the phases.

E: Ja.

Int: Um, in your questionnaire, you mentioned that it was sort of the, of the positions of the Moon and the Sun that caused the phases**.**

E: <u>Uhmm hmmm</u>**.** (Agrees). **(SciEMS).**

Int: Can you elaborate on that a bit and maybe use the, the model to show me how-

E: (Overlapping). Alright.

Int: Why we would see those different shapes?

(EmmaI:1:1-11)

E: <u>As far.. the way I always saw it, right, if the .. if you've got for example a full Moon, like in six *{refers to Diagram six on the Diagram Sheet, which shows full Moon}.*</u>

Int: Ja.

E: <u>Then there's nothing blocking the, the, the Sun's rays from getting to it. So the whole thing is being reflected</u>**. (Alt: something blocking).**

Int: OK. So where, where would you put the Moon to see *{holds Moon up}* that if this is your Moon and this *{rotates Earth on axis}* is um-

E: (overlapping) OK, well if we see it here, if I put it here *{places Moon in new Moon position},* then it will be .. probably here {*points to diagram sheet and keeps Moon in new Moon position}.*

(EmmaI:1:16-25)

Int: OK. And if it's in this position here {*indicates new Moon position},* can you explain to me what's happening to the light from the Sun that we would see the full Moon?

E: Look, as I understand it, the, the Moon doesn't have its own light-

Int: (Overlapping). Uhmmm Hmmm.

E: Obviously, everything comes from the Sun-

Int: (overlapping) OK.

E: So it's the rays being reflected off the Moon. So for us to see this (the Moon), these rays {*points to Sun}* are being reflected here *{Holds Moon in waning gibbous position and points to side of the Moon facing both Earth and Sun in this position}* so these rays then are reflected to us and then we see this part *{points where she indicated that reflection takes place – on the side of the Moon}.***(SciSee).**

(EmmaI:2:35-45)

Int: So can you show me how it would move .. roughly over that month so that we.. and where we would see the different phases?

E: How would, the Moon would move?

Int: Ja, and, and what shape we would see at which position basically?

E: Mmmmm (laughs). I don't actually have a cooking (indistinct) clue. As far as I think, alright, I know the Sun doesn't move. That I know.

Int: OK.

E: Right and I know that we orbit around the Sun. (Pause).

Int: OK.

E: Right? The Moon? I'm not sure how.. if it moves, how it moves.

Int: OK.

E: I think it moves around us, you know, like this {*shows Moon orbiting Earth in clockwise direction roughly at equator level*}. **(SciOrb).**

Int: … Alright.

E: I'm not sure.

Int: So, assuming it does move like that, then if, if you were to see the full Moon with it placed where you had it here {*indicates new Moon position*}, basically um, from full Moon, what.. what would happen to its shape after full Moon?

E: <u>Oh well, I'd assume it would go half {*indicates last ¼*} and then it would go ¼ {*Indicates waning gibbous – moving Moon clockwise*} and then some nights we don't see it {*Full Moon position indicated*}. Then it will probably be here, because the Sun can't reach it</u>. **(SciOrb).**

Int: OK.

E: <u>And then it will be here. {*shows waxing gibbous*} and then the Sun will also get to part of it. *{Indicates that some of the Sun's rays will be able to move past the Earth to reach the Moon}.*</u> **(SciOrb).**

Int: OK.

E: So we will see a part of it.

Int: Uhmmm Hmmm.

E: Right and then here {*first ¼*} it will get all the rays again and then we will see a full Moon again.

Int: OK. (Coughs). And um, basically when you had it behind the Earth there *{indicates full Moon position – E places Moon at full Moon position}*, why would we not be able to see the Moon there?

E: Because it doesn't get any of the Sun's rays that's being reflected off it.

Int: OK now what, what is the reason that the Sun's rays aren't reaching it?

E: <u>We are blocking it</u>. **(Alt: Earth blocks Sun's rays).**

Int: The … the Earth?

E: <u>Yes</u>. **(Alt: Earth blocks Sun's rays).**

(EmmaI:2-3:52-89)

Int: OK. And then, um, in your questionnaire (long pause – Int looks for comment in questionnaire) um you said that a-a-a, … ok, when you have, have an eclipse you thought the Moon would be basically there {*Places Moon in new Moon position*}. So…

E: No, it's where I said we'd have no Moon.

Int: {M*oves Moon to full Moon position}* (as this is where Emma stated that new Moon would be). Do you think it would be the same, in the same position?

E: No I don't think so. (Pause). Because we don't have an eclipse every time we don't see the Moon.

Int: OK.

E: That I know.

Int: OK.

E: (Laughs).

Int: Um .. so do you, do you think the Moon is there or do you think it might be somewhere else when an eclipse takes place?

E: I think it's there *{Indicates full Moon position}*. It's just, its rays are being blocked or, it's there, we just don't see it. (**SciPos; SciSha).**

Int: And, and what do you think is the difference, if it's in the same position as the new Moon (as indicated by E – actually full Moon position), what, why would we call it an eclipse sometimes-
(Interruption)

E: Sorry?

Int: Um.. why would you think, um it would be… sometimes called an eclipse and others not?

E: That's why it can't be in the same position That's why it can't be in the same position (laughs), because it won't be an eclipse and then no Moon, you know. It can't be. So mmmmm. I don't know. (Laughs)

Int: You're not sure?

E: No.

Int: That's fine. Um, any other ideas or..?

E: Look, I'm not exactly sure how this … how the Moon rotates. I know some planets have nine Moons and some have one and we have one. Um .. I don't know if maybe we rotate around the Moon. We rotate around the Sun, that much I know. (Laughs). I don't know.

Int: Not sure?

E: I don't know.

(EmmaI:4-5:109-140)

APPENDIX D

Scale in the Sun-Earth-Moon System

Activity 1

Astronomical Data

(Sears, F., Zemansky, M. & Young, H.1982. *University Physics (6th Ed.).* Addison Wesley).

Body	Mass (kg)	Radius (m)	Orbit radius (m)	Orbit period
Sun	1,99 x 10^{30}	6,95 x 10^{8}	-	-
Earth	5.98 x 10^{24}	6,38 x 10^{6}	1,49 x 10^{11}	365,3 d
Moon	7,36 x 10^{22}	1,74 x 10^{6}	0,38 x 10^{9}	27,3 d

Aim: Make a scale model of the Earth-Sun-Moon System

1. Refer to the table of astronomical data. Use a scale of 1 m represents 10^{10} m i.e. 1 mm represents 10^{7} m. On this scale, work out the **diameter** (in mm) and the **orbit radius** (in m) of the Sun, Earth and Moon.
2. Make a scale model of the Sun, Earth and Moon, according to the scale calculated in Step 1. Label your models.
3. Find a suitable area outside. Put your models the correct distance apart.
4. Make notes on any difficulties you experienced when making the model or anything that surprised you.

(Activity adapted from Gundry, D. Earth and Beyond: Solar System Models. 2nd year physics curriculum studies notes. University of the Witwatersrand).

Activity 2

An alternative model without using the big numbers!

Use two retort stands, each with a ball hanging from it. One ball is bigger, representing the Earth, and the other ball is smaller, representing the Moon. (Try and make the bigger ball about 3,7 times the size of the other since the Earth's diameter is about 3,7 Moon diameters). Select two learners to hold the models. The teacher explains that the Earth will remain stationary and the class has to decide where the learner holding the Moon needs to stand for the Moon to be roughly the correct distance from the Earth. Once the class have decided, the teacher can ask the 'Moon' learner to move to the correct position, which the teacher will have measured out prior to the lesson. The Sun can now be introduced using the OHP lamp. Again, learners will have to work out how far away the Earth-Moon system will need to be and the teacher can show them once they have agreed on a position.

[Taken from Fanetti, T.M. 2001. The relationships of scale concepts on college age students' misconceptions about the cause of the lunar phases. (Master's Dissertation). Ames, Iowa: Iowa State University].

Phases and Eclipses of the Moon

Activity 3

Aim: Make a model which explains the phases of the Moon, and eclipses

1. Read through the material supplied on phases and eclipses of the Moon. Discuss any questions you may have in your group.
2. Switch off the classroom lights and make the room as dark as possible.
3. Use the overhead projector lamp to represent the Sun. Let your head represent the Earth. Use the white polystyrene balls mounted on wooden sticks to represent the Moon.
4. Use your model to explain the following:
   a. Why does the Moon have different phases?
   b. What happens when there is a lunar eclipse? (In your explanation, include detail about why we don't see lunar eclipses every month).
   c. What happens when there is a solar eclipse?
5. Appoint two people to explain your model to the whole class.

(Activity adapted from Gundry, D. Earth and Beyond: Solar System Models. 2nd year physics curriculum studies notes. University of the Witwatersrand).

Motion and Elevation of the Moon

Activity 4

1. At the time of full Moon, you will see the Moon rising just after sunset. Where would you see the Moon rising?
2. Where does it set?
3. Does it follow the same path in the sky as the Sun?
4. Why do the Sun and Moon rise and set?

The sky ‘moves’ about 15° every hour. This is the speed at which the Earth rotates. In a month, the Earth revolves a little bit and so there are different reports as to how long the Moon takes to revolve around the Earth.

It’s very difficult to picture how the Moon revolves around the Earth (why?), so it is very important to look at the Moon at the **same time** every day. Start at sunset at the time of New Moon.

5. What will the positions of the Sun, Earth and Moon be at New Moon?

The New Moon will be roughly on the horizon. The next day at the same time, it will appear a little higher. When the Moon has completed ¼ of its revolution (known as the 1st quarter) after about a week, it will be at its zenith. A few days later, it will appear as a gibbous Moon. Every night at the same time, the Moon moves further away from the Western horizon and every day it gets bigger (waxing). After approximately two weeks, just after sunset, we will see the full Moon. A week later, we won’t see the Moon at sunset, because it rises later.

{Notes taken from a lecture given by Lee Rusnyak given to 1st year geography in education students, University of the Witwatersrand, 2005}.

APPENDIX E

Information Sheet (Questionnaires – Teachers)

Research Study: Introducing the Moon to Natural Science Classrooms

My name is Lesley Kelfkens and I am an M.Sc. (Science Education) student at the University of the Witwatersrand. I am carrying out a study about the introduction of the geography component ‘Planet Earth and Beyond’, into the natural sciences curriculum.

My research study aims to investigate natural science teachers’ understandings of the Moon’s motion, phases and eclipses and my intention is that it will benefit the South African education system by improving the teaching and learning of natural science. I would value your input and I would like to invite you to participate in this study by completing a questionnaire. The questionnaire contains questions about the Moon’s motion, phases and eclipses, which is one of the core knowledge areas in ‘Planet Earth and Beyond’. There are also questions concerning your views on the inclusion of this component in the natural sciences curriculum. The questionnaire will take about 20 minutes to complete and a suitable and convenient time to complete the questionnaire will be arranged with you. No background reading or preparation is required, as I wish to ascertain teachers’ knowledge, as is.

If you agree to take part in my study, your participation is entirely voluntary, there are no risks to you and all information will be treated with confidentiality and anonymity. If you do choose to participate, you may decline to answer any questions, and you may withdraw from the study at any time. There is no penalty for withdrawing from the study. In order to protect confidentiality, all names used in my research dissertation will be fictitious.

I would be more than happy to provide you with a summary of my research results on completion if you would like me to.

Thank You.
Lesley Kelfkens

Information Sheet (Interviews – Teachers)

Research Study: Introducing the Moon to Natural Science Classrooms

My name is Lesley Kelfkens and I am an M.Sc. (Science Education) student at the University of the Witwatersrand. I am carrying out a study about the introduction of the geography component ‘Planet Earth and Beyond’, into the natural sciences curriculum.

My research study aims to investigate natural science teachers’ understandings of the Moon’s motion, phases and eclipses and my intention is that it will benefit the South African educational system by improving the teaching and learning of natural science. I value your input and I would like to invite you to further participate in this study by partaking in an interview. As a model will be used in the interview, I would like to use video-recording equipment to accurately capture data on how the model is used. You are under no obligation to participate in the interview. This will be entirely at your discretion. The interview contains questions about the Moon’s motion, phases and eclipses, which is one of the core knowledge areas in ‘Planet Earth and Beyond’ and will take about 45 minutes to complete. A suitable and convenient time to complete the interview will be arranged with you.

If you agree to take part in my study, your participation is entirely voluntary, there are no risks to you and all information will be treated with confidentiality and anonymity. Only the researcher will see and hear any recordings made. If you do choose to participate, you may decline to answer any questions, and you may withdraw from the study at any time. There is no penalty for withdrawing from the study. In order to protect confidentiality, all names used in my research dissertation will be fictitious.

I would be more than happy to provide you with a summary of my research results on completion if you would like me to.

Thank You.
Lesley Kelfkens

Information Sheet (Case Study – Teachers)

Research Study: Introducing the Moon to Natural Science Classrooms

My name is Lesley Kelfkens and I am an M.Sc. (Science Education) student at the University of the Witwatersrand. I am carrying out a study about the introduction of the geography component 'Planet Earth and Beyond', into the natural sciences curriculum.

My research study aims to investigate natural science teachers' understandings of the Moon's motion, phases and eclipses and my intention is that it will benefit the South African educational system by improving the teaching and learning of natural science. I value your input and I would like to invite you to further participate in this study by partaking in a case study. This case study will involve five Grade eight teachers from two schools. We will meet for about three sessions, each lasting for a maximum of two hours on a day and time convenient for all case study participants. During these sessions, we will work through Astronomy education materials and use models to explore concepts related to the Moon's motion, phases and eclipses. I would like to videotape these sessions so that I can have an accurate record of how you used the models and materials.

Finally, I would like to come and observe the lessons in which you teach this topic and again make use of video-recording equipment in order to accurately capture how the models and materials are used. These observation sessions are not intended to evaluate your teaching, but merely to see how you used the models and materials from the group sessions in your classrooms.

If you agree to take part in my study, your participation is entirely voluntary, there are no risks to you and all information will be treated with confidentiality and anonymity. Only the researcher will see and hear any recordings made. If you do choose to participate, you may decline to answer any questions, and you may withdraw from the study at any time. There is no penalty for withdrawing from the study and you may keep the resource materials provided. In order to protect confidentiality, all names used in my research dissertation will be fictitious.

I would be more than happy to provide you with a summary of my research results on completion if you would like me to.

Thank You.
Lesley Kelfkens

Information Sheet (Case Study – Learners)

Research Study: Introducing the Moon to Natural Science Classrooms

My name is Lesley Kelfkens and I am an M.Sc. (Science Education) student at the University of the Witwatersrand. I am carrying out a study about the introduction of the geography component ‘Planet Earth and Beyond’, into the natural sciences curriculum.

My research study aims to investigate natural science teachers teaching about the Moon’s motion, phases and eclipses and my intention is that it will benefit the South African educational system by improving the teaching and learning of natural science. I would like to come and observe the lessons in which these topics are taught and make use of video-recording equipment in order to accurately capture the relevant lessons.

If you agree to take part in my study, your participation is entirely voluntary, there are no risks to you and all information will be treated with confidentiality and anonymity. Only the researcher will see and hear any recordings made. If you do choose to participate, you may withdraw from the study at any time. There is no penalty for withdrawing from the study. In order to protect confidentiality, all names used in my research dissertation will be fictitious. This research has the permission of (Principal’s Name) of (School Research Site).

Thank You.
Lesley Kelfkens

Information Sheet (Case Study – Parents of Minor Learners)
Research Study: Introducing the Moon to Natural Science Classrooms

My name is Lesley Kelfkens and I am an M.Sc. (Science Education) student at the University of the Witwatersrand. I am carrying out a study about the introduction of the geography component 'Planet Earth and Beyond', into the natural sciences curriculum.

My research study aims to investigate natural science teachers teaching about the Moon's motion, phases and eclipses and my intention is that it will benefit the South African educational system by improving the teaching and learning of natural science. I would like to come and observe the lessons in which these topics are taught and make use of video-recording equipment in order to accurately capture the relevant lessons.

If you agree to your ward taking part in my study, his/her participation is entirely voluntary, there are no risks to him/her and all information will be treated with confidentiality and anonymity. Only the researcher will see and hear any recordings made. If s/he participates, s/he may withdraw from the study at any time. There is no penalty for withdrawing from the study. In order to protect confidentiality, all names used in my research dissertation will be fictitious. This research has the permission of (Principal's Name) of (School Research Site).

Thank You.
Lesley Kelfkens

Code:

Informed Consent Form (Questionnaires)

Research Study: Introducing the Moon to Natural Science Classrooms

I, ____ consent to participate in this study conducted by Lesley Kelfkens for her research on teaching about the Moon's motion, phases and eclipses.

I realise that no harm will come to me and that the study is being conducted for educational purposes. I participate voluntarily and understand that I may withdraw from the study at any time. I also understand I have the right to review the questionnaires I complete before these are used for analysis if I so choose. I can delete or amend any material. I will only be identified by a pseudonym (a made-up name) in the transcript (write-up).

Verbatim quotes from me may be used in the research report, but they will be reported in such a way that my identity is anonymous. Any specific individuals I refer to will be given pseudonyms. I understand that the results of the study may be published, but my identity will be anonymous. I am aware that permission has been granted by (the GDE / Principal of School) for this research.

Name: ____

Signature: ____

Date: ____________________________

Informed Consent Form (Interviews)

Research Study: Introducing the Moon to Natural Science Classrooms

I, ____ consent to participate in this study conducted by Lesley Kelfkens for her research on teaching about the Moon's motion, phases and eclipses.

I realise that no harm will come to me and that the study is being conducted for educational purposes. I participate voluntarily and understand that I may withdraw from the study at any time. I further consent to being video and audio recorded as part of the study. I also understand I have the right to review the transcripts made of our conversations before these are used for analysis if I so choose. I can delete or amend any material or retract or revise any of my remarks. Everything I say will be kept confidential by the researcher. Any recordings made will only be seen and heard by the researcher. I will only be identified by a pseudonym (a made-up name) in the transcript (write-up). In addition, any persons I refer to at any stage in the study will be kept confidential.

Verbatim quotes from me may be used in the research report, but they will be reported in such a way that my identity is anonymous. Any specific individuals I refer to will be given pseudonyms. I understand that the results of the study may be published, but my identity will be anonymous. I am aware that permission has been granted by the (Principal's Name) of (Name of School) for this research.

Name: ____

Signature: ____

Date: __________________________

Informed Consent Form (Intervention)

Research Study: Introducing the Moon to Natural Science Classrooms

I, ____ consent to participating in the intervention sessions using materials and models conducted by Lesley Kelfkens for her research on teaching about the Moon's motion, phases and eclipses.

I realise that no harm will come to me and that the study is being conducted for educational purposes. I participate voluntarily and understand that I may withdraw from the study at any time. I further consent to being video and audio recorded as part of the intervention. I also understand I have the right to review the transcripts made of the intervention sessions before these are used for analysis if I so choose. I can delete or amend any material or retract or revise any of my remarks. Everything I say will be kept confidential by the researcher. I understand that any recordings made will only be seen and heard by the researcher. I will only be identified by a pseudonym (a made-up name) in the transcript (write-up). In addition, any persons I refer to at any stage in the study will be kept confidential.

Verbatim quotes from me may be used in the research report, but they will be reported in such a way that my identity is anonymous. Any specific individuals I refer to will be given pseudonyms. I understand that the results of the study may be published, but my identity will be anonymous. I am aware that permission has been granted by the (Principal's Name) of (Name of School) for this research.

Name: ____

Signature: ____

Date: __________________________

Informed Consent Form (Classroom Observation – Teachers)

Research Study: Introducing the Moon to Natural Science Classrooms

I, ____ consent to classroom observation conducted by Lesley Kelfkens for her research on teaching about the Moon's motion, phases and eclipses.

I realise that no harm will come to me and that the study is being conducted for educational purposes. I participate voluntarily and understand that I may withdraw from the study at any time. I further consent to being video and audio recorded as part of the classroom observation. I also understand I have the right to review the transcripts made of these classroom observations before these are used for analysis if I so choose. I can delete or amend any material or retract or revise any of my remarks. Everything I say will be kept confidential by the researcher. I understand that any recordings made will only be seen and heard by the researcher. I will only be identified by a pseudonym (a made-up name) in the transcript (write-up). In addition, any persons I refer to at any stage in the study will be kept confidential.

Verbatim quotes from me may be used in the research report, but they will be reported in such a way that my identity is anonymous. Any specific individuals I refer to will be given pseudonyms. I understand that the results of the study may be published, but my identity will be anonymous. I am aware that permission has been granted by (Principal's Name) of (Name of School) for this research.

Name: ____

Signature: ____

Date: __________________________

Informed Consent Form (Classroom Observation – Learners)

Research Study: Introducing the Moon to Natural Science Classrooms

I, ____, agree to participate in the study conducted by Mrs L. Kelfkens for her research on teaching about the Moon's motion, phases and eclipses. I realise that no harm will come to me, and that the study is being conducted for educational purposes. I take part voluntarily and understand that I may withdraw from the study at any time. I further consent to being video and audio recorded as part of the study. Everything I say will be kept confidential by the researcher. I understand that any recordings made will only be seen and heard by the researcher. I will only be identified by a pseudonym (a made-up name) in the transcript (write-up). In addition, any people I refer to at any stage in the study will be kept confidential.

Verbatim quotes from me may be used in the research report, but they will be reported in such a way that my identity is anonymous. Any specific individuals I refer to will be given pseudonyms. I understand that the results of the study may be published, but my identity will be anonymous. I am aware that permission has been granted by (Principal's Name) of (Name of School) for this research.

Name: ____

Signature: ____

Date: ____

Informed Consent Form (Classroom Observation – Parents of Minor Learners)

Research Study: Introducing the Moon to Natural Science Classrooms

I, ____, parent/guardian of my ward ____ consent to her/him participating in the study conducted by Mrs L. Kelfkens for her research on teaching about the Moon's motion, phases and eclipses. I realise that no harm will come to my ward, and that the study is being conducted for educational purposes. I allow my ward to participate voluntarily and understand that s/he may withdraw from the study at any time. I further consent to my ward being video and audio recorded as part of the study. Everything my ward says will be kept confidential by the researcher. I understand that any recordings made will only be seen and heard by the researcher. My ward will only be identified by a pseudonym (a made-up name) in the transcript (write-up). In addition, any persons my ward refers to at any stage in the study will be kept confidential.

Verbatim quotes from my ward may be used in the research report, but they will be reported in such a way that her/his identity is anonymous. Any specific individuals my ward refers to will be given pseudonyms. I understand that the results of the study may be published, but my ward's identity will be anonymous. I am aware that permission has been granted by (Principal's Name) of (Name of School) for this research.

Name: ____

Signature: ____

Date: ____

APPENDIX F

PO Box 10869 Vorna Valley 1686		Phone: (011) 315-0467 Cell: 082 330-1040 E-mail : Lesley@kelfkens.com

To:		**From:**	Lesley Kelfkens
Fax:		**Date:**	
Phone:		**Pages:**	
Re:	Research Request	**Att:**	**HOD Natural Science / Science**

Dear *Sir / Madam*.

I am currently doing my Master's in Science Education at the University of the Witwatersrand. As part of the course, I am required to do a research dissertation on an aspect of Science Education. Detail about my research is provided on the attached information sheet.

I am looking for teachers who teach Grade 8 or 9 science / natural science to participate in a questionnaire, which will take approximately 20 minutes to complete. Permission has been granted by the GDE to conduct this research in GDE schools and I will provide a copy of their permission letter to the Head of Department and the School Principal.

I would be honoured if you and / or any of your colleagues would be prepared to complete this questionnaire. Any teachers who agree to complete the questionnaire must please do so by their own choice. Please can you let me know by **Monday the 18th of September**, how many teachers would be willing to complete the questionnaire (by phone, sms or email) and I will deliver the appropriate number of questionnaires to you and collect them again on completion.

Thanking you in anticipation.
Kind Regards,
Lesley Kelfkens

APPENDIX G

	Motion					Phases														
	1																			
	a	b	c	e	1d	2						3					4			
	F	T	F	T	T	A	B	C	D	E	F	A	B	C	D	E	A	B	C	D
1																				
2																				
3																				
etc																				

	Phases				Coding for Phases											
	5															
	SciEMS	SciOrb	SciHaf	SciSee	Scientific	Sci Fragments	Sci with Misconceptions	Alt Eclipse	Alt Sun's Shadow	Alt Earth's Rotation	Alt Moon's Rotation	Alt Sun's position	Alt Sun's distance to Moon	Alt:Time of Month	NoCU	Comments
1																
2																
3																
etc																

	Eclipses				Coding for Eclipses						
	Qu 6 & 7										
	SciAli	SciPos	SciSha	SciDPE	Scientific	3 frags	1 or 2 frags	Alt Solar Eclipse	Alt Sun blocks Moon	No CU	Comments
1											
2											
3											
etc											

Background Questions																																Coding for Background Qu 5						Coding for Background Question 6								
Qu 1		Qu 2							Qu 3							Qu 4						Qu 5					Qu 6																			
Gender		No of years taught NS							Studied anything on Moo							Taught anything abou						How confident do					How important is Planet Earth & Beyond for NS curriculum?																			
Male	Female	<1	1 - 5	6 - 10	11 - 15	16 - 20	21-29	30+	No	School	Uni	Fam	Friends	Other	Other - comment	No	Motion	Phases	Eclipses	Other	Specify	Not at all	Not very	Not sure	Confident	Very confident	Not at all	Not very	Not Sure	Important	Very NB	Research	Prior Knowledge	Currently Teaches this Content	Taught Elsewhere	Minimal Background	Learner Issues	Geography	Integrated Teaching	Learner Benefits	Other Benefits	Teachers Unprepared	Repetition	Time Issue	Rote Learning	Not Relevant

APPENDIX H

UMnyango WezeMfundo
Department of Education

Lefapha la Thuto
Departement van Onderwys

Date:	19 August 2006
Name of Researcher:	Kelfkens Lesley
Address of Researcher:	3 Hoogenhout Street
	Vorna Valley
	Midrand 1686
Telephone Number:	(011) 3150467
Fax Number:	(011) 3150467
Research Topic:	Introducing the Moon to South African Natural Science Classroom
Number and type of schools:	Secondary Schools
District/s/HO	Johannesburg East, South, West & North and Ekurhuleni East and West

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

Permission has been granted to proceed with the above study subject to the conditions listed below being met, and may be withdrawn should any of these conditions be flouted:

1. ***The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.***
2. ***The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.***
3. ***A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.***

Office of the Senior Manager – Strategic Policy Research & Development
Room 525, 111 Commissioner Street, Johannesburg, 2001 P.O.Box 7710, Johannesburg, 2000
Tel: (011) 355-0488 Fax: (011) 355-0286

ST STITHIANS COLLEGE

A South African School Making a World of Difference

17 July 2006

Ms Lesley Kelfkens
MSc Student
University of the Witwatersrand
P O Box 10869
VORNA VALLEY
1686

Fax: 011-315-0467

Dear Ms Kelfkens

YOUR RESEARCH REQUEST

You are referred to your letter dated 03 July 2006.

In terms of the St Stithians Educational Surveys Policy (copy attached for easy reference) and following liaison with the Head of the Boys' College (Mr Ian McLachlan), I hereby grant permission for you to undertake the proposed educational research at St Stithians Boys' College.

May I please draw your attention to Point 3 of the policy and ask you to ensure that you comply fully with the details requested; and that you adhere to Points 5 & 6 of the policy.

Further, should you intend writing to any parents/ staff/ students about this research, kindly have the draft correspondence approved by Mr McLachlan and include a sentence in your letter advising them that permission for the research has been granted by the Rector and Head of the Boys' College, on condition that you comply with the College's Educational Surveys Policy.

It would be appreciated if you would liaise further with the Boys' College Headmaster about this project (Tel: 011-577-6207).

I look forward to reading the results of your research and wish you every success.

Yours sincerely

STEPHEN LOWRY
RECTOR

TEL: 011-577-6387/6300
E-MAIL: rector@stithian.com
FAX: 011-789-7519

cc Mr I McLachlan

St Teresa's Mercy School

MERCY

6 July 2006

TO WHOM IT MAY CONCERN

Re: Educational Research Request from Lesley Kelfkens.

Our school has been approached by Ms L. Kelfkens to use our school as part of her case study in the teaching and learning of Natural Science.

I hereby grant permission for St Teresa's Mercy School in Rosebank to be used as a research site and for our Grade 8 Teacher, Mrs. L. Botha, to be involved in the study.

I furthermore give Ms. Kelfkens permission to use video and audio recording equipment in the process of the research.

Yours sincerely

Sr Barbara

Sr. Barbara
Principal

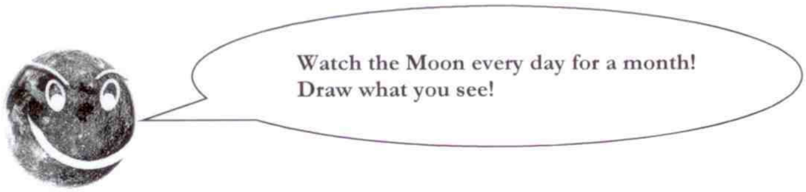
Junior Primary
30 Rutland Avenue, Craighall Park
P O Box 41082, Craighall, 2024
☎ (011) 442-9127 (011) 788-7943
e-mail: juniorprimary@stteresas.co.za

Senior Primary
14 Keyes Avenue, Rosebank
P O Box 445, Parklands, 2121
☎ (011) 447-1446 (011) 447-4571
e-mail: senior-primary@stteresas.co.za

High School
18 Keyes Avenue, Rosebank
P O Box 445, Parklands, 2121
☎ (011) 442-6235 (011) 447-2576
e-mail: principal@stteresas.co.za

APPENDIX I

Worksheet 1: I Saw the Moon



The Moon I saw Date:__________ Time:__________	The Moon I saw Date:__________ Time:__________	The Moon I saw Date:__________ Time:__________	The Moon I saw Date:__________ Time:__________
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HARTRAO (no date)

REFERENCES

Aldous, C. 2004. Science and mathematics teachers' perceptions of C2005 in Mpumalanga secondary schools. African Journal of Research in Mathematics, Science and Technology Education, **8**(1), 65-76.

Appleton, K. 1995. Student teachers' confidence to teach science: is more science knowledge necessary to improve self-confidence? *International Journal of Science Education*, **17**(3), 357-369.

Atwood, R.K. & Atwood, V.A. 1996. Preservice elementary teachers' conceptions of the causes of seasons. *Journal of research in science teaching,* **33**(5), 553-563.

Bailey, J.M. & Slater, T.F. 2003. A review of astronomy education research. *Astronomy Education Review*, **2**(2), 20-45.

Barnett, M., Keating, T., Barab, S.A. & Hay, K.E. 2000. Conceptual change through building three-dimensional virtual models. IN: *Proceedings of the Fourth International Conference of the Learning Sciences.* Mahwah, NJ: Erlbaum. (pp 131-141)

Barnett, M. & Morran, J. 2002. Addressing children's alternative frameworks on the Moon's phases and eclipses. *International journal of science education,* **24**(8), 859-879.

Brown, S. J., Collins, A. & Duguid, P. 1989. Situated cognition and the culture of learning. *Educational Researcher*, **18**(1), 32-42.

Brunsell, E. & Marcks, J. 2005. Identifying a Baseline for Teachers' Astronomy Content Knowledge. *Astronomy Education Review,* **3**(2), 38-46.

CAER. 1999. Introductory Astronomy Survey. Version 2.0. Collaboration for Astronomy Education Research. Retrieved 29 June 2005 from the World Wide Web: http://solar.physicsmontana.edu/aae/adt/ADTv2.0.PDF.

Callison, P.L. & Wright, E.L. 1993. The Effect of Teaching Strategies Using Models on Preservice Elementary Teachers' Conceptions about Earth-Sun-Moon Relationships. Paper presented at the National Association for Research in Science Teaching Annual Meeting, April 15-18, 1993, Atlanta, Georgia.

Cameron, A. & Lelliott, A. 2006. Lost in space. An investigation into selected astronomy concepts held by students at two levels in the South African educational system. In Proceedings of the 14th Annual SAARMSTE Conference. Pretoria: University of Pretoria. (pp. 219-226).

Carr, M., Barker, M., Bell, B., Biddulph, F., Jones, A., Kirkwood, V., Pearson, J. & Symington, D. 1994. The Constructivist Paradigm and Some Implications for Science Content and Pedagogy. Chapter 11. IN: Fensham, P., Gunstone, R. & White, R. 1994. *A constructivist approach to teaching and learning.* London: Falmer Press.

Cobb, P. & Bowers, J. 1999. Cognitive and Situated Learning Perspectives in Theory and Practice. *Educational Researcher,* **28**(2), 4-15.

Comins, N.F. No date. Heavenly Errors. Our Moon: Phases and Motion. Retrieved 15 March 2006 from the World Wide Web: http://www.physics.umaine.edu/ncomins/Moons.htm#phases

Cooley, K. 2001. Moon Phases. Retrieved 23 November 2007 from the World Wide Web: http://home.hiwaay.net/~kcool/Astro/Moon/Moonphase/

Department of Education. 2002. Revised National Curriculum Statement for Grades R – 9 (Schools) Natural Sciences. *Gazette No 23406,* **443**, 1-89. Cape: FormeSet Printers.
http://education.pwv.gov.za/documents/12.pdf (23 June 2005).

Driver, R., Guesne, E. & Tiberghien, A. 1985. Children's Ideas and the Learning of Science. Chapter 1. IN: Driver, R., Guesne, E. & Tiberghien, A. 1985. *Children's Ideas in Science.* Milton Keynes: Open University Press. (pp. 1-9).

Dunlop, J. 2000. How Children Observe the Universe. *Publications of the Astronomic Society of Australia,* **17**(2), 194-206.

Fanetti, T.M. 2001. The relationships of scale concepts on college age students' misconceptions about the cause of the lunar phases. Unpublished Master's Thesis. Ames: University of Iowa.

Fraenkel, J. & Wallen, N. 1990. Survey Research. Chapter 15. In: *How to design and evaluate research in education.* New York: McGraw-Hill. (pp. 330-335).

Gundry, D.L. 2005. Earth and Beyond: Solar System Models. School of Education, University of the Witwatersrand. (Handout issued to B.Ed. students completing a second-year physics curriculum studies course (2pp)).

Gundry, D.L. 2007. Coding: an e-mail requesting me to clarify some coding issues which had arisen during cross-checking. (9 August 2007)

Gundry, D.L. 2007. Coding: an e-mail containing my coding cross-checker's comments and coding. (12 September 2007)

Hammersley, M. 1987. Some Notes on the Terms 'Validity' and 'Reliability'. *British Educational Research Journal,* **13**(1), 73-81.

Hanks, W.F. 1991. foreward to Lave, J. & Wenger, E. 1991. *Situated learning: Legitimate peripheral participation* Cambridge: Cambridge University Press. (pp. 13-24).

HARTRAO. No Date. Astronomy Notes for Educators. The Moon. (pp. 1-18).

Hatch, J.A. 2002. Analyzing Qualitative Data. Chapter 4. IN: *Doing qualitative research in educational settings.* New York: SUNY (pp 147-210).

Hattingh, A., Rogan, J.M., Aldous, C., Howie, S. & Venter, E. 2005. Assessing the attainment of learner outcomes in Natural Science of the New South African Curriculum. *African Journal of Research in Mathematics, Science and Technology Education*, **9**(1), 13-24.

Henning, E. 2005. *Finding your way in qualitative research.* 1st Ed. 3rd Imp. Pretoria: Van Schaik Publishers.

Jenkins, E.W. 2000. The impact of the national curriculum on secondary school science teaching in England and Wales. *International Journal of Science Education,* **22**(3), 325-336.

Kelfkens, L. 2005. Seeing the Crescent Moon or Full Moon? An investigation into student-teachers' understandings of the phases of the Moon. Research

Report for B.Sc. Honours degree: University of the Witwatersrand, South Africa.

Kelfkens, L. & Lelliott, T. 2006. Seeing the Crescent Moon or Full Moon? An investigation into student-teachers' understanding of the phases of the Moon. In Proceedings of the 14th Annual SAARMSTE Conference. Pretoria: University of Pretoria. (pp. 402-412).

King, C. 2001. The Response of Teachers to New Subject Areas in a National Science Curriculum: The Case of the Earth Science Component. *Science Education,* **85**(6), 636-664.

Lave, J. 1996. Teaching, as learning, in practice. *Mind, Culture and Activity,* **3**(3), 149-164.

Leedy, P. 1997. Planning your Research Design. Chapter 5. In: *Practical research planning and design.* New York: Macmillan. (pp. 105-108).

Lemmer, M., Lemmer, T.N & Smit, J.J.A. 2003. South African student's views of the universe. *International Journal of Science Education,* **25**(5), 563-582.

Mant, J. & Summers, M. 1993. Some primary-school teachers' understanding of the Earth's place in the universe. *Research Papers in Education,* **8**(1), 101-129.

Mishler, E.G. 1990. Validation in Inquiry-Guided Research: The Role of Exemplars in Narrative Studies. *Harvard Educational Review,* **60**(4), 415-442.

Mousley, J.A. 2003. Mathematical and Pedagogical Understanding as Situated Cognition. In: Pateman, N.A., Dougherty & B.J., Zilliox, J.T. (Eds.).

Proceedings of the 2000 Joint Meeting of PME and PMEVA, **3**, University of Hawaii.

Mulhall, P., Berry, A. & Loughran, J. 2003. Frameworks for representing science teachers' pedagogical content knowledge. *Asia-Pacific Forum on Science Learning and Teaching*, **4**(2,2), 1-25.

Opie, C. 2004. What is Educational Research? Chapter 1. In Opie, C. (Ed). *Doing educational research.* London: Sage Publications Ltd. (pp. 1-14).

Opie, C. 2004. Research Approaches. Chapter 5. In Opie, C. (Ed). *Doing educational research.* London: Sage Publications Ltd. (pp. 73-94).

Opie, C. 2004. Research Procedures. Chapter 6. In Opie, C. (Ed). *Doing educational research.* London: Sage Publications Ltd. (pp. 95-129).

Parker, J. & Heywood, D. 1998. The earth and beyond: developing primary teachers' understanding of basic astronomical events. *International Journal of Science Education,* **20**(5), 503-520.

Rogan, J.M. 2004. Out of the frying pan …?: Case studies of the implementation of Curriculum 2005 in some science classrooms. African Journal of Research in Mathematics, Science and Technology Education, **8**(2), 165-179.

SABER Astronomy. 2006. Astronomy Education Research: An Annotated Bibliography. Retrieved 27 March 2007 from the World Wide Web: www.astronomy.uwp.edu/saber/biblio.pdf.

Scaife, J. 2004. Reliability, Validity and credibility. Chapter 4. In Opie, C. (Ed). *Doing educational research.* London: Sage Publications Ltd. (pp. 58-72).

Schoultz, J., Säljö, R. & Wyndhamn, J. 2001. Heavenly Talk: Discourse, Artifacts, and Children's Understanding of Elementary Astronomy. *Human Development* **44**, 103-118.

Shulman, L.S. 1986. Those who understand: Knowledge growth in teaching. *Educational Researcher,* **15**(2), 4-14.

Sikes, P. 2004. Methodology, Procedures and Ethical Concerns. Chapter 2. In Opie, C. (Ed). *Doing educational research.* London: Sage Publications Ltd. (pp. 15-33).

Stahly, L.L., Krockover, G.H. & Shepardson, D.P. 1999. Third grade students' ideas about the lunar phases. *Journal of Research in Science Teaching,* **36** (2), 159-177.

Stake, R.E. 1995. The Unique Case. Chapter 1. In: *The Art of Case Study Research*. Thousand Oaks: Sage Publications. (pp. 1-13).

Stake, R.E. 1998. The Case Study Method in Social Inquiry. *Educational Researcher,* **7**(2), 5-8.

Summers, M. & Mant, J. 1995. A survey of British primary school teachers' understanding of the Earth's place in the universe. *Educational Research,* **37**(1), 3-19.

Suzuki, M. 2003. Conversations About the Moon with Prospective Teachers in Japan. *Science Education,* **87**(6), 892-910.

Trumper, R. 2001. A cross-age study of junior high school students' conceptions of basic astronomy events. *International Journal of Science Education,* **23**(11), 1111-1123.

Trundle, K.C., Atwood, R.K. & Christopher, J.E. 2002. Pre-service Elementary Teachers' Conceptions of Moon Phases before and after Instruction. *Journal of Research in Science Teaching*, **39**(7), 633-658.

Trundle, K.C., Atwood, R.K. & Christopher, J.E. 2007. A Longitudinal Study of Conceptual Change: Pre-service Elementary Teachers' Conceptions of Moon Phases. *Journal of Research in Science Teaching*, **44**(2), 303-326.

Van Driel, J.H., Verloop, N. & De Vos, W. 1998. Developing Science Teachers' Pedagogical Content Knoweldge. *Journal of Research in Science Teaching,* **35**(6), 673-695.

Van Teijlingen, E.R. & Hundley, V. 2001. The importance of pilot studies. *Social Research Update*, **35**, 1-4. Retrieved 25 January 2008 from the World Wide Web: http://sru.soc.surrey.ac.uk/sru35.pdf.

Vosniadou, S. & Brewer, W.F. 1994. Mental models of the day/night cycle. *Cognitive Science,***18**(1), 123-183.

Vosniadou,S., Skopeliti, I. & Ikospentaki, K. 2005. Reconsidering the role of artefacts in reasoning: Children's understanding of the globe as a model of the Earth. *Learning and Instruction* **15**, 333-351.

Wikipedia. 2008. Apollo Moon Landing Hoax Theories. Retrieved 1 March 2008 from the World Wide Web: http://en.wikipedia.org/wiki/Apollo_Moon_Landing_hoax_accusations.

Whitehouse, D. 2001. *The Moon. A Biography.* London: Headline Book Publishing.

Yin, R.K. 1994. Analyzing Case Study Evidence. Chapter 5. In: Yin, R.K. 1994. *Case Study Research: Design and Methods.* 2nd Ed. Thousand Oaks: Sage Publications. (pp. 102-126).