OUTLINE OF THESIS

This thesis is presented as six chapters, some of which contain several sections. These are followed by the list of references, and finally the appendices, which contain examples of the research instruments and extracts showing the analysis of the data.

The chapters are presented as follows:

In quoting from the data, codes or pseudonyms have been used in accordance with University of the Witwatersrand ethics requirements to protect the identity of the respondents. All quotes have been transcribed as written by the students, without any correction of spelling or grammatical errors. Where possible, the data (particularly the interviews) have been checked by the participants and have been used in this thesis with their permission.

The terms that have been used in this thesis conform to common usage of these terms in the science education literature. However, in some cases, these make use of the negative as a ‘catch all’ phrase, for example ‘non-Western’ or 'non-Christian'. In South Africa, the negative has carried a racist connotation in some cases, for example the use of ‘non-European’ as a descriptor for Black South Africans, where the use of the 'non' acted to create an inferior 'other'. Consequently 'South African' or 'African' have been used wherever possible, with Black, White and Indian being used to denote the different race groups making up the research sample. The capitalization of these descriptors is extended to the use of 'Western' as opposed to 'African' beliefs or epistemology or science, and to proper nouns such as the 'Earth', 'Moon' and 'Sun'.

This thesis supports the call to recognize and value other ways of knowing and suggests a simple way to act on this that will not compromise the personal beliefs of the educator or student, but act to prevent the erection of barriers to learning and possibly serve to reduce those that already exist.

CHAPTER 1

INTRODUCTION

CHAPTER 1

> "A lot of White people – this is what I think and it makes sense to me – basically, I think a lot of White people, they understand this Universe thing well than a lot of us Black people. I don't know why… I don't know why it's like that. They seem to have a better understanding of this solar system, Universe, everything like that. I've tried to understand why it's like that, but I have been failing to. But, that's what I think. And they always show interest… you know? There is a major difference though, between a Black man trying to show interest in the Universe and things like that – you know, the solar system and the stars, things like that … but for White people, they always show that kind of interest – they even understand it better. They can even explain it to you and maybe you will get something you maybe didn't even know."
>
> (Madala, interview, 2004)

1.1 BACKGROUND

1.1.1 South Africa

It has long been a cause for concern in science education that learners who come from a background based in traditional culture appear to struggle more than their Western counterparts in the meaningful learning of science (Abimbola, 1977; Adeyinka, Kyeleve and Yandila, 1999; Aikenhead, 1996; Ogunniyi, 1995). In South Africa, recent research into the state of science and mathematics education by the Centre for Development and Enterprise (CDE), described the poor performance and participation in mathematics and science as a 'national crisis', with the effects being "most evident in respect of African learners" (Bernstein, Clynick and Lee, 2004, 23). In 2002, only 7 129 African learners passed Higher Grade science[1], representing only 14% of the total number of Senior Certificate passes (*Ibid*.)[2]. Concern about the poor quality of teaching and learning is shared by politicians, parents, economists, business people and universities, with the low numbers of graduates in mathematics and science being seen as "holding back African advancement" and "placing a huge obstacle in the way of achieving almost all the government's ambitions to open up vast new areas of opportunity for Black South Africans" (*Ibid*.). The common purpose of initiatives in South Africa to improve mathematics and

[1] "Science" refers to Physical Science in terms of the South African curriculum. Physical Science is usually simply referred to as 'science', while Biological Science is referred to as 'biology' and Earth Science is included in 'geography'.

[2] Similar demographic statistics for 2005 / 6 were unobtainable, but the pass rate overall for Higher Grade Physical Science at matric level in 2005 was 48% (Department of Education statistics, accessed through the Independent Schools Association of South Africa, 30th November, 2006).

science education is related to the “fact that these subjects are increasingly important to any economy that wishes to compete in the global economy” (*Ibid*., 5), indicating that these initiatives have economic advancement as a common driver.

The consequence of the results of research such as that conducted by the CDE, which highlights the low levels of achievement in these subjects is further research, directed at improving teaching and learning in these areas. This includes studies which focus on multicultural education, where the potential effect of worldview on learning is investigated. In this context, issues that may form barriers to learning - and how to overcome them - come under the spotlight, but broader issues are also raised, such as questions regarding the unexamined extension of the hegemony of Western science in comparison to other ways of knowing.

South African society is enormously diverse in terms of culture, and since South Africa’s historic change to a democratic government in 1994, the development of the national education policy has been transformed as a result of its alignment with South Africa’s internationally acclaimed constitution which gives status and recognition to people regardless of race, gender or religion. The apartheid era educational system, Christian National Education (CNE) - one of the most important apartheid structures to be dismantled after the 1994 elections - has been replaced with Outcomes Based Education (OBE) which has been designed to be culturally sensitive and to address the inequalities of the past. Because OBE is based on a constructivist approach, the focus is on learning which builds on prior knowledge, as well as on learning outcomes, rather than on transmission and the assessment of rote learning.

One of the most exciting developments in the new curriculum has been the explicit recognition of the presence of ‘other ways of knowing’ in South Africa’s ‘Rainbow Nation’. These 'other ways of knowing', or as they are becoming commonly known, Indigenous Knowledge Systems (IKS), have been described in the Revised National Curriculum Statement (RNCS, which covers Reception to Grade 9), as “a body of knowledge embedded in African philosophical thinking and social practices that have evolved over thousands of years” (Department of Education, 2002 (a), 9). The importance of these other worldviews is recognized in Learning Outcome 3 in the RNCS for the Natural Sciences, while in the National Curriculum Statement (NCS) which provides the curriculum for Grades 10 to 12, the need to value indigenous knowledge is given as one of the underlying principles of the new curriculum (Department of Education, 2003). The draft document of the NCS (Department of Education (b), 2002) required that these culturally based 'other ways of knowing' should be 'recognized and valued'. This wording was somewhat altered in the final NCS document (Department of Education, 2003), to state that the wide diversity of knowledge systems through which people made sense of, and attached meaning to the world in which they live, was to be recognised, and that the NCS had 'infused' IKS into the subject statements. However, the implicit requirement that there should be recognition or at least acknowledgement, if not valuing, of these 'other ways of knowing', remains embodied in the principles of this curriculum. Yet neither the RNCS nor the NCS provide any guidelines on how these other worldviews should be acknowledged, nor how IKS should be incorporated into a science curriculum that continues to be based on a positivist Western epistemology.

This study, which falls into the broad spectrum of research in multiculturalism in science education, is an investigation of the cultural barriers to learning experienced by South African university foundation and first year students, in a course in basic astronomy offered at the University of the Witwatersrand. Astronomy is an ancient science, with knowledge of the heavenly bodies stretching back into the written and oral histories of past cultures. But it is also an ultra-modern science that has allowed for manned space travel and the means to explain the formation of the Universe and the solar system. This modern 'Western' science has enabled us to collect Moon rocks and perform laser surgery on human foetuses; it has created genetically modified foods, satellite television and cellular phones, as well as weapons of mass destruction and global warming. It has created a knowledge system that is different and separate from the traditional knowledge systems that have evolved over thousands of years - and in a relatively short time, it has been disseminated by colonialism and entrenched by globalization in countries all over the world. This has meant that in formal educational environments around the world, Western science is privileged over traditional knowledge, including in multicultural situations like South Africa.

1.1.2 Astronomy education

In South Africa, the scientific explanations for natural phenomena such as day and night, the seasons, phases of the Moon, eclipses, the stars, and our home galaxy, the Milky Way, have historically formed part of the geography curriculum at both primary and high school levels. However, despite this intended provision for a good grounding in basic astronomy at school level, many students finish school with a very weak background knowledge in this area (Summers and Mant, 1995; Atwood and Atwood, 1996; Trumper, 2001; Mosoloane and Stanton, 2005; Kelfkens and Lelliott, 2006). In the context of this study, of first year and foundation students who were taking a course in basic astronomy ('The Earth in Space'), it appeared that the Black students struggled far more than their White counterparts in being able to learn and understand the content of the course.

International research in astronomy education has indicated that irrespective of culture, human experience produces a pre-Copernican understanding of the Earth as a cosmic body: the modern scientific conception of a heliocentric Solar System is counter-intuitive and abstract, and can only become part of the learner's body of knowledge through explicit teaching and learning. The weak background knowledge encountered in the students in this study may thus be ascribed to inappropriate or inadequate teaching at school level, especially in South Africa, where the political agenda of the apartheid era limited the teaching of mathematics and science to the majority of its Black population, creating a negative legacy that is likely to continue its impact for generations to come. However, science education research in international multicultural situations has suggested that conceptual difficulties could be related to the idea that “the learner’s understanding of any new meaning is strongly influenced and determined by prior knowledge that is in turn determined by cultural beliefs, traditions and customs governed by a world view”[3] (Jegede, 1998, 160). It has thus been suggested that in traditional societies, cultural beliefs can impede the construction of scientific concepts. It has even been suggested that traditional cultural understandings can result in scientific explanations being seen as a “pack of lies” (Abimbola, 1977).

Much research has been conducted internationally in the rapidly growing field of astronomy education[4]. However, there is little empirical research that has been published in this field in South Africa. There are currently a few post-graduate studies being conducted, with findings being reported at local annual conferences such as the Southern African Association for Research in Mathematics, Science and Technology Education (SAARMSTE), the Geoscience Africa Conference (Cameron, 2004) and the South African Association of Science and Technology Educators (SAASTE) conference. These include, for example Cameron, Doidge and Rollnick (2003), Lelliott, Rollnick and Pendlebury (2005), Mosoloane and Stanton (2005), Cameron, Rollnick and Doidge (2005), Mosoloane, Sanders and Stanton (2006), Kelfkens and Lelliott (2006), and Cameron and Lelliott (2006). While the fairly recent review of research in astronomy education by Bailey and Slater (2003) contains no reference to research in astronomy education in Africa at all, there have been some studies in African cosmology which have appeared in the Science Education literature, notably those by Ogunniyi (e.g. 1987 and 1996). However, these have focused on issues of worldview related to learning in science, rather than investigating misconceptions or interventions specifically related to astronomy education.

1.1.3 The current study

The students who formed the sample for this study were either registered as mainstream first year Geology students in the Faculty of Science at the University of the Witwatersrand, or were registered in one or other of two access courses: the ‘College of Science’, an access programme in the Faculty of Science, or ‘Geography Preliminary’, an access course in the Faculty of Humanities. The access courses, which provide an opportunity for entry for students who did not achieve the university’s requirements in terms of matric points[5], focus on the development of content and subject skills. Although

[3] worldview, as defined by Ogunniyi (1995, 1), refers to “a set of beliefs or dynamically interrelated assumptions held by a people about the basic nature of reality and their response to that reality. It is a cultural framework that determines the likelihood in which a new idea is accepted or rejected."

[4] Bailey and Slater (2003) provide a recent review of this research.

[5] South African universities assign points to levels of attainment in school subjects in the national exit exam (matric). The points achieved for each subject taken are totaled and allow access according to university requirements.

there are a growing number of White students who are selected for these courses, the majority of the students are Black South Africans, who tend to come from traditionally disadvantaged education situations. Many have strong cultural ties, although urbanization and western education have led to the dilution, to varying degrees, to contact with and affiliation to traditional understandings and ways of life.

As part of their first year at university, all these students take a course in basic astronomy as a refresher course to ensure sound foundational knowledge for a potential degree in Geography or Geology. Matric Geography is not a requirement for registration, which means that the students begin 'The Earth in Space' course with widely varying levels of geographic knowledge. However, all the students should have encountered the scientific explanations for common natural phenomena such as day and night, the seasons, eclipses, tides, and the concept of the Earth as a member of the Solar System, during the time they were in primary school and up to the end of Grade 9. They would thus have covered these basic astronomy concepts before being required to make matric level subject choices.

"The Earth in Space" course is taught separately to each of the groups making up the sample, and while the same basic content is covered, it is tailored differently for the different groups. The Geography Preliminary course, for example, is more descriptive and less detailed than the College of Science and Geology mainstream courses. The reason for this is that the Geography Preliminary students, unlike the students registered in the other two courses, are not required to have matric level Mathematics, and tend to be weaker academically than students registered for the other two courses. However, what was common to all the students regardless of which group they belonged to, was that they seemed to struggle with understanding many of the concepts presented in the course. The question was: was this difficulty related to poor or no teaching in this area at school? Was it due to rote learning? Was it due to language difficulties? Or could it be associated with difficulties related to a difference in worldview, as suggested in the science education literature? If so, how could this particular aspect be applied to improving the pedagogic practice and curriculum development at university to enhance learning for these students?

1.2 THE RESEARCH PROBLEM

Science, or ‘Western Modern Science’ as it has come to be known (Cobern, 1998), has also come to be regarded as a ‘culture’ in its own right. In contrast to traditional cultures, which are said to have an anthropomorphic worldview which is holistic and links the spiritual and the physical (Ogunnyi, 2002), science is regarded as having a mechanistic worldview associated with dualism (Maddock, 1981, Ogunnyi, 2002). Differences in the ontology and epistemology associated with these two worldviews have come to be regarded as lying at the heart of learning difficulties experienced by students whose life-worlds lack congruence with the world of Western science. The ‘Earth in Space’ course covers theories that provide the Western science perspective on the formation of the Universe and the Solar System. The ontology and epistemology from which these theories have arisen is in contrast with that of traditional African culture [6] (Ogunnyi, 2002). Most of the students taking the course were Black South Africans. This implied that their prior knowledge, with its cultural basis, would, as suggested by Jegede (1998), be a 'handicap' in their learning of science. Since the course presents scientific explanations that may clash with the previously held beliefs of these students, “collateral learning" (Jegede, 1995) and “cultural border crossing” (Aikenhead, 1996), two theories (explained in section 2.7) which highlight and explain how students deal with conflicting knowledge systems, and are able (or not able) to move between them, were seen as potentially fruitful as a theoretical framework to provide insight into the difficulties experienced by these students in the course. African culture may also, however, as in the African Independent Church movement, incorporate religious beliefs associated with African Traditional Religion (ATR) as well as Christianity.

Research reported in the science education literature on learning in multicultural situations has tended to focus on culture rather than specifically on religion. While religious beliefs may implicitly be part of the broad definition of 'culture' and 'worldview', the significance of religion as a belief system that helps to shape this worldview, and the impact that this may have on learning in science, has only irregularly been brought to attention in the international science education literature. The interface between science education and religion is more frequently reported in journals where the emphasis is on *religion* rather than on science, for example *Religious Education.* There is also a journal, *Zygon*, which specifically deals with the relationship between science and religion. However, the articles in these journals lie outside of the core science education discourse, and are likely to be accessed only by individuals with an interest in the relationship between science and religion. In 1996, *Science & Education* produced a special edition (Volume 5 No. 2) on "Religion and Science Education", which in keeping with its focus on the History and Philosophy of Science (HPS) and the Nature of Science (NOS), consisted of position papers in response to the logical positivist philosophy of the lead article by Mahner and Bunge (1996). Papers reporting on the impact of religion on learning in science in other science education journals have been far less conspicuous. Examples include the work of Jackson, Doster, Meadows and Wood (1995), Cobern (e.g. 1995, 1996), Roth and Alexander (1997), Stanley and Brickhouse (2001), and Shipman, Brickhouse, Dagher and Letts (2002). Other papers, such as that by Oulton, Dillon and Grace (2004), have focused more generally on the impact of controversial issues on teaching and learning. However, all these studies, and the views expressed in them, have been in the context of the First World.

Research in African countries into the effect of culture on learning in science has rarely specifically addressed religion as a separate issue from culture. For example, Shumba’s-(1999) study, concerning the relationship between Zimbabwean science teachers' cultural beliefs and their teaching ideology, did not address the potential impact or effect of their

[6] For a philosophical discussion regarding 'African culture', see Wiredu (1980); a short and helpful definition is provided by Manzini (2000).

Christian beliefs - in contrast to their cultural beliefs - even though the majority of the sample (84%) reported Christianity as their religion. African cultural beliefs are different to Christian beliefs, however, so the apparent lack of awareness of potentially different responses as a result of these different belief systems may be due to such a strongly perceived conflation between cultural and religious belief systems. Where Western philosophy is characterized by dualism, African philosophy is seen as holistic. Consequently, considering culture and religion separately, or examining their impact separately, is not viewed as having any merit. Another example comes from Ogunniyi (1996, 22), who said that "the African's worldview, to a great extent, is determined by his/her religious disposition" and that it is "rare to meet an agnostic or atheistic African" (*Ibid*.). However, he also stated (1987, 111) that "religion does not seem to exert any significant influence on the traditional cosmological ideas of Nigerians". In his seminal work '*African Religions and Philosophy'*, Mbiti (1969, 1) made the statement that “Africans are notoriously religious". He also described African ontology and epistemology as being 'religious'. Wiredu (1996) however, has argued that the concept 'religion' is a western concept, indicating that the use of the term 'religious' is inappropriate in African philosophy, which incorporates, for want of a better word, an all encompassing African *spirituality.* However, the differences in belief systems in the 'West', in terms of science and religion, may, I believe, be viewed as equivalent to the differences in belief systems between Christianity and African cultural (or spiritual) beliefs, and that both can have a significant effect on learning in science. Studies that have been done overseas, particularly in the United States of America, and the reaction of students in this study, indicate that *Christian* beliefs have an important impact on the learning of science. Many other studies, referred to in the literature review, indicate that *culture* has a profound impact on the learning of science. Consequently, the semantics of the debate raised by Wiredu in terms of religion and spirituality, fall beyond the scope of this study. Here, Indigenous Knowledge Systems (IKS) and 'African Traditional Religion' (ATR) have been regarded as incorporated into 'African culture', while Christianity has been viewed as a separate belief system from African culture.

Having said the above, it is acknowledged that the history of missionary activity and colonialism in Africa over the past 200 years has resulted in the permeation of African Traditional Religion and Christianity, which is particularly noticeable in the form of Christianity practised by the African Independent Churches. Christianity spread rapidly throughout Africa, with more than 40% of the African population identifying themselves as Christian in the opening years of the 21^{st} Century (Exploring Africa, 2004). In South Africa, data from the most recent census indicated that 80% of South Africans reported their religion as 'Christian' (Hendriks and Erasmus, 2005). It is estimated that by the middle of this century over one third of the Christians in the world will live in Africa (Exploring Africa, 2004) It is clearly important then, in South Africa, and even Africa as a whole, in terms of the impact of culture on learning in science, that the impact of Christian beliefs is worthy of recognition - separately from, and in addition to, cultural beliefs. This is particularly true in a field such as basic astronomy, where key scientific theories may oppose both religious and cultural beliefs.

In South Africa, where the post-democracy curriculum requires that IKS needs to be recognized and valued, the definition of IKS does not include a specific reference to religion. It “acknowledges that all learners should be able to develop to their full potential provided they receive the necessary support. The intellectual, social, emotional, spiritual and physical needs of learners will be addressed through the design and development of appropriate Learning Programmes and through the use of appropriate assessment instruments” (Department of Education, 2003, 4). However, no direction is given for how science teachers are to be involved in or support the spiritual development of their learners. In terms of teaching and learning in astronomy, these issues are critical and particularly complex. This complexity arises from the fact that many of the explanatory concepts of basic astronomy are contrary to human experience, resulting in teaching and learning difficulties that are peculiar to astronomy education (Taylor *et al.*, 2003).

1.3 AIM OF THE STUDY

The primary aim of this study was to investigate, within the framework of socio-cultural constructivism, and in the context of foundation and first year university students at a South African university, the effect of culture on their learning in a course in basic astronomy. A subsidiary aim, using the theories of collateral learning (Jegede, 1995) and cultural border crossing (Aikenhead, 1996), which both fall under the framework of socio-cultural constructivism, was to contribute to discussions arising from the recognition, in South Africa's new, post-democracy science curriculum, of 'other ways of knowing'. The importance of religious beliefs, as a barrier in their own right and in addition to barriers associated with cultural beliefs, only emerged during the course of the research process.

1.4 THE RESEARCH QUESTIONS

Two research questions were posed to guide the study:

1. What is the nature and effect of the prior knowledge about selected astronomical phenomena held by students enrolled in a basic astronomy course?

2. How applicable are the theories of ‘Cultural Border Crossing’ and ‘Collateral Learning’ in explaining the cognitive difficulties experienced by the students taking this course?

1.5 RATIONALE

Establishing the prior knowledge of the students would reveal how much or how little the students actually knew in terms of the explanations of Western science, as well as indicating levels of alternative conceptions. Research in the field of astronomy education has indicated that because of the nature of these explanations, learners will not be able to understand them unless they are explicitly taught the concepts, and at a time when they are developmentally ready to understand them. The data to emerge from the first research question would provide a basis for comparison with data from other countries. The second research question was to illuminate the difficulties experienced by students in relation to differences between their life world and that of science and how they coped, or didn't cope with any conflicts that arose.

South African society is enormously diverse in terms of its culture, and the South African educational system requires that this multiculturalism should be acknowledged. However, the recently proposed National Curriculum Statement (Department of Education, 2003), while stating the importance of including the indigenous knowledge systems of South Africa's many cultures, still follows a positivist, Western science epistemology and western science content. The fact that many university foundation students presented either alternative conceptions or a complete lack of Western science knowledge in answering some of the questions in the research questionnaire, indicates that students are either not successfully learning the basic astronomy concepts prescribed in the science curriculum, or that they are simply not being taught these concepts at school level. There were also students (the honest or the brave?) who gave traditional explanations for the phenomena, instead of just leaving gaps, indicating the existence of a completely different epistemology and set of beliefs, based on cultural understandings.

Odora-Hoppers (2002) has highlighted the difficulty associated with South Africa's desire to be part of the global economy, yet at the same time maintain and celebrate its multicultural heritage. At the centre of this debate lies the school curriculum, and the fact that "while rural areas retain traditional cultures, urban areas are fast losing contact as they embrace Western culture" (Jegede, 1998, 169). Within the field of science, where western hegemony is prevalent, and positivism alive and well in the attitude of many educators, students are expected to conform to the concepts of Western science to become 'insiders', i.e. members of the scientific discourse, as it is experienced at school or university. Their prior knowledge and worldview are not normally taken into account despite the appeal of researchers such as Jegede, Aikenhead, Ogunniyi and others, who state that in order to promote learning in African students, it is necessary to recognize the differences and difficulties experienced by them because of their different worldview and develop appropriate methods of teaching to promote learning.

Questions of cost must also be asked: what social price is to be paid through the loss of cultural explanations of natural phenomena? Is it possible to maintain cultural explanations? How can they be accessed? It would seem that the new curriculum only pays lip service to the importance of recognizing multicultural understandings of natural phenomena, because it does not provide the means for how teachers are to do this, nor does it specify the pedagogic advantages. How do teachers strike the balance between two epistemologically different understandings of the same phenomenon without any form of marginalization, unless, for example, they are introduced to concepts such as cultural border crossing and collateral learning?

Teachers of basic astronomy, whether at school or university level, have little easily accessible information to alert them to all the difficulties or guide them in how to teach effectively in this field. During the Earth in Space course the clash between knowledge systems became painfully apparent, indicating that there is an urgent need for both other ways of knowing and the pedagogical difficulties associated with teaching basic astronomy to be recognised. The Earth in Space course may usefully be seen as a 'dip-stick' in relation to learning and teaching science in multicultural situations, particularly where there may be a clash between different ways of knowing. Establishing the prior knowledge of the students became part of the teaching strategy for the Earth in Space course. This proved to be extremely effective in enhancing the level of questioning and interaction by the students. Consequently, the pre-instruction questionnaire, while forming the basis for data collection for the research, thus became an integral part of the course.

1.6 LIMITATIONS

Generalizations and assumptions weaken any study. In the case of this study, the most significant problems have to do with positionality, the subject of Chapter 3. Issues of positionality may result in error or bias, but are very difficult to control. So many issues are involved in studying the effect of culture on the learning of western modern science that it is not possible to even know and acknowledge what they all are. This includes a concern regarding the monopolization of truth and knowledge by the Western thinking that has shaped my worldview, and which is only brought under the spotlight through exposure to critique by commentators such as Hountondji (2002) and Mazrui (2002). My background and life experience is different to that of my students, but even in making that statement, assumptions are being made. Linked to this limitation is the extent of my background knowledge. A study in science education involving cultural and religious barriers to learning requires at least some fluency in many -'ologies', including theology and philosophy (both Western and African), anthropology, possibly sociology and history. One illustration to show how knowledge in these areas would add to the richness of analysis relates to the significance of the word 'meet' in students describing an eclipse (see Appendix 1). It is clear that knowledge of the cultures represented by the students in the class would lead to greater depth in the analysis of the data, as would collaborative research involving specialists in the fields noted above.

Another limitation relates to the choice of theoretical framework that is used to guide the research questions and the analysis of the data, and consequently the findings and application of these findings. To illustrate this limitation, it is necessary to look at similar studies, but ones that have been based on a different theoretical framework. Research in Australia, for example, which has also focused on explaining why learners from traditional societies struggle with learning science, has, according to Singh (2002), been based on the work of Bernstein, and has consequently focused on pedagogy. The focus of the present study has been to understand what was involved in border crossing and to identify what the barriers to learning were, rather than to investigate what could be done to remediate the problem in the classroom.

1.7 STRUCTURE OF THE THESIS

Chapter 2 is a literature survey which outlines the development of constructivism as a theory of learning in science education, referring particularly to research which acknowledges the role of culture and worldview in relation to barriers to learning science in multicultural situations. It then provides an overview of the findings of research in astronomy education in terms of the special cognitive difficulties associated with learning in this field. As it emerged from the data that Christian beliefs, as well as cultural beliefs, formed an important barrier to learning, it became necessary to refer to further literature to provide a background to the conflict between science and religion as competing 'ways of knowing'. Christianity, however, is an 'imported' religion in South Africa. This meant that it was also necessary to understand how Christianity has impacted on African culture, and how together these various beliefs and knowledge systems serve to shape responses to science.

Chapter 2 also outlines the theoretical framework on which this research has been based. It describes 'cultural border crossing' and 'collateral learning', theories proposed by Aikenhead and Jegede in the mid-1990's, which have been used extensively in multicultural science education research situations. These two theories were linked together by Aikenhead and Jegede, who also drew on other complementary ideas and bodies of research in their development and application of these theories. With the emergence of religion as a barrier to learning in this study, Barbour's Typology (Barbour, 2000) has been incorporated into the creation of the framework that has been used to support this study. This typology, which is specific to the science/religion debate, could be usefully applied to any competing knowledge systems, including IKS and science. Its versatility has thus been useful in this context, which involves three ways of knowing: cultural ways of knowing, religious ways of knowing, and the Western science way of knowing.

Research in a multicultural situation means that what is produced invariably carries the stamp of the researcher. Consequently it is necessary for the researcher to provide something of their own background: chapter 3 is a positionality statement, in which I try to make transparent the features in my background that have a bearing on my approach to and interest in this study.

Chapter 4 describes the choice of a research method and the preparation and implementation of the research instruments, samples of which are provided in the appendices. The research sample is described and the issues of trying to ensure rigour in qualitative research are discussed. This chapter also contains a detailed explanation of the coding systems used for the analysis of the data.

The results of the data collection are presented in Chapter 5, which is made up of three sections: the first presents the results of the pre-instruction questionnaire, the purpose of which was to record the prior knowledge of the students. The second presents the results of the post-instruction questionnaire, where the barriers to learning were investigated. The third section provides vignettes from the interviews, with the student 'voice' being used extensively to highlight the experience of the students.

The final chapter is a discussion of the findings in relation to the theoretical framework and the literature that has informed the study. It highlights the importance of the human endeavour in education, especially in science education where it is common for the human being to get lost or become invisible in the world of a scientific way of knowing.

CHAPTER 2

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

CHAPTER 2

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

> "African children learn about their environment using prior knowledge situated within their non-Western worldview[7]…(but)… prior knowledge situated within the African worldview becomes a handicap when a Western worldview is used as a framework for learning science" (Jegede, 1998, 161).

2.1 INTRODUCTION

The fact that teaching is a barren activity if it takes place without meaningful learning, is a perspective that has inspired educational researchers, psychologists and teachers to try to understand what learning is and how it happens. The importance of their work in attempting to unlock all the 'secrets' of human cognitive development is grounded in the need for successful teaching in our modern 'education for all' world, with its demand for skilled, literate and creative citizens. The number of journals dedicated to the reporting of research in science education, and the hundreds of papers carried in these journals that focus on issues of learning, bears testimony to the fact that learning is an enormously complex cognitive activity. Gilbert and Watts (1983) have captured something of this complexity by describing it as "messy"!

While we do not yet have a full understanding of how learning happens or of all the factors that impact on it, there has been a growing interest in science education in the 'other' factors that impact on the purely cognitive aspects of learning. Lemke has stated that

> "New technologies are removing our excuses for not paying more attention to social, cultural, and linguistic differences and their importance to students. One size never fit all (sic) in science education, and in my opinion the most urgent, challenging, and exciting agenda for science education in the first decades of the next century will be to diversify the range of ways in which a diverse population of people can come to understand, appreciate, and criticize science as a human activity, a social institution, a specialized culture, and a means of making sense of the vast complexity of our natural and social worlds" (Lemke, 2001, 307).

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[7] Worldview is given variously in the literature as 'world view', 'world-view' and worldview'. Here it will be given as 'worldview'.

The study presented here, with its focus on learning issues in basic astronomy, can be seen as a contribution to Lemke's charge to 'pay attention' to some of the important social and cultural factors that affect learning in our multicultural classrooms, albeit only in the context of South Africa.

However, it is not possible to "diversify the range of ways in which a diverse population of people can come to understand, appreciate, and criticize science", as suggested by Lemke, without first knowing what it is that the diverse people we are trying to teach know, and believe, about the natural world. In order to do this, and due to its grounding in a particular subject area, this study has had to draw on literature from several fields. This has included the vast amount available on constructivism as a theory of learning and literature from the more specialized field of astronomy education. As the study progressed and data were gathered, it also became necessary to turn to African philosophy and theology, as well the history and substance of the science – religion debate, as many of the students referred to the conflicting beliefs which they saw as inherent in these two ways of knowing.

The literature review begins with an overview of constructivism and its development as a learning theory. This is followed by an overview of research in the field of astronomy education, where the focus has largely been on conceptual development and issues of alternative conceptions. The first two sections after the introduction (2.2 and 2.3) predominantly reflect research that has been carried out beyond South Africa's borders, while sections 2.4, 2.5 and 2.6, which are introduced below, focus on issues relevant to the current study in the context of South Africa.

In the science education literature it has frequently been pointed out that the ontological and epistemological differences between Western and African ways of knowing have serious implications for Africans in terms of learning western science (e.g. Jegede, 1997). The basic purpose of science through the ages has been the search to understand how nature works, while the purpose of religion has been regarded as the search for the meaning of human existence. Consequently, science and religion are taken by many to be intimately connected (Forsthoefel, 1994; Cutler, 2004). Section 2.4 introduces the development of Western philosophy and the history and development of the science versus religion debate in order to provide a background for the implications of this debate in South Africa. Christianity, Islam and African Traditional Religions (ATR), all present creation accounts that stand in contrast to the scientific account. Since the research sample at the University of the Witwatersrand reflected the 2001 South African census in terms of race and religion, where the records indicate that 80% of the population describe themselves as Christian, and only 1.5% as Muslim (Hendriks and Erasmus, 2005), the discussion is largely confined to the Christian versus science debate, while recognizing that because 40 of the 48 million people in South Africa are Black, African Traditional Religious beliefs underlie and permeate, to a greater or lesser extent, all other religious beliefs. Section 2.5 introduces some of the implications of African ‘ways of knowing’ in relation to the ‘mainstream’ ideas of Western Modern Science and Christianity.

The overview of African philosophy in Section 2.5 is followed by a discussion of the principles in the new curriculum which focus on the need to recognize that there are 'other ways of knowing' in South Africa. As noted in the introduction, the national school education system was one of the key areas of change in South Africa’s transition to a democracy in 1994. The pre-democracy system was changed to 'Outcomes Based Education' (OBE), which was designed to address the imbalances of the past and to be inclusive of 'other ways of knowing'. The curriculum that was developed, known as C2005, was revised in the late 1990’s, resulting in the creation of the ‘Revised National Curriculum Statement’ (RNCS) covering Reception to Grade 9. Both the RNCS, and the National Curriculum Statement (NCS) which covers Grades 10 to 12, are based on principles that have the potential to introduce transformative debate into our multicultural school science classrooms. At the tertiary level, institutions such as universities have greater autonomy over their curricula. However, Higher Education institutions need to be aware of changes that are happening at school level, and recognize that OBE applies at these levels as well. In an education system where Western Modern Science has been privileged, the requirement to recognize other ways of knowing could lead to more meaningful learning of the part of learners/students who come with a traditionally based ontology and epistemology. It could also result in a change in attitude towards science on the part of both teachers/lecturers and learners/students: the introduction, for example, of studies on the Nature of Science (NOS) and the History and Philosophy of Science (HPS), linked to the concept of ‘other ways of knowing’, could help to change the presentation of science from dogmatic positivism and even scientism, to a more inclusive multicultural approach to describing natural phenomena.

The literature review concludes with a presentation of the theories which form the framework around which this study has been carried out. The concept presented by Cobern (1996), of worldviews being grounded in society and culture, together with that presented by Aikenhead (1996), of science as a culture, which necessitates successful ‘border crossing’ for successful learning, have been widely applied to research in situations where Western science has been taught to children from traditional cultures. In many third world countries, including South Africa, Western-style education is seen as the gateway to opportunity in an increasingly globalized world, yet despite huge efforts, on both the level of personal experience (as in rural children walking many kilometres to school every day) and national efforts (with curriculum changes, increased budgets and schools specifically focusing on science and mathematics), international surveys indicate that South Africa’s educational system is not succeeding in producing the quality of learning that is desired (Reddy, 2006). Jegede (1995) suggested that this was due, in part, to African students compartmentalizing their knowledge and maintaining two knowledge systems. He called this compartmentalization ‘collateral learning’ and suggested several different types of collateral learning. For the purposes of this study, Jegede’s categorizations have been linked with the categories suggested by Barbour (2000) to describe the different ways in which people deal with the conflict between science and religion. The framework for the study is thus based on Aikenhead's analogy of students having to cross the 'borders' from their life-world into the world of science, and is linked to typologies suggested by Jegede and Barbour to understand what the borders look like and what price needs to be paid in crossing them. The study thus seeks to contribute to research, that through socio-cultural constructivism, combines cognition and context.

It is important, however, to acknowledge at the outset that the issues affecting science education in South Africa are very complex. Availability of resources and issues of language, for example, are fields of study in their own right. As can be seen from the outline of the literature review just presented, the focus of this study lies in trying to understand how African ontology and epistemology may affect learning in basic astronomy. The lens which has been used to do this has been formed in the context of Science Education (rather than in Philosophy or Anthropology), but it is hoped that the overview of literature provided will give sufficient background against which the data can be viewed.

2.2 CONSTRUCTIVISM

Much of the contemporary, commonly-held understanding and discourse on teaching and learning is closely tied to the developmental theories of Piaget (1964, 2003) and Vygotsky (1979). Their ideas largely replaced those of the behaviourists, for example Pavlov and Skinner, whose approach emphasized passivity of mind and the notion of the learner as a *tabula rasa* (Gilbert and Watts, 1983). Behaviourist ideas were gradually discarded with the growing understanding that "knowledge is always the result of a constructive activity and, therefore, it cannot be transferred to a passive receiver" (von Glasersfeld, 1992, 71). Consequently the most significant notion shared by cognitive theorists after the 1970's was that learners have to actively and adaptively appropriate knowledge through a personal process of internal mental construction. This 'cognitive construction', where new ideas are built on previously held conceptions, became known as 'constructivism' (Maddock, 1981). This term grew out of the idea of "personal constructs", postulated by Kelly in 1955, who emphasized the idea that "individuals construct knowledge for themselves through construing the repetition of events, and that knowledge is individual and adaptive rather than objective" (in Geelan, 1997, 17).

While Kelly may be responsible for the terminology that is used today, constructivism had its roots in ancient Greek philosophy, with Matthews (2004, 107) aptly describing modern constructivism as "old philosophical wine in new bottles". The old problem of relativism, which is inherent in constructivism, can be traced back to a fundamental disagreement between two Pre-Socratic philosophers, Protagorus and Democritus: Democritus was a realist, insisting that things existed separately from our perception of them, while Protagorus argued that there could be no objective truth independent of the knower - all we know comes through our senses, and we can only know what *we* know - there is no such thing as a “God’s eye” view (Thompson, 2001). The debate between realism and relativism is still with us, with logical positivism[8] representing the philosophical position of many scientists and teachers of science, but one which is being challenged by constructivism. The “(re)discovery of epistemology in the 1970’s” (Taylor, 1998, 1112); the understanding that science itself is a human construct; and the understanding that knowledge is individually constructed, have all resulted in the re-emergence of relativism, with constructivism coming to dominate theoretical debate in science education (Matthews, 1997).

2.2.1 A brief history of the development of Constructivism as a theory of learning

Von Glasersveld (1989), best known as a proponent of radical (i.e. personal) constructivism, claimed Piaget as the ‘father’ of constructivism as a result of his extensive work in the field of cognitive psychology. Piaget’s theory of constructivism encompasses two main ideas: first, that knowledge is not passively received, but rather that it is actively and individually built up, and second, that the function of cognition is adaptive. Piaget suggested that knowledge grew as the result of a process he called ‘equilibration’, where the learner chose whether or not to adjust or discard his/her original understanding in order to accommodate a new idea. Piaget thus saw learning as a process of ‘assimilation’ i.e. the active consideration of a new idea, and its subsequent possible ‘accommodation’ (internalization or acceptance) as a new mental schema (Piaget, 1964, 2003). Equilibration was thought to be provoked through conceptual conflict, with new ideas challenging and possibly replacing or altering the existing ones. Piaget’s main concern lay in explaining cognitive development on the individual level, ‘before the cognitive organism could begin to know and interact with others’ (von Glasersfeld, 1992, 170). He was interested in the internal construction of knowledge rather than being concerned, as was Vygotsky, with the social aspects of learning.

Piaget’s work was foundational to that of Vygotsky. Vygotsky, like Piaget, suggested that learning involved a process of internalization, but he rejected Piaget’s views that "development always preceded learning but was never the result of it" (Vygotsky, 1979, 80). Vygotsky believed instead that the child could be enabled to progress beyond his or her developmental level through the guidance of "an adult or a more able peer" (in Wertsch, 1984). He felt that language, and the development of meaning on the ‘inter-psychological plane’ (i.e. between people), preceded the potential internalization of this meaning on the "intra-psychological plane" (i.e. within the individual) (Scott, 1998). His conception of the existence of a ‘"Zone of Proximal Development" (ZPD) emphasized the role of external social interaction in the formation of internal consciousness (Jaworski, 1997), an idea similar to Bruner’s concept of “scaffolding” (Scott, 1998, 69). Vygotsky’s idea of the ZPD was extended by Wertsch, who introduced the notions of "situation

[8] Logical positivism posits that "unless a statement is empirically viable or an analytic truth it is meaningless" (Pence, 2000, 32)

definition" (defined as “the way in which a setting or context is represented – that is defined – by those who are operating in that setting” (Wertsch, 1984, 8)); "semiotic mediation" (“the mediation by signs, especially linguistic signs” (*Ibid*., 13)); and "intersubjectivity" (the existence of a “shared situation definition…..where people represent objects and events in identical ways” (*Ibid*., 12)). While this work confirmed the social dimension of learning, it was claimed that almost all studies of rational conceptual change were found to indicate that most students resisted the conceptual changes required by science teachers (Aikenhead, 1996). Consequently it was suggested that the construction of knowledge went beyond classroom interactions to the wider interaction of the social and cultural environment outside of the classroom (Jaworski, 1997; Wertsch, 1985; Lee and Fradd, 1995). Kuhn’s characterization of scientific development and the introduction of the idea of paradigms also provided the science education community with the understanding that society was inherent in the enterprise of science itself, not just in the learning of science (Matthews, 2004). The purely social aspects in the science classroom thus came to be viewed as insufficient in accounting for all the peculiarities of conceptual development. The widely held Conceptual Change Model, developed by Posner, Strike, Hewson and Gertzog (1982) - which suggested that Piagetian assimilation and accommodation would only occur if the newly presented conception met with an acceptable level of three criteria, i.e. it should be intelligible, plausible and fruitful to the learner - was increasingly critiqued on the grounds that it involved a notion of knowledge that was too narrow (West and Pines in Gilbert and Watts, 1983; Cobern, 1996). It did not accommodate for the ‘softer’ factors: those that were ‘non-rational’, such as intuition, emotion, simplicity, ethnic harmony and personal integrity. Consequently, the science education research field broadened to take into account the non-rational aspects of conceptual change, and the focus of attention became the role played by culture, with many science education specialists, especially those with an orientation to indigenous cultures, such as Abimbola (1977), Ogunniyi, Jegede, Ogawa, Yandila and Dladela (1995), Jegede (1995), Aikenhead (1996), Cobern (1996) beginning to examine the role played by culture in the construction of scientific knowledge.

The technological and economic developments of the 20th Century, particularly after the World Wars, led to the development of a global economy, with all countries competing, to a greater or lesser extent, for market share. In Third World countries[9] education has been seen as a key to development, particularly with regard to science and technology. However, despite huge investments in education, many Third World countries have failed, even over decades, to make significant progress in teaching and learning in these fields (Abimbola, 1977; Ogunniyi, 1996; Jegede, 1998). Research which has sought to understand this has been deeply influenced by ‘ worldview theory’, a concept borrowed from social anthropology by Cobern in the mid 1990’s. Cobern stated that it

[9] For a discussion on the problems of terminology with reference to the use of 'First' and 'Third' world, see Hammond and Brandt, 2004)

> "…brings under a single umbrella the philosophic issues of epistemology and metaphysics, which respectively deal with arguments that provide explanations and understanding, and the presuppositions upon which epistemological arguments are founded and delimited" (Cobern, 1996, 591).

Constructivism as a learning theory thus grew to take account not only of social practices, but also of the worldview of the learners. It was called 'worldview constructivism' (*Ibid*.), but also came to be known as 'socio-cultural' constructivism. As a theory of learning that could recognize deep seated differences in the worldviews of western science and traditional cultures, socio-cultural constructivism became valued as a way to explain the difficulties experienced by learners in Third World countries, or learners in multicultural First World classrooms, who come from traditional cultures.

Apart from grappling with problems in terms of learning, another problem faced by science educators is the nature of science itself.

2.2.2 Constructivism and the nature of science

The traditionally accepted view of science has been the realist view (von Glasersfeld, 1989). Western Modern Science is thought by many (particularly those responsible for the transmission of scientific knowledge, i.e. the science teachers) to represent the ultimate reality or truth about the Universe: they see the natural world as a "vast single system in which the basic rules are everywhere the same" (AAAS Project 1989 in Snively and Corsiglia, 2000, 21). The description of these basic rules and laws is known as the 'standard account'. It is accepted by 'realists' (or 'positivists' or 'universalists') who believe that the natural world can only truly be known, understood and represented through the use of the scientific method, which involves the rigorous testing of hypotheses. This 'empirico-realist' view is the predominant representation of science in the school curriculum today (Desautels and Larochelle, 1998), and scientists and science educators who have been steeped in Western Modern Science are often not aware of the hegemonic nature of this knowledge, nor of their universalism or positivism.

However, if science is defined as the 'knowledge and understanding of nature', then "there is no one way to do or think about science" (Kawagley *et al.* in Cobern and Loving, 2001, 54), as all cultures have their own knowledge and understanding of their environment, sometimes developed over thousands of years. The 'relativists' who ascribe to this definition believe that "the objects of science are not the phenomena of nature, but constructs that are advanced by the scientific community to interpret nature" (Driver, Asoko, Leach, Mortimer and Scott, 1994, 5). As a result, they acknowledge the existence and validity of different accounts of natural phenomena, and through this, the existence of different types of science, such as "African science" or "Japanese science" (Ogawa, 1995; Stanley and Brickhouse, 2001; Cobern and Loving, 2001; Snively and Corsiglia, 2000).

Cobern and Loving (2001, 51) point out that “in today’s schools there are often competing accounts of natural phenomena, especially when schools are located in multicultural communities”. Consequently the acceptance or rejection of an explanation depends on the outlook of the individual and “the resolution of such questions hinges on the definition of science, including the concept of universality” (*Ibid*., 51).

The knowledge and understanding of nature held by indigenous people is categorized as ‘non-Western nature-knowledge’ (Lewis and Aikenhead, 2001), ‘traditional ecological knowledge’ (TEK), (Snively and Corsiglia, 2000) or ‘indigenous knowledge systems’ (IKS) (Cobern and Loving, 2001). The South African curriculum refers to these ‘other ways of knowing’ as Indigenous Knowledge Systems, which Odora-Hoppers defines as:

> “those systems of knowledge in philosophy, science, technology, astronomy, education, mathematics, engineering etc that are grounded in the total “cultural” (very broadly defined) heritage of a nation or society, and maintained by communities over centuries. These systems are underlaid by an interlocking web of ethical, social, religious and philosophical sub-systems that determine broad cognition patterns, and provide it with the rational essence and emotional tone” (Odora-Hoppers, 2001, 10).

These indigenous knowledge systems surround the child as he or she is growing up: children’s beliefs and explanations are built up from their direct experience of events, and from such accounts as their culture offers for why things are as they are (Hawkins and Pea, 1987). Research which focuses on the impact of culture on learning includes the following: in Africa, studies have been reported for example by Abimbola (1977); Jegede and Okebukola (1991); Jegede (1997, 1998); Ogunniyi (1987, 1996); Dzama and Osborne (1999); and Shumba (1999). In other developing nations, research work includes that reported by Waldrip and Taylor (1999) from a small South Pacific country, a more recent study from Papua New Guinea by Pauka, Treagust and Waldrip (2005), and George and Glasgow’s report on their work in the West Indies (1988). Research has also been conducted with minority groups in First World countries (for example the Australian Aboriginals (Jegede and Aikenhead, 1999; web discussion: Linkson, 2002), the First Nations People of Alaska and Canada (Aikenhead, 1997, 1998) and the Amerindians of the United States of America (Janotta, 1986; Ollerenshaw and Lyons, 2001). Ogawa has also reported on the impact of culture on learning in science in the context of Japan, as a highly developed, but non-Western country (Ogawa, 1986, 1995).

Constructivism has proved itself a very powerful theory of learning. Volume 6 (1997) of the journal ‘Science & Education’ provides many useful papers and critiques by well known and well established authors in the area of constructivism, with Geelan’s (1997) paper being particularly helpful in providing a framework for categorizing and understanding the numbers of different forms of constructivism encountered in the literature.

Constructivism has been widely used as a theoretical framework for research in science education in South Africa, with much of the work reported in the Southern African Association for Research in Mathematics and Science Education (SAARMSTE) being based on constructivism. It has also had an enormous impact on teaching, with Matthews (1997) commenting that it is seen as synonymous with anything that is pupil-centered, engaging, questioning and progressive and suggesting that teachers who use constructivist classroom practices should be called ‘pedagogical constructivists’ (*Ibid*., 8). However, constructivism is a theory of *learning* rather than a theory of teaching, and in the science classroom, the problem of the nature of science still remains. For realists, there is only one way of knowing, i.e. the standard account, while for relativists, science may be only one way of interpreting the world. Relativism can thus create problems in terms of curriculum and assessment. Matthews highlights a further problem in terms of relativism in science education by pointing out that:

> “…there has been an explosion of epistemological niches, with most of them now occupying academic and institutional corridors: queer theory, black theory, white theory, hundreds of indigenous knowledge theories, and so on. Multiple approaches to understanding natural and social reality is laudable; what is lamentable is when these approaches insulate themselves from criticism and appraisal by invoking “special niche privileges” – as when, for example, indigenous groups claim that they alone can investigate their origins (Matthews, 2004, 111).

The focus of this study is to investigate any ‘epistemological niches’ that might, in this context, affect learning, while appealing, because of my position outside of the culture of the majority of the students in my sample, to Matthews's indictment of ‘special niche privileges’. The change in the South African school curriculum to Outcomes Based Education and the inclusion in the principles of the Revised National Curriculum Statement regarding the recognition and valuing of Indigenous Knowledge Systems confirms what Matthews calls ‘constructivist-inspired relativism’ (*Ibid*., 113). This relativism, in recognizing the existence of other worldviews and other ways of knowing, could facilitate learning in science for students with traditional worldviews. One of the basic tenets of constructivism is finding out what the learner already knows, and using this as a foundation for further construction. In order to assess this foundation, it is necessary to consider issues of learning which are specific to basic astronomy before turning, in Chapters 3 and 4, to the 'epistemological niches' that are relevant to this study.

2.3 ASTRONOMY EDUCATION

2.3.1 Conceptions of the Earth as a cosmic body

Piaget’s pioneering ideas have formed not only the basis of research in the broad field of learning development theory, but he also had the ‘first word’ in the more specialized field of astronomy education. His two books, *The Child’s Conception of the World* (1929) and *The*

Child's Conception of Physical Causality (1930), reported on the evolutionary stages of development displayed by children as they grow and learn to understand the concepts of Astronomy (in Lelliott, 2007). Piaget suggested that it would be 'completely useless' to teach young children a Copernican view of the solar system as they 'could not possibly understand it' (in Sharp, 1996). This view is shared by Bishop (1996) whose research has indicated a close connection between the child's ability to understand certain astronomical concepts and their level of development.

In a review of the period between 1922 and 1972, Wall (1973) identified a total of 58 studies that were conducted in the area of astronomy education. Most of these were doctoral and masters theses, many of which were concerned with planetaria and the development of appropriate curricula and teaching materials for schools in the United States of America. Some of the studies were concerned with the nature of concepts held at different stages and the appropriate age at which to teach different concepts, with one of the most important comments for the present study being made by Boyd (in Wall, 1973, 661), who recommended a history of science approach to teaching astronomy. The most important work to emerge after the period covered by Wall's review was that of Nussbaum and Novak (1976), whose research, in science lessons for 2nd graders in New York, involved children's ideas on the Earth as a cosmic body. This work led them to introduce the term 'Earth Concept' – a term directed towards describing the shape of the Earth, the effect of gravity, and the Earth as a cosmic body, all of which are central to the study of basic astronomy. They identified 5 levels of 'notions' held by the children, summarized as follows by Mali and Howe (1979, 686 - 687):

Notion I: Earth is considered as a flat surface. The child tries to make some sense of what he/she hears about the roundness of the Earth.
Notion II: Holds that the Earth is round; can even suggest proof. Lacks a notion of unlimited space. Feels that there should be some bottom which also determines the up-down direction in the sky. Objects fall down. Sky limits the space above.
Notion III: Has some idea about the unlimited space that surrounds the round Earth. Still does not use the Earth as a frame of reference for the up-down directions. Assumes absolute and independent up-down directions in space and around the Earth.
Notion IV: Demonstrates some understanding of the elements of the Earth Concept. Uses Earth as a whole as the frame of reference for up-down directions. Does not relate up-down direction to the Earth's centre.
Notion V: Can overcome immediate perceptual distractions and responds persistently in a mode which is compatible with the content of a scientific concept of Earth.

These levels of understanding established the developmental changes in children from naïve flat-Earth conceptions through to the scientifically correct notion of a sphere surrounded by space, with gravity acting towards the centre of the Earth. While these five notions were later slightly modified by Nussbaum (1979), they have formed the basis for all subsequent work in this area (see for example Vosniadou and Brewer, 1992; Baxter, 1991; Sharp 1996; Roald and Mikalsen, 2000; Trumper 2001, Liu, 2005). There is general agreement that while not all children pass through all the stages, development will proceed from a naïve, egocentric view towards the commonly accepted scientific view, but *only* if the child is exposed to these ideas. The development of higher level notions of the Earth as a cosmic body depends, then, not only on the level of cognitive development of the child, but also on the level of schooling they have received, as well as their access to other sources of information (Mali and Howe, 1979). Consequently, the development of scientifically correct astronomical notions depends on the quality of exposure, and the timing of this exposure, to the concepts of Western science (Feigenberg, Lavrik and Shunyakov, 2002; Liu, 2005). Nussbaum and Novak's work in the mid-1970's also indicated that these phases are age related (Nussbaum and Novak, 1976). Various subsequent studies (Nussbaum, in Sharp, 1996; Mali and Howe, 1979; Bishop, 1996, Liu, 2005) have shown that the ages at which children pass through these stages may vary from one country to another, indicating that age differences may be linked to education systems and the construction of school curricula.

Whatever the reason for the age differences, it has been widely recognized that the idea of a heliocentric solar system and the concept of the Earth as a sphere are counter-intuitive and abstract (see for example the critical review by Albanese, Danhoni Neves and Vicentini, 1997). Feigenberg *et al*. (2002) suggest that it is not possible for individuals, without access to vast amounts of data from around the world (and the interest to process them), to develop the Western science understanding of the Earth as a cosmic body, without being *taught* about it. Consequently, unless people are exposed to the Copernican view, they will hold alternative (geocentric) conceptions, based on their own observations or on cultural explanations (Mali and Howe, 1979; Parker and Heywood, 1998).

2.3.2 The prevalence of alternative conceptions

Over the last few decades there has been a growing body of literature that has shown that it is incorrect to assume, that with education, adults and children would be post-Copernican in their views of basic astronomy (Trumper, 2001). Pupils come to school having either constructed their own explanations for many of the easily observed astronomical events, or they may have had cultural explanations provided when they were children. These become part of their belief systems (Mali and Howe, 1979; Vosniadou, 1991; Fleer, 1997; Anamuah-Mensah, 1998), and may cause them to regard the scientific explanations as a "pack of lies" (Abimbola, 1977). Gilbert and Smith (in Baxter, 1991) suggest that these concepts will only be exchanged when challenged, and the old conceptions fail to hold good in the light of the new conceptions. Vosniadou (1991) suggested that the cultural explanations need to be removed before it is possible for correct scientific conceptions to be constructed, but this idea has been challenged by work that has shown that it is possible to understand scientific concepts without necessarily believing them (Sinatra, Southerland, McConaughy and Demastes, 2003).

Trumper's work (2001) has also shown that many misconceptions are carried into adulthood. He refers to public national surveys carried out in Great Britain, the United States of America and France, where 34%, 46% and 33% respectively of the general adult public indicated that they believe that the Sun orbits the Earth. There are no equivalent studies involving adults in Third World countries, but it is probably reasonable to assume that because national education systems have existed in these First World countries for longer, and been available to a larger percentage of the public than would be the case in the Third World, the scientific understanding of basic astronomical phenomena should be far more limited in the Third World.

Research among First World school teachers has found that even they hold incorrect views of the Earth as a cosmic body. Studies of British (Summers and Mant, 1995; Parker and Heywood, 1998), American (Atwood and Atwood, 1996) and Finnish (Ojala, 1992) pre-service and Primary School teachers found that many teachers held misconceptions and naïve notions of the Earth in Space. This is true in South Africa as well, where studies by Mosoloane and Stanton (2005) and Kelfkens and Lelliott (2006), on pre-service and teachers' understanding of the phases of the Moon, indicate that few teachers have clearly developed conceptions of Moon phases, and that alternative conceptions are commonly held. These studies indicate that unless the learning of these concepts has been successful (and research such as that done by Trumper, 2001, and Kelfkens and Lelliott, 2006, shows that often it is not), adults will hold similar views to those of children, with the misconceptions being passed into adulthood and in the case of teachers, being passed on to the children in their classrooms.

Almost all the studies in conceptual development in astronomy have been carried out with children in First World countries. These children, when compared to those in the Third World, would probably have been repeatedly exposed through the school curriculum, if not also through television programmes, computer games, and videos, to the western science concepts of the Earth as a cosmic body. The findings from these studies (for example, Baxter, 1991; Trumper, 2001) support the early work of Nussbaum and Novak (1976) in this field, but the results of these studies have been questioned by researchers who have suggested that the use of a prompt (a globe) enables a different level of response than a pencil and paper test for understanding (Schoultz, Saljo and Wyndham, 2001; Trundle, Atwood and Christopher, 2002). They suggest that the 'misconceptions' are more a reflection of the test than they are of the learner's underlying mental model. Engestrom (1991) has also raised the problem of text-book diagrams which can result in misapplied learning because the diagrams lack any relationship to the scale of what they are trying to represent. An interesting study which supports the idea that the Copernican view is gained through explicit teaching was carried out in Norway on deaf children (Roald and Mikalsen, 2000). Sign language 'contains' the Copernican view, so when children are taught the sign for the Earth, the spherical nature of the Earth is inherent in the 'shape' of the term - in Norway, the sign is a fist; in South Africa the ball is formed with the fingers spread and curved, with the hands moving as though caressing a ball (St Vincent School for the Deaf, Johannesburg, personal communication, 19th May 2006). For deaf children there is thus a built in connection between two dimensional images of the Earth and the sign for the Earth.

Some of the most relevant studies to the current research are those by Trumper, who studied Israeli senior high school (Trumper, 2001) and university students' (Trumper, 2000) conceptions of basic astronomy. The latter study, because of the age of the students, provides a basis for comparison with the students in the present study (recognizing that socio-economic levels are likely to be different). Trumper found that, even after being taught, the students in his study held "a series of misconceptions on several central topics in basic astronomy" (*Ibid*., 12), including the day/night cycle (where 62% held the correct view); Moon phases (with 51% with the correct view) and seasons (67% with the correct view). It is well known that conceptual change is extremely difficult to achieve, in both children and adults, but it has also been suggested that in traditional societies, in the field of basic astronomy, conceptual change may be even more difficult to achieve because people tend to hold cultural explanations embedded in traditional worldviews.

2.3.3 Alternative conceptions in traditional cultures

Studies that have been done in developing countries include Mali and Howe's (1979) study in Nepal, Mohapatra's (1991) in India, and Fleer's (1997) with Aboriginal children in Australia. Mali and Howe's study in Nepal reported that one of the traditional beliefs in that country is that the Earth is a large flat mass supported at each of its four corners by an enormous elephant. They noted that adults who had no formal schooling and no opportunity to be introduced to modern scientific ideas tended to have beliefs about the Earth that fitted with Nussbaum and Novak's first three notions or stages of development in understanding in this field, indicating that with the passage of time, there was some exposure to, and acceptance of ideas beyond their own culture. This is supported by Anamuah-Mensah (1998, 121) in terms of schooling, where as a result of work done in Ghana, he concluded that "as one goes up the educational ladder, beliefs in native science decrease considerably".

Fleer's (1997) work on Australian Aboriginal children's understandings of night and day is relevant particularly in terms of her comments regarding the difficulties she experienced in the research process, for example, in terms of issues of language, positionality, worldview (with reference to the problem of an emic (relativist) versus an etic (universalist) approach) and rights to knowledge. She also pointed out that instruments developed in western societies may be inappropriate for research in traditional societies.

South African research that bears relevance for the current work includes, particularly, that of Ogunniyi (for example Ogunniyi 1987, and Ogunniyi *et al*. 1995), who is well known for his work on the effect of traditional culture on learning in science. However, it is only very recently that a few studies have been carried out in South Africa using the northern hemisphere research methodologies specifically associated with astronomy education. An internet and an ERIC search (1966 to 2006) revealed only a few empirical studies in the field of basic astronomy in South Africa. These include a study by Lemmer, Lemmer and Smit (2003) on South African university students' ideas about the Universe, which was published in an international journal, and several studies presented at SAARMSTE conferences and published in the Proceedings of these conferences. These include Lelliott *et al*., 2005) whose research interest lies in informal learning in basic astronomy at extra-school centres such as Planetaria, and extracts from a few Masters studies in Science Education, such as Mosoloane and Stanton (2005); Kelfkens and Lelliott (2006); and papers extracted from the current study (Cameron and Lelliott, 2006; Cameron *et al*., 2003 and Cameron *et al*., 2005). A recent study, but one which investigated science *teachers'* understanding of the Universe, is that of (Webb, Ogunniyi, Sadek, Rochford, Dlamini, and Mosimege, 2006).

2.3.4 Implications for teaching

While most of the literature is concerned with misconceptions in basic astronomy, there are some papers that provide insight into pedagogic strategies which are helpful in promoting the learning of Western science. Vosniadou (1991) stresses the importance of the order in which concepts are introduced and the necessity for providing the opportunity for falsification of entrenched beliefs and misconceptions. Parker and Heywood (1998) indicate that practical exploration and demonstration, combined with group discussion, are significant factors in students' learning. They also stress that for teachers, subject knowledge without pedagogic content knowledge ("PCK") (Shulman, 1986) i.e. an in-depth knowledge of how best to represent the subject in the classroom setting is not sufficient for good teaching. A study by Shin, Jonassen and McGee (2003) is important in this regard in confirming that well developed domain knowledge is a pre-requisite for solving both well-structured and ill-structured problems in science. Because science-based explanations in astronomy are abstract and counter-intuitive, they require a level of thinking that needs to be supported by teachers with good subject knowledge and good PCK, which takes into account prior knowledge and sensitivity to deal with misconceptions and entrenched beliefs. This is clearly easier said than done, however. Kelfkens and Lelliott (2006), working in South Africa, found that cultural beliefs remained even after instruction that was specifically designed to address misconceptions.

Dr Mokhele, President of the National Research Foundation in South Africa, is reported as saying:

> "If we define astronomy as a Western scientific discipline, it was introduced to South Africa in 1820. It took us until 2002 to produce our first black PhD. That, for me, is a story." (Sunday Times, May 19, 2002).

Perhaps the story *is* simply a question of time, as suggested by Anamuah-Mensah, combined with good resources and excellent teaching, but perhaps it also has to do with worldviews issues, contained in Matthews' Kuhnian-inspired idea of "epistemological niches" (Matthews, 2004, 111). The next section presents the development of the science/religion debate that is linked to Western philosophy, as a beginning to addressing these worldview or epistemological niches.

2.4 RELIGION AND SCIENCE

An African child in a science classroom in South Africa is no *tabula rasa*: research in education has shown that we are well advised to acknowledge that culture and society play a profound role in influencing how the learner will respond to the content of the science curriculum. In addition, science itself has come to be viewed as a

> "…relativist project, culturally determined in many of its assumptions and choices of projects, and … just one of the ways in which humans have sought to make sense of their world and manipulate it" (Barrett, 2000, 10).

Consequently, a great deal of attention has been focused on epistemic issues with regard to learning, but an aspect that does not seem to have been sufficiently highlighted in the science education literature, concerns the complexity of religious influences in shaping a cultural response. The child and teacher are likely to be similarly unaware of how historical developments in this area influence the choices and decisions that they make and the knowledge that they already carry and trust.

It has already been noted that the 2001 South African census recorded that 80% of South Africans listed themselves as Christian, and 1.5% as Muslim (Hendriks and Erasmus, 2005). This statistic for the number of Christians includes people whom Appleyard (2006, 20) has dubbed "cultural Christians" i.e. people who are essentially secular but refer to "the most generally accepted form of external authority" when asked about religious affiliation for purposes of marriage, death and birth. In South Africa (as in Britain, which was the context of Appleyard's article) cultural Christianity is a 'White' phenomenon. Seventy two percent of Britain's 60 million people consider themselves Christian, yet only 4 million go to Church. Black people represent only 2% of the population, but Appleyard notes that "the black churches are booming" (*Ibid*., 20), with Black people accounting for two-thirds of the churchgoers in London. In South Africa, the White population accounts for only 4% of the total. It follows then, that the statistic that records 80% of South Africa's population as Christian is a more realistic reflection of the actual church going population than is the case in Britain. The result of this is that the majority of South Africa's population has chosen to identify with scriptures that are, or appear to be (depending on how fundamentalist you are), in contradiction with some of the science that is taught at school - particularly with regard to the creation of the physical Universe and the evolution of humankind. One of the oft repeated claims in the South African science education discourse on the impact of culture on the learning of science, is that Africans are monistic -

they do not separate the material from the spiritual world. This approach to life prevents them from being able to view science as 'value' free, and their response to those aspects of science that appear to be in opposition to their religious beliefs is, as a result, loaded with emotion. The importance of emotion in affecting learning in science has only very recently been recognized (Zembylas, 2005).

Religious beliefs have been shown to act as a barrier to learning science in classrooms in the developed world (Roth and Alexander, 1997; Brickhouse, Dagher, Letts and Shipman, 2000; Shipman *et al*., 2002).Since Western religious beliefs have been imported into Africa, an overview of the history of support, confrontation and conflict in the evolution of science and religion within Western culture forms part of the background needed to examine issues of learning in this study. For most of the students making up the sample, however, it is not just a Western religious ontology and epistemology that has an impact on their learning in the field of basic astronomy: African culture, despite its apparent dilution in urban areas and among the emerging Black elite in South Africa, is considered un-eradicable, even in those cases where it is only unconsciously present (Mbiti, 2006; Inyait, 2006). Consequently African Traditional Religions and Indigenous Knowledge Systems also provide an epistemic and ontological basis for many of these students. African philosophy and religion will be the focus of section 2.4, but the intention of this section is to briefly examine the path of science in challenging Christianity as the source of knowledge and truth, in order to understand the basis of the conflict. (Because only a very small number of the students in the research sample identified themselves as Muslim, the discussion is largely limited to the Christian religion.)

2.4.1 Historical background to the conflict between science and religion

It is widely held that science had its roots in Greek philosophy. Science, as a systematic and rational endeavour to critically examine life and ultimate reality, began with the efforts of Greek philosophers in the 6^{th} Century BC (Thompson, 2001; Robinson and Groves, 2004). The traditional mythological explanations for natural phenomena gave way through the writings and discussions of philosophers such as Thales, Xenophanes and Parmenides in the pre-Socratic period, to the development of a rationalist worldview and the establishment of, for example, logic, ethics, metaphysics and mathematics, through the work and ideas of such great philosophers as Socrates, Plato and Aristotle (*Ibid*.). The first accurate prediction of a solar eclipse, the conception of atoms as the smallest indivisible units in nature and the idea that observation is observer and culture dependent are some of the achievements of this time (*Ibid*.).

During the Middle Ages, Greek philosophy and science practically disappeared from Western Europe. After the adoption of Christianity as the official religion of the Roman Empire by Constantine in 313 AD (Hetherington, 2003), the Christian Church took over control of education - a move described as the "repression of free enquiry" by Alexakos and Antoine (2005, 37). While many "scholars and scientists fled east to the more cosmopolitan and tolerant Arabic-Islamic lands" (*Ibid*.), cosmology continued to be studied by Christians as a way to know and glorify God. However, cosmology was seen as "subservient to theology, pursued not for its own sake but for its usefulness in the interpretation of Holy Scripture" (*Ibid*., 2). The Bible was understood to contain a complete history of the world and was seen as the only reliable source of information, with the Genesis account providing the history of the Earth's creation (Cutler, 2004). It has been argued that while Greek philosophy laid the foundations for modern Western science five hundred years before the birth of Christ, and flourished for a thousand years until the closure of the Athenian schools of Philosophy by Justinian in 529 (Hutchinson Dictionary of Ideas, 1994, 407), it was actually the specific beliefs of the Judeo-Christian worldview that provided the pre-conditions for the development of science in Western Europe (Hodgson, 2002; Deane-Drummond, 1994). According to this view, it was the belief in divine creation rather than the Aristotelian idea of an eternal world that encouraged scientists to study and investigate the world as a way of revealing the wisdom of God in creating and sustaining the world.

When Greek classical thought, which had been nourished by Arabic-Islamic influences (Alexakos and Antoine, 2005), was reintroduced to Western Europe in the 12th Century, much discussion was stimulated as scholars tried to integrate Christian doctrines with ancient Aristotelian cosmology. The universities that had been founded in Europe in the Middle Ages, and which became the centres of these debates, had been developed not so much to create 'new', as to preserve 'old' knowledge (Cutler, 2004). However, the reintroduction of Greek philosophical thought, particularly through the works of Aristotle, stimulated 'Scholasticism', which involved the creation of theological and philosophical systems and methodologies which sought to reconcile the conflict between Aristotelian rationality (and all the different branches of science) and Christian doctrine (which required belief in apparently irrational ideas such as a virgin birth and a host of miracles, including resurrection) (The Dictionary of Ideas, 1994, 467). One of the most famous Scholastics, Thomas Aquinas (1225 – 1274), whose works have become classic texts of Catholic doctrine (*Ibid*.), succeeded in fusing orthodox Christianity with the metaphysics of Aristotle. Thompson (2001,19) describes the result as "being in its day both intellectually and emotionally satisfying, combining the best in philosophy with a religious outlook that gave full expression to Aristotle's 'final causation' – in other words, that everything had a final purpose." Cutler (2004, 10) puts it a little more bluntly, saying that

> "medieval monks … felt free to fudge a little in their reading of the text…Saint Augustine and the other early Church Fathers (did) not hesitate to interpret Scripture metaphorically when necessary."

Scholasticism began to be taught in the universities, but in 1277 Pope John Paul XXI directed the Bishop of Paris to "investigate intellectual controversies" that had arisen at the university in Paris in response to the Bishop condemning several propositions derived from the teachings of Aristotle (Hetherington, 2003, 2). The consequence was that 219 propositions were condemned, with excommunication as the "penalty for even holding one of the damned errors" (*Ibid*.). Hetherington maintains that this 'condemnation' marked the beginning of the end of the 'stranglehold' of Aristotelian cosmology on Western thinking: instead of having to refer to Aristotle's final causes, where everything had to be interpreted in terms of its intention or goal, cosmological studies could now be "understood as a working hypothesis in agreement with observed phenomena" (*Ibid*., 3). None of the hypotheses formulated were seen to pose a threat to religious authority as none could be insisted upon: God could have made the world any way he pleased, with the same observational consequences. As a result, science was also freed from religious authority, and "…confidence developed that the essential structure and operation of the cosmos was knowable – a pre-requisite to the work of Copernicus, Galileo, Kepler and Newton" (*Ibid*.) This freedom was to lead to serious conflicts with the Church, however, as the new theories 'set the world in motion', whereas before it had been 'static' and the centre of the Universe. This resulted in a paradigm shift in peoples' perception of humanity's place in the Universe (Michaels and Bell, 2003) - ideas that were very disconcerting and threw doubt on the meaning and purpose of life (Cutler, 2004).

From the beginning of the serious problems that started with the ideas of Copernicus, the 'storm' grew to involve the whole Church. It deepened the divide between Catholics and Protestants which had started with the Protestant demand for literal adherence to the Bible. The Catholic Church had shown a liberal stance to the idea of heliocentricity, with Copernican cosmology being taught in some Catholic universities and even being used for the new calendar of 1582 (*Ibid*.). However, Galileo's support of Copernican heliocentric cosmology "culminated in a clash with Catholic authorities so dramatic that it forms the foundation of the most widely held stereotype regarding the general relationship between science and religion" (Hetherington, 2003, 4). The primary opposition to Galileo came from Aristotelian philosophers who saw this as an opportunity to enlist the support of the church against ideas that were counter to their own (Cutler, 2004). It is diverting to wonder how things would have progressed if the Church had heeded Galileo's appeal to St Augustine's caution ('don't make cosmological arguments into a doctrine of faith that can be used to discredit the Bible') and St Aquinas's comment (that there was no need for conflict between what reason teaches us and the revelation of truths in the Bible, if the Bible is interpreted correctly). The problem then, as now, lay in the acceptance of a metaphorical versus a literal translation of the Bible.

In 1616, Pope Paul V submitted questions raised by Copernicus and Galileo regarding the motion of heavenly bodies to the 'official qualifiers of disputed propositions' (Hetherington, 2003). They were not aware, as we are now, that much of astronomy is counter-intuitive and abstract, and consequently found "both the motion of the Earth and the stability of the sun false and absurd" (*Ibid*., 4). As a result, an edict was issued forbidding the reconciliation of Copernicanism with the Bible. In 1623, however, a new pope was chosen: Pope Urban VIII encouraged Galileo to write a book on Copernican cosmology, with the intention that it would "demonstrate that the Church did not interfere with the pursuit of cosmology, only with unauthorized interpretations of the Bible" (*Ibid*., 5) Galileo wrote his *Dialogue*, but in casting Urban as the Aristotelian representative who lost every argument in the dialogue with the Copernican representative, all Galileo managed to succeed in doing was to have even hypothetical discussion of Copernican cosmology deemed as heresy.

Copernicus, Galileo, Kepler and Newton, whose ideas were followed by new challenges to Christian theology in the fields of the Geological and Biological sciences, were men of faith who did not set out with the intention of causing conflict. Newton for example, "thought that his discoveries provided new evidence of the existence and providence of God" (*Ibid*., 6), yet his law of universal gravitation changed the perception of the world from one which was spirit-filled to one which was mechanical and predictable. Similarly, Descartes, while using his famous "cogito, ergo sum" as the basis for his ontological argument (for the existence of God), believed that the Universe was entirely material (Dictionary of Ideas, 1994, 467). He thus provided the Scientific Revolution with a rationalist vision of nature as a perfectly ordered machine governed by mathematical laws, and in consequence, one in which a supernatural power was obsolete (Barrett, 2000). In 1786, Pierre-Simon Laplace (1749 – 1827) used Newton's laws in his proposal of a purely physical theory which could successfully replace *ex-nihilo* creation: his Solar Nebula theory was powerful in that it could explain not only the formation of the Solar System but also its observed order, with the terrestrial planets located closer to the sun, and the gas giants orbiting at a distance where they did not vaporize. At the same time that science was providing compelling explanations at the macro level of the Solar System, the newly emerging discipline of geology was providing its own challenge to Biblical creation accounts of the formation of the Earth. The work of Nicolaus Steno (1659 – 1686), James Hutton (1726 – 1797), William Smith (1769 – 1839) and Charles Lyell (1797 – 1875) discredited the time limit set by the Bible in terms of creation and established that the Earth was far older than the 6 000 years of prevalent Biblical theory.

The translation into English of the King James version of the Bible was completed in 1610, six years before Pope Paul V submitted the Copernican ideas of motion to the 'Official Qualifiers of Disputed Propositions'. In 1642, John Lightfoot, Vice Chancellor of Cambridge University, announced his calculation of the date of creation of the Universe as the 17th September 3928 BC. This calculation was based on a careful study of the genealogies in the King James Bible. Eight years later, James Ussher, the Anglican Archbishop of Ireland changed Lightfoot's date by 76 years and claimed that the beginning of the Universe was on the 3rd October, 4004 BC. Ross (2004, 22) records that

> "In a final round of sparring, Lightfoot adjusted Ussher's date. He concluded that all creation took place the week of October 18 – 24, 4004 B.C., with the creation of Adam occurring on October 23 at 9.00 am, 45th meridian time. This extraordinarily precise conclusion provoked considerable mirth among both Bible scholars and critics, but its far reaching effects are nothing to laugh about".

Ussher also derived dates, based on genealogical records, for every historical event mentioned in the Bible. Subsequent printings of the King James Bible, copies of which would have accompanied English Christian missionaries all over the world – including

Africa - carried these dates in the margins, which gave them the stamp of authority (Cutler, 2004; Ross, 2004). But the fossil record in Smith's painstaking development of stratigraphy (the theory that layers of rock could be ordered according to their fossil record), and Hutton's theory of uniformitarianism (that 'the present is the key to the past', i.e. that processes currently at work in shaping the Earth's topography are the same as those that had taken place in the past, a suggestion at variance with the Flood concept of 'catastrophism') indicated that the Earth was much older than suggested by Ussher and Lightfoot's calculations. Lyell's book, '*Principles of Geology*', which also implied that the Earth was much older than 6 000 years, provided Darwin with a geological framework within which his ideas of evolution could be applied. Charles Darwin's '*Origin of Species*' was published in 1860, with the legendary Wilberforce – Huxley debate taking place in the same year. The story is summarized by Ross (2004, 29):

> "After being humiliated at a Royal Society meeting in England, Britain's foremost biologist invited a brilliant orator (Samuel Wilberforce) to debate his nemesis, Thomas Huxley, on the topic of Darwin's book. Wilberforce (the bishop of Oxford), with limited training in science and inadequate preparation, stumbled into several serious blunders during the debate. Huxley (a young scientist) seized upon and exposed these scientific errors. Backed against a wall, Wilberforce sought a rhetorical victory by asking Huxley on which side of his family he claimed descent from monkeys. Huxley's brilliant reply dealt a blow that continues to reverberate: "I would rather be descended from a poor chattering ape than from a man of great talents who would appeal to prejudice rather than to truth." "

This incident brings to mind the response of the Church authorities to Galileo, but by the late 19th Century, the relationship between science and religion in the 'modern West' had largely been reversed. The Church was powerful enough in Galileo's day to quell Copernican cosmology, but by the time of the Wilberforce – Huxley debate, science had been so successful in explaining the operations of natural phenomena in so many fields, that this

> "rhetorical defeat shattered public opinion of Christians and Christianity (and) from that day forward, scientists – not all, but many – associated Christians with prejudice, deception, error, ignorance, emotionalism, and blind opposition to scientific pursuits" (Ross, 2004, 29).

This stance was itself prejudiced as many important scientific breakthroughs came as the result of research done by Christians, the work of Abbot Gregor Mendel in establishing the basic laws of heredity being one example. However, for many people, science was being confirmed as the new truth, and the ridicule of established Church views was followed by "a revolution of atheism and agnosticism, fuelled by the techno-scientific advances of that period" (Nair, Williams and Williams, 2006, 27). In 1897, the President of Cornell University published a book titled "History of the warfare of Science with Theology in Christendom"

(Hetherington, 2003), which illustrates the perception of the nature of the relationship between science and religion at that time.

2.4.2 Modern responses to the conflict between science and religion

During the 20th Century, major strides in the development of the scientific understanding of the Universe have come as a result of (among others) Einstein's theories, Hubble's discovery of Red Shift, and Penzias and Wilson's detection of 'left-over' radiation from the Big Bang. The success of science and the scientific method, particularly in its application through technology, has resulted in a growing acceptance that 'only science gives real knowledge' (Forsthoefel, 1994). Many Christians, however, have felt "…a moral obligation to preserve a divinely revealed body of doctrine whose source is a God who cannot deceive, who is Truth itself and who is the origin of all truth" (*Ibid.*, 12). As a result the theories of science, have periodically been challenged by proposals such as Gosse's 'Appearance of Age' theory, posited in 1857, which was a response to geology's claims regarding the age of the Earth (Ross, 2004), and the so-called 'God of the Gaps' theory, which ascribes anything that cannot be explained by science to be the result of God's handiwork – a self-defeating theory which sees God being credited with less and less as science explains more and more.

The problem of whether belief and knowledge are compatible has occupied philosophy and theology since medieval times (Gaarder, 1995; Sinatra *et al*., 2003). Rationalism, reductionism and empiricism, which are the hallmarks of science, have forced many contemporary Christians to adopt a 'theology of faith', one of the two paths to God proposed by Thomas Aquinas. This enables many Christians, particularly literalists or fundamentalists who are also scientists or interested in science, to compartmentalize their knowledge and belief, a mechanism which allows them to cope with apparently unresolvable conflicts. Forsthoefel (1994, 18) for example, has stated that "faith and science when each stays in its own area of competence do not and should not contradict each other". This compartmentalization, dubbed "independence" by Barbour (2000) and "Gouldian dualism" by Gevers (2002, 48) in response to Gould's advice in his book '*Rocks of Ages: Science and Religion in the Fullness of Life*' that "the 'magisterium of science' should be kept completely separate from that of 'morality/religion'", seems to be the simplest solution to avoiding conflict between science and religion, but it does not work for everyone. This is especially evident in the protracted and well documented curriculum battles regarding evolution that have been fought in the United States (Skoog and Bilica, 2002) which bear testimony, according to Forsthoefel (1994) to a wider and ongoing conflict in society between fundamentalist religious 'truths' and the 'truth' of science. Many organizations have also been founded, particularly in the USA, in response to the threat of secular scientific hegemony: examples include the "World's Christian Fundamentals Association" which was founded in 1919 and the "Creation Research Society" (in 1963) which is a powerful organization that fights for the inclusion of creationism in the science curriculum (Ross, 2004).

An age old resolution to the conflict, and one which is adopted by more liberal Christian rationalists, is to appeal to a metaphorical or interpretive rather than literal approach to the Scriptures. This is Aquinas's 'other' path to God, through reason and the senses (i.e. natural theology) but this was dealt a severe blow by the success of mechanistic science, particularly when associated with the 'God of the Gaps' model of conflict resolution. However, Barrett (2000, 9) points out that since the confirmation of the Big Bang model of the Universe in 1965,

> "…new perspectives from the realm of the natural and human sciences have raised questions which lie beyond the competence of science and invite response from the discipline of theology. Consequently, in the Western world there has arisen a fresh wave of discussion over the last three decades between theology and science".

Barrett (2000) and others (e.g. Schroeder, 2001) claim that the development of 'The New Physics', comprising studies of the very small - particle physics - and the very large - astrophysics and cosmology, have introduced a new 'brand' of science, which through proposals such as the Quantum, Chaos and Dynamical Systems Theories, along with the Anthropic Principle, may provide the route to a synthesis of religious and scientific belief. This new understanding is here dubbed 'secured scholasticism'. This term combines Jegede's (1995) concept of '*secured* collateral learning' which describes a position of integration between different ways of knowing, and *scholasticism*, the doctrine which sought to reconcile the conflict between Aristotelian philosophy and Christianity. 'Secured scholasticism' could dispense with the need for compartmentalization (or even the need for flexibility) in interpreting Scripture to accommodate the discoveries of science. A well known example is the Big Bang theory: while Einstein altered his theory of relativity to fit the prevalent understanding of the day of an eternal Universe, it was a Jesuit priest and astrophysicist, Georges Lemaitre, who promoted the idea of a 'big bang style' beginning to the Universe. This was supported – to the astonishment of many theologians - by Pope Pius XII, as he considered that it affirmed the notion of a Judaeo-Christian beginning to the Universe and a transcendental creator (Hetherington, 2003). Four years later, in 1929, Hubble's Law concerning the rate of expansion of the galaxies was publicized, and in 1948 Hoyle coined the term 'Big Bang'. It is well known that Hoyle intended this as a derisive description of the hypothesis that proposed the evolution of the Universe from a singularity, but it is perhaps less well known that Hoyle was an atheist. It has been suggested that his support of the Steady State model of the universe suited him better as it dispensed with the need for a creator (Barrett, 2000). The polarity of Christian responses to the Big Bang model can be seen by comparing Pope Pius's response to that of a 21st Century Louisiana (USA) community edict, which was "to glue textbook pages together so that pages describing the " big bang" theory will be unseen" (Skoog and Bilica, 2002, 456).

A more recent example of the possibility of ‘secured scholasticism’ comes from the Human Genome Project and the 'Eve hypothesis': that a single (African) female ancestor to our species has been established from studies of mitochondrial DNA (mtDNA) (Stringer, 1994). The recently opened exhibits at Maropeng in the 'Cradle of Humankind' World Heritage Site near Johannesburg in South Africa, make strong reference to the 'Out of Africa Hypothesis', which maintains that “part of the African stock of early modern humans spread from the continent into adjoining regions and eventually reached Australia, Europe and the Americas” (*Ibid*., 186). There is also reference to mtDNA research, but no reference is provided to the 'Eve Hypothesis', an interesting omission in an exhibit which could be deeply offensive to many South Africans as it only portrays the evolutionary perspective of Hominid development. (It would have been culturally sensitive, and in line with the national education policy, which requires the valuing of South Africa’s indigenous ways of knowing, to have portrayed traditional African as well as religious perspectives on the ‘origin of man’.) Another example of potential new intersections between science and religion comes from quantum mechanics, which also appears to be ‘cage rattling’ the ideas of modern physics by alluding to connections between particles that transcend the concepts of space and time (Nair *et. al.,* 2006).

The problem with the idea of ‘secured scholasticism’ is that it is limited to an academically elite group of people who have the capacity and interest to engage deeply in scientific disciplines as well as theology. Science is able to pursue its version of truth with little regard to theology, but it is the work of theology to try to relate religious doctrine to the new discoveries of science. The concept ‘secured scholastics’ is proposed here to refer to people who are either theologians who are also scientists, or scientists who are theologians or philosophers, who seem to have achieved a ‘secured’ way of knowing – a single truth, with little need for metaphorical interpretation of the Bible and no need to compartmentalize their knowledge and their faith. Barrett (2000, 133), in his conception of a spectrum of positions with regard to the interaction between science and theology, places these ‘secured scholastics’ (or in his view, ‘critical realists’), in the centre of his spectrum (see Table 2.1), which has non-scientific theism, and non-theistic science, at its poles.

Table 2.1: Spectrum of relationships between science and religious beliefs (adapted from Barrett, 2000, 133)

non-theistic science	science & spirituality unlinked	science & theology interacting (“Secured Scholastics”)	faith & science unlinked	Non-scientific theism
e.g.: Monod, Dawkins, Atkins.	Many religious scientists	e.g.: Barbour, Peacocke, Polkinghorne and Pannenberg	Many religious believers	e.g.: Bryan, Gish, Morriss

The examples given by Barrett include Ian Barbour (whose typology (Barbour, 2000)) will be used as a framework, in conjunction with cultural border crossing and collateral learning, for analysis in this study, Arthur Peacocke (who is described by Hill (1990) as having a “rare combination of familiarity with the findings of modern science and a keen understanding of contemporary theological thought”) and John Polkinghorne. However, it would seem appropriate here to add some South Africans to the list: George Ellis (University of Cape Town), David Block (University of the Witwatersrand) and Peter Barrett (University of KwaZulu-Natal), are (in my understanding) among those who have a ‘secured’ understanding of science and religion. But while they are widely published and well known in specific circles, their worldview has yet to penetrate the discourse of science education.

2.4.3 The impact of religion on learning in science

In his editorial for the special edition on Religion and Science Education in the journal *Science & Education*, Matthews (1996, 91) states that "the overall theme of Science, Religion and Education has been dealt with many times in books, journal special-issues, and articles". However, Shipman *et al*. (2002, 527), point out that the issue of science and religion has only been “episodically addressed” (notably in the special edition of *Science & Education* edited by Matthews), confirming that in the discourse of science education, as presented in science education journals, the importance of this issue is not highlighted. They explain the general lack of interest or exclusion of religion from science as a result of the view that

> “(f)rom certain vantage points, restricting the content of science courses to a narrow view of science content makes sense. Scientists, acting as scientists, are naturalists. They study natural phenomena and the interaction of material objects in the Universe. The rules of the game exclude God from the picture” (*Ibid*., 527).

As noted in the introduction, this is a First World/Western perspective. However, Matthews (1996, 96) points out that while "(i)t may be thought that the issues connected with Science, Religion and Education have run their course" and that in secular Western cultures they are now "dated", interest in the occult, astrology, extra-sensory perception, ghosts and re-incarnation has soared, and "anti-science is on the rise". Barrett (2000, 1) reflects the perception from within the discourse of theology and religious education, rather than that of science education, and describes the interaction between science and religion as “lively”. Consequently, it is clear that there are many different views. A great deal of literature on science and religion is available, and there are a number of forums, associations and centres dealing with this issue, many of which are associated with academic institutions. Examples include the Centre for the Study of Science and Religion at Columbia University and the Philadelphia Centre for Religion and Science, and as a local example, the Research Institute of Theology and Religion based at the University of South Africa. Clearly those interested in theology have been challenged to address the new developments in science, but, as has been noted, the debates have apparently been less significant to science education.

One of the few papers to be published in a Science Education journal that focused on religion in relation to science education was that of Roth and Alexander (1997). As a result of their work, they recommended that there should be intervention of the part of teachers to help their students deal with conflicts between religion and science. In South Africa, Laugksch's (2003) Bibliography of South African Science Education Research, which covers the period 1930 – 2000, gives only four references to religion, three of which focus on evolution, and one on values and morals in the science curriculum. In 2003, Lemmer, Lemmer and Smit published an interesting paper on the conceptions of Physics students, and very recently, a few presentations were given at the 2006 South African Association of Science and Technology Educators in Durban (Govinden and Govender, 2006; Govender, 2006 and Stanton, 2006) which drew attention to some of the issues around the inclusion of evolution and cosmology in the new Further Education and Training Curriculum (FET: Grades 10 - 12). Cosmology and evolution are to be included for examination at the matric (Grade 12) level for the first time in 2008. Stanton (*Ibid*.) comments that the inclusion of topics such as the expanding Universe, gravitational lenses and nuclear synthesis is very ambitious at this level, and questions whether school science educators have the pre-requisite content knowledge to be able to deal with these notions. Govinden and Govender (2006, 26) point out that the traditional teaching of Physical Science did not include these topics - therefore in-service educators "are barely equipped to handle these contexts at the FET level". Govender's paper is a case study describing some aspects of Zulu and Basotho indigenous beliefs related to astronomy.

On the international front, important journal contributions include those of Mahner and Bunge (1996) and the responses to this paper, for example Settle (1996), Lacey (1996), Poole (1996) and Woolnough (1996), all of which were part of a special edition on science and religion in the journal Science and Education. Other papers include those of Cobern (for example 1996), Fysh and Lucas (1998), Francis and Greer (2001), Stanley and Brickhouse (2001), and Shipman *et al*. (2002), but the only ones to specifically examine student perceptions on the effect of religion on their acceptance and understanding of astronomy are those by Roth and Alexander (1997), Brickhouse et al. (2000) and Shipman *et al*. (2002).

Barrett (2000) has identified three major shifts in Western understanding of the physical world: the Scientific Revolution in the 16th and 17th Centuries; Darwin's Theory of Evolution in the 19th Century and The New Physics of the 20th Century. With regard to the first 'shift', i.e. the Scientific Revolution and specifically the change from a geocentric to a heliocentric solar system, it was pointed out in section 2.3 that research in astronomy education has shown that many people are pre-Copernican in their understanding of the solar system. However, there has (recently at least) been little contention regarding the scientific explanation here: on October 31, 1992, according to Forsthoefel (1994, 19), "Pope John Paul II officially rehabilitated Galileo, declaring him a better theologian than the ones who had insisted on his condemnation"! As far as the third 'shift' is concerned, Particle and Quantum Physics are inaccessible to most people outside the discourse in this field. Here it would appear that there is support for, rather than conflict with, religious perspectives.

Of the three shifts identified by Barrett, it is the second (i.e. evolution), that has been a frequently examined and contested issue in science education and specifically in relation to biology education. The book "*The Architect and the Scaffold*" edited by James and Wilson (2002), provides a selection of South African responses to the South African debate, but other papers of interest include those of Jackson *et al*. (1995); Skoog and Bilica (2002); Brem, Ranney and Schindel (2003); and Sinatra *et al*. (2003). It would seem that when evolutionary theory is limited to studies of adaptation, little controversy is generated. But when it is applied to human beings, there is likely to be dissention. Within the second shift, evolutionary theories which have received less attention in terms of controversy are Plate Tectonic Theory, the Solar Nebula Theory and the Big Bang Theory. These affect many people because of their inclusion in school and undergraduate Earth Science curricula, but they also remain at odds, for many people, with Biblical accounts of creation, but there does not seem to be much specific research interest in controversies in the area of Earth Science within the field of science education.

However, there is interest in the wider role of ethics and values in education as a whole, and here an intersection with religion is unavoidable. Interest also seems to be growing as science is questioned in the wake of environmental problems, and as 'old' ideas are challenged by "developments in the field of physics which have impelled many physicists to adopt, or re-adopt, philosophical views that have traditionally been associated with religion" (Sarracino, 1998, 127). Two interesting international developments that are addressing the intersection of science and religion are the 'Science and Religion in Schools Project', started in the United Kingdom in 2002 (www.srsp.net) and 'The First International Congress on Dialogue between Science and Religion' which took place in May 2006 in Teheran. Despite this interest, it is clear from the relative dearth of reported research in the science education literature on the impact of religion on learning in science, in comparison to the wealth of literature on the impact of culture and society, that religion is not high on the science education research agenda in the West. But what of the situation in Africa?

2.4.4 Africa's links with the science/religion debate

Mbiti's seminal work "Religion and Philosophy in Africa" begins with the words "Africans are notoriously religious" (Mbiti, 1969, 1). Apart from African Traditional Religions, which will be considered in the next section, Mbiti states that both Christianity and Islam are "indigenous in Africa and are deeply rooted in the history of our continent" (*Ibid.,* 223). Mbiti is of the opinion that European (missionary) Christianity "hardly touched African peoples" (*Ibid*., 225) – rather that it is the Christianity that was deeply rooted in Ethiopia, Sudan and Egypt from the earliest spread of the Christian gospel, and the Christianity that was brought back by returning slaves towards the end of the 18th Century, that really accounts for the widespread following of Christianity in Africa today. Mbiti, who is Kenyan by birth, is possibly referring more to the central and northern parts of Africa, rather than to southern Africa, which was not affected by the slave trade in the same way that those areas to the north were. In addition, South Africa's apartheid history resulted in missionaries playing a significant role in education in South Africa, at both school and tertiary level (with theological colleges and Universities such as Fort Hare, which was closely linked with Fedsem (the Federal Theological Seminary) being enormously influential and instrumental in education and evangelization in South Africa). However, Mbiti explains what he describes as the "superficiality of mission Christianity" by saying that Christianity was imposed on African culture without contextual adaptation or interpretation, but indicates that since the 1960's this has been changing, with the active development of African theology. This has led to the indigenization of the Christian faith, resulting in many sects and independent Church movements – more than seven thousand such independent Churches being reported in Africa in 1984 (*Ibid*., 226). Hendricks and Erasmus report from the 2001 census data in South Africa that the general trend of this data shows that "a growing number of people in this country associate with Christianity" (2005, 109) and that the fastest growing Churches are those belonging to the African Independent Church movement – with membership of the Zionist Christian Church (the biggest of the African Independent Churches) having increased from 9.5% to 11% of the South African population in the space of the 5 years between the 1996 and 2001 censuses.

The reason given by Edwards (1998) for this growth is that there are aspects of Christian spirituality that are resonant with the African worldview, and consequently tend to reinforce it. The role of community and the role of the spirit are prime examples, giving African Christianity a flavour that is uniquely African, while another commonality, especially for those groups that follow and emphasize the Old Testament rather than the New Testament, relates to animal sacrifice (Arden, 1996; Elion and Strieman, 2001). The various 'African brands' of Christianity also provide a response to the disintegrating traditional African way of life, particularly as a result of urbanization, with people being attracted to organizations that will give them a sense of belonging and support – a replacement for the traditional community base that has been left behind in the rural areas. One of the notable features of the Independent Churches in relation to the current study is a tendency towards fundamentalism. Mbiti notes that

> "The literal interpretation of the Bible is common among these Churches. It is to be remembered, however, that some of their leaders cannot even read, and the majority are poorly educated, so that only a few of them have been to theological colleges or seminaries. There is a tendency among some groups to stick almost exclusively to the Old Testament and its precepts." (Mbiti, 1969, 229)

The large Christian following in South Africa and the tendency to fundamentalism just mentioned, means that a strong reaction (in terms of numbers of people and degree of reaction) can be anticipated to the 'different' story told by science. The issues that have historically resulted in conflict between science and Christianity are likely to be repeated here, but uniquely moulded by a deep-rooted respect of authority as well as the sense of community that defines African culture. There is also the ‘deeper layer’ that needs to be taken into consideration: African culture, or what Mbiti describes as African Traditional Religion (ATR) and philosophy is said to underlie the worldview of Africans. There is recognition that it has been put under severe strain by education, urbanization and industrialization, but

> “(u)nless Christianity and Islam fully occupy the whole person as much as, if not more than, traditional religions do, most converts to these faiths will continue to revert to their old beliefs and practices for perhaps six days a week, and certainly in times of emergency and crisis” (Ibid., 3)

Ochieng'-Odhiambo (1995, 45) explains this reversion by saying that people would turn to a traditional way of life “because their forefathers and ancestors had left them with practical solutions (to) the great problems of humanity; the problem of life and death, of salvation or destruction.” In contrast to Western spirituality, which Edwards (1998, 86) describes as having been “diminished through its run-in with Western science (and) relegated to the limbo of the unreal”, African philosophy does not suffer from any form of dualism: for the African, “to be is to be religious in a religious universe” (Mbiti, 1969, 256). The section that follows shifts the focus from Western ideas to African ideas with regard to philosophy, religion and science.

2.5 AFRICAN RELIGION AND PHILOSOPHY

2.5.1 African ontology and epistemology

The Scottish philosopher, J.F. Ferrier (1808 – 1864) is usually credited with formally having coined the terms 'ontology' and 'epistemology' to distinguish between the two main concerns of philosophy: reflection on the meaning of existence and life, and reflection on human ability to even know and judge matters such as the nature, source and reliability of that knowledge (Groome, 1997). The hegemony of the Western ‘way of knowing’, carried worldwide through the voyages of exploration and colonization of the new world by the old, has only recently been challenged as ‘other ways of knowing’ have come to be acknowledged by the Western world. ‘Knowing’ is closely linked to culture: it shapes how people live and who they are, i.e. it permeates their identity. This knowledge is usually not questioned: it is taken for granted – ‘that is just how things are’. In education, the widespread acceptance of constructivism, which is a product of this relativism, has stimulated research that has expounded on the impact of traditional philosophies on the learning of Western science. In section 2.4, in the light of the 20th Century “explosion” of Christianity in Africa (Mbiti, 1969, 236), the relationship between science and religion was examined to provide part of the background necessary for the analysis of student responses in this study. Now we turn to African philosophy and religion – the ‘skeleton’ inside the Christian body - which, it is widely claimed by African philosophers and theologians is the “source and cause of being” in Africans (Setiloane, 1998(a), 70). Whether you are rich or poor, urban or rural, Christian or Muslim - or do not subscribe to any non-indigenous faith – if you are African, African religion and philosophy defines who you are and where you come from. It is what gives Africans identity (Mbiti, 1969).

The formalization of what actually comprises African philosophy has, however, been the subject of much debate. Masolo (in Ochieng'-Odhiambo 1995, 1) notes that

> "(t)he birth of the debate on African philosophy is historically associated with two related happenings: Western discourse on Africa, and the African response to it."

Ochieng'-Odhiambo (*Ibid*.) provides a useful historical survey of the attempts to define African philosophy, starting with what is termed the 'conventional conception'. This is usually ascribed to the work of anthropologist Lucien Levy-Bruhl, but his ideas, according to Ochieng'-Odhiambo (*Ibid*., 2, 4), were based on the ideas of Hegel, who believed that "reason was the driving force of events" and that Africans were "innocent" of reason. Levy-Bruhl developed the idea that without reason, Africans had no knowledge of God, believing rather in magic and sorcery. His books '*Primitive Mentality*' (1923) and '*How Natives Think*' (1926) contain his views on the differences between Western and African epistemology. These are summarized by Ochieng'-Odhiambo as follows:

> "…whereas important concepts in Western cultures are formed through academic and intellectual discourses, (those) in non-Western cultures are basically learnt in rites and rituals that involve intense affective and psychomotor experiences. Concepts in non-Western cultures are, as a result, mystical and not intellectual. Their explanations make sense in supernatural and occult powers… (their) mentality is primitive and pre-logical" (*Ibid*., 6).

This view reflects the racism inherent in the belief that Western ways of knowing are superior to any others. Okere (2005a, 5) explains that

> "Starting from the Enlightenment, when the first stories about other, different and stranger peoples and places reached Europe, the new context of contrast and comparison soon portrayed Europeans in better light than their new objects of curiosity. Very soon, this acquired a racist dimension. The West became "civilized Europe" and the rest of the world, those exotic others discovered by European travellers, became heathens or savages fit only to be conquered and enslaved, colonized and Christianized to become civilized. Civilization was now defined in western terms and by western standards. The contribution of the rest of the world to the common pursuit of humanity could be conveniently ignored or quietly co-opted with little or no acknowledgement. Reason, which ultimately would mean humanity itself, virtually became western."

During the 20th Century, Levy-Bruhl's books were followed by others written by Europeans such as Diedrich Westerman, Placide Tempels and Christian Neugebauer, who either supported or disputed the original Hegelian views, but as noted by Ochieng'-Odhiambo, “all the scholars belonging to this worldview are undoubtedly under the influence of Western mental bondage” (Ochieng’-Odhiambo, 1995, 18).

The response of African (e.g. P. Hountondji; C. W. du Toit) and other scholars has been to challenge these views, particularly with regard to the existence of African rationality, and particularly as Western styles of education have been imposed on, and/or adopted, with varying degrees of success, in African countries. Some of these challenges have asserted a fundamental connection with Ancient Greek rationality (linked to the “Out of Africa Hypothesis” mentioned earlier), claiming common foundations for Greek and African thought, and maintaining that philosophy became identified with Greece rather than Africa because of different systems of knowledge acquisition. These were open market place discussions in Greece, with written documentation of ideas, while in Africa, initiation and the passing on of oral tradition was traditionally done in secret (Ochieng’-Odhiambo, 1995). Some scholars, for example Bernal, Olela and James (details provided in Ochieng’-Odhiambo, 1995) and Motshega (2006) claim that ancient Greek philosophy was a stolen legacy from ancient Africa, and indeed, there is commonality between the ideas of Aristotle and those of African traditional thinking (although these are likely to be encountered in other traditional societies as well). For example, Aristotle’s idea of ‘final causes’ was teleological, i.e. that everything is interpreted in terms of purpose. African philosophy also relies on purpose as the cause of natural phenomena such as rain, i.e. it rains because plants and animals need it to rain. Okere (2005b) notes that further challenges to the perception of a lack of rationality in indigenous knowledges have come from the recognition of science as a social and cultural enterprise, accompanied by the change in understanding in science from determinacy to indeterminacy as a result of Heisenberg’s work, and the acknowledgement of the possibility of error in science.

But while science is recognized as a culture in its own right, with even those children brought up in Western societies struggling to “cross the borders” into the culture of science (Aikenhead, 1996), the question that is asked here is what specifically might it be in the African worldview that might make it a ‘handicap’, as suggested by Jegede (1995, 1997, 1998), ‘to Africans learning science’? At the beginning of the 1990’s, Jegede and Okebukola, through their studies in culture and science education in Nigeria, suggested five areas that have an influence on the learning and teaching of science in the African context. These are traditional worldview, authoritarianism, goal structure, societal expectation and the sacredness of science (Jegede, 1997, 9). Jegede points out that

> “… for the teacher who perhaps shares the same sociocultural background, the issue is as real as it is frustrating. The situation is even worse (and may be horrendous) for the teacher with a western background who has to teach students of non-western backgrounds” (*Ibid*.)

Jegede briefly explains each of the areas identified above, but it is useful (particularly for anyone with a Western background) to draw on the literature outside of the science education discourse to more broadly understand how these areas may affect border crossing into science. For Jegede, traditional worldview “relates to traditional beliefs and superstitions being used as a framework through which occurrences are interpreted" (*Ibid*., 10), so to understand how these aspects of worldview can have such a profound effect, it is helpful, as suggested by Temples, to trace the differences between traditional and scientific worldviews "to the radically different way in which the two groups look at reality and their conceptions of ontology" (in Ochieng'-Odhiambo, 1995, 46). One way to do this is to look at the development of the philosophies of the two groups and search for commonalities and differences.

One of the commonalities between ancient Greek and African philosophy relates to monism, i.e. the theory that all being may ultimately be referred to one category: that there is no separation between mind and matter. Aristotle saw no division between knowing and being, or mind and matter – a view which is also frequently stated as a 'hallmark' of African culture (Ogunniyi, 1996). The dualism of modern science, which has frequently resulted in problems associated with reductionism (Okere, 2005b), stands in contrast to the African understanding that matter and spirit are one. This understanding translates into anthropomorphism, that all things - "people, ancestors, spirits, God, animals, plants, rocks – are persons, so the 'I' and the 'we' are connected to all things" (Malcolm and Alant, 2004, 49), as well as into the understanding of the supremacy of the community over the individual. This comes from the African principle of 'ubuntu' - i.e. that "I am because we are; and since we are, therefore I am" (Mbiti, 1969, 106). The contrast between monism and dualism produces fundamental differences between the ontologies of traditional African philosophy and Western science. For example, for Africans, true knowledge is ontological knowledge, and since the Universe is seen as a hierarchy of forces, and knowledge is seen as a kind of force, knowledge, like being, is hierarchical (*Ibid.*, 47). Mbiti (*Ibid*., 15) puts the hierarchy into the following order: God in the highest position, followed by Spirits; then 'Man'; then animals and plants; and phenomena and objects without biological life at the bottom. Thus God is seen as

> "the originator and sustainer of man; the Spirits explain the destiny of man; Man is at the centre of this ontology; the Animals, Plants and natural phenomena and objects constitute the environment in which man lives, provide a means of existence and, if need be, man establishes a mystical relationship with them" Mbiti (*Ibid*., 15).

African philosophy is thus anthropocentric, which according to 'The Hutchinson Dictionary of Ideas' (1994), means that humans are seen as the centre of the Universe, as well as anthropomorphic, which means that that human characteristics are attributed to animals and inanimate objects. Kudadjie and Osei (1998) are of the opinion that the God-man-nature relationship is critical to the promotion of scientific thinking. They support the thesis of the Judeo-Christian worldview origin of the development of science, suggesting that in Africa, the absence of a worldview that demythologizes the Universe by placing humans at the 'crown of creation with a mandate to take charge of the rest of creation', continues to be a serious obstacle to scientific thinking in Africa. In Africa, traditional worldviews still prevail, with the Universe populated "by thousands of gods, ancestors, witches and other spirits beside the Supreme Being" (*Ibid*., 37). Kudadjie and Osei state that because Africans are subordinated to a range of spiritual entities, they can

> "… hardly conceive of themselves as autonomous beings (and are) no longer in a position to think independently enough to insist on their right to self determination. Perceiving themselves to be helpless without spiritual forces, there is hardly anything they can do for themselves. To expect such a person to engage in any detached scientific thinking is, therefore, to portray one's ignorance or misconception of his or her worldview" (*Ibid*., 45).

Historians of the development of Western science have noted that the "bondage to Aristotle" had to be broken for the development of science in Europe (Hodgson, 2002, 12). Africa has had two Western knowledge systems - Christianity and Science - imposed on it, but neither have supplanted it i.e. neither have 'broken the bondage' of its indigenous philosophy and culture, with its Aristotelian beliefs in the eternity of creation and its central positioning of humans in the ontological hierarchy. It is interesting to note that, at the beginning of the Scientific Revolution, Kepler initially attributed planetary motion to moving souls (Hetherington, 2003), an idea that resonates with traditional African beliefs that the stars are the ancestors: awake and visible, watching over us by night, asleep during the day when we can take care of ourselves. Kepler's initial ideas show a 'petticoat' of ancient mythology, which according to Rowse (in Barrett, 2000, 14) was not uncommon in the sixteenth century in northern European countries, when "everybody believed in the supernatural; everybody believed, more or less, in magic or the possibilities of magic; everybody believed, to a greater or less extent, in the stars." From the time of Kepler, however, mechanistic science grew to dominate the worldview of Western Europe, while in Africa traditional views have been maintained, alongside imported religion and science curricula.

A worldview difference raised by Mbiti (1969) that may be helpful in shedding light on conceptual problems relating to geological time and the concept of space is that African time is two-dimensional and intimately connected with life and death. There is the present, and there is a long 'past'. There is virtually no future, although it is expected that the years will come and go "in an endless rhythm like that of day and night, and like the waning and waxing of the Moon" (*Ibid*., 21). But the future is not 'real', as it has not happened yet. Mbiti writes:

> "In traditional African thought, there is no concept of history moving 'forward' towards a future climax, or towards an end of the world. Since the future does not exist beyond a few months … African peoples have no 'belief in progress', the idea that the development of human activities and achievements move from a low to a higher degree" (*Ibid*., 23)

For Africans, the events of the 'now period' (termed '*Sasa'* by Mbiti, 1969, 21) become part of the '*Zamani'* - the developing historical past which is beyond physical death, extending into 'forgotten time'. The *Sasa* period does not terminate with physical death – it continues in the memory and remembrance of those left behind, who will continue to consult the physically departed. Mbiti explains that “while the departed person is remembered by name, he is not really dead: he is alive … such a person I would call the *living-dead*” (*Ibid*., 25). These spirits and ancestors are a vital part of the community, about which Mbiti writes:

> “Traditional religions are not primarily for the individual, but for his community of which he is part. Chapters of African religions are written everywhere in the life of the community, and in traditional society there are no irreligious people. To be human is to belong to the whole community, and to do so involves participating in the beliefs, ceremonies, rituals and festivals of that community. A person cannot detach himself from the religion of his group, for to do so would be to be severed from his roots, his foundations, his context of security, his kinships and the entire group of those who make him aware of his own existence…to be without religion amounts to a self-excommunication from the entire life of society, and African peoples do not know how to exist without religion.” (*Ibid*., 2)

The anthropocentric view, involving religion and community, is thus central to an understanding of past history. The beginning of the Earth is held as synonymous with the beginning of humanity: the past is not examined from the point of view, for example, of the physical formation of the Earth or patterns of climate change or geological epochs. The departed are also not seen to be very ‘far away’ – they remain an integral part of the community, either as the living dead, who are still accessible, or in the spirit world, where they may be associated with the stars which are in the ‘sky’ – an undefined ‘up there’ – but one which is still tangible. Time and space are thus measured in anthropocentric terms, with space linked to the sense of sight, and time limited by the unreality of the future, and in terms of the past, the length of the zamani and Africa’s (oral) history.

The importance of community is linked to another of the ‘cosmological obstacles’ to scientific thinking suggested by Kudadjie and Osei. This is the problem of taboos, which they describe as “the do’s and don’ts prescribed by the supernatural forces and backed by their sanctions” (Kudadjie and Osei, 1998, 50). They suggest that while scientific explanations will often be known to the elders in the community, this knowledge is regarded as “too sacred for the youth and others in the community. If the enquirers persisted, they would be dismissed with such proverbs or maxims as: ‘It is not for the child to crack (the shell of) a tortoise but that of snails’ or ‘If you probe too deep into the eyes of the dead, you will find a ghost’.” (*Ibid*., 51).

A story by Jannotta in ‘The Science Teacher’ (1986), while it concerns American and not African indigenous culture, provides an insight into traditional practices and the breakdown that can happen in the lack of passing on of cultural understandings, especially as traditional societies become Westernized. Janotta described the experience of a White American science teacher and her class of Navajo seventh graders in a reservation school. They had been on a field trip and had come across a snake, which the teacher recognized as a harmless species. She picked up the snake and conducted an impromptu lesson, during which time she encouraged the children to touch it. Later that evening, one of the children came to her home in a very agitated state to ask if he had touched the snake, because his father needed to know. She later discovered that the Navajo belief was that if you touched a snake, an evil spirit would enter your body “maybe not right away, but some time in your lifetime” (Jannotta, 1986, 56). It is clear that the child had not known about the belief before touching the snake. His lack of knowledge did not, however, prevent him from experiencing at least some of the consequences of his action.

A further community-related issue, identified by Jegede as one of the five most important socio-cultural influences on the learning and teaching of science, is the ‘problem of authoritarianism’ which is linked to societal expectations. Jegede indicates that African society “frowns at a situation where the elder’s point of view is challenged or questioned (and that) it behoves the younger individual to accept without question the directives passed down by the elder” (1995, 114; 1997, 9). Jegede explains that this locus of authority of knowledge is transferred to the classroom where the science teacher is seen as the elder who knows all. The African philosopher, Wiredu (1980), has also identified and condemned authoritarianism as one of the 'cultural evils' hindering the orientation to science in Africa.

It is interesting here to reflect on the freedom of thought and discussion that was permitted and encouraged in Greek society (despite the condemnation of Socrates for corrupting the youth and introducing new gods (Robinson and Groves, 2004)). The fact that Aristotle, more than two millennia ago, could disagree so fundamentally with the ideas of Plato, his elder and teacher, stands in sharp contrast with African cultural norms of “respect for authority and old age…and abhorrence of vices like pride, defiance of authority (and) individualism” (Kudadjie and Osei, 1998, 41). The African authoritarian tendency is to “discourage the youth and other enquirers from raising critical questions” (Kudadjie and Osei, 1998, 51). Jegede (1995, 114) claims that the interaction pattern among the people of Africa, which he refers to as ‘goal structure’, is co-operative in nature, and consequently “contrasts very markedly with the individualistic and competitive orientation that school science portrays to learners”. Cowling (1996) also points out that the lack of questioning comes from the attitude that knowledge that comes from ‘authority’ takes precedence over knowledge that is empirically observed. This serves to preclude the development of new ideas. In contrast to the legacy of honouring individual achievement that is so fundamental to Western society and critical to the development of new ideas and critical thinking, “the concept of ‘individual’ is nonexistent in traditional African thought” (Setiloane, 1998a, 69). In his recent biography, Khumalo (2006, 15), a South African journalist, communicates the everyday reality of this approach to life by writing:

> “In Soweto they say, “*Wie se laaitie is jy*?” Whose son are you? In Zulu we say, “*Ungowakwabani*?” It means essentially the same thing. There are no easy ways of responding to the question because it arrogantly tells you that you cannot exist in a vacuum. You have to be somebody’s son. You are not a statistic, but part of a long human narrative. You don’t exist in isolation.

> *Wie se laaitie is jy*? ... The question… robs you of your individuality, which as a concept, is still anathema in African society. In African society a child does not belong to a parent only: it (we don't have the pronouns he and she in Zulu) belongs to the community… The introduction becomes a narrative that says that you acknowledge and respect where you come from."

It has also been noted that the African worldview tends towards fatalism and an acceptance of destiny (Mbiti, 1969; Kudadjie and Osei, 1998). Abimbola (1977) explains the difference between traditional African and Western science modes of thinking by saying that what is missing in the African worldview is the concept of chance - that for the African, nothing happens by chance. In addition, as already noted, causal explanations tend to be teleological for Africans rather than mechanical or scientific, with personal explanations being sought to account for various phenomena. Kudadjie and Osei (1998, 48) explain that Africans "will typically begin with questions such as 'Why?, 'Why here?', 'Why here now?', and proceed to pursue 'who?' or which spiritual force is responsible for the calamity" rather than search for a non-personal, or, according to the scientific worldview, rational, answer. Horton (1967) explained the difference between traditional and scientific responses by claiming that African societies were 'closed' in their views to alternative explanations, while scientifically oriented cultures were 'open', allowing the latter to progress and the former to remain confined to mystical explanations. This view has been criticized by suggestions that it is Western societies that were (or are) closed and traditional societies that are open. This has been deemed to be true during colonial times, when Western colonists did not learn the languages and customs of the people in the countries they colonized, and latterly, where any recognition that there are other ways of knowing that may be valuable, is only very recent. du Toit (1998, 23) presents a reconciling view by arguing that rationality must be viewed holistically since it has a 'means-end function'. He also points out that African rationality has an axiological dimension that is lacking in Western science, and suggests this should not be lost in the education and development of Africa.

In his '*Introduction to African Philosophy',* Ochieng'-Odhiambo provides a useful overview of the ideas of many of the most important writers and thinkers in African philosophy. He suggests that the views of philosophers such as Temples, Mbiti and Horton reflect an 'ethnophilosophical approach' which has been rejected in favour of what is called 'the professional approach" (Ochieng'-Odhiambo, 1995, 74). This latter approach, he says, is represented by philosophers such as Kwasi Wiredu, Paulin Hountondji, H. Odera Oruka and Peter Bodunrin, with the distinction relating to the involvement of critical independent reflection, rather than the 'simple' presentation of ethnographies which use philosophical language. He notes that Hountondji rejects the recording of worldview as philosophy, arguing that to qualify as philosophy the work "must involve rigorous, sustained and independent thought" (*Ibid*., 82). Criticisms of the ethnophilosphical approach also centre on the nationalities of the 'ethnophilosophers' (often Western) and their education

(Western), the audience for whom they were writing (mostly Western) and the fact that African tradition was oral until ‘foreigners’ started recording it, with all the attendant difficulties of accurately ‘trapping’ meaning. Ochieng'-Odhiambo refers to Wiredu's suggestion that the problem can be solved by distinguishing between “folk thought preserved in oral tradition” and “critical, individual reflection”, and *not* making the mistake of comparing African folk thought with Western philosophy (*Ibid*., 83). He points out that Wiredu acknowledges that the traditional worldview “is intuitive, essentially unanalytic, and unscientific” making it “appropriate given the unsophisticated traditional mode of life”, but recognizes that it needs to “change and become logical, mathematical, analytical and scientific, in order to cope with the modern mode of life” (*Ibid*., 84). The problem of course is how is this to be done? Ochieng’-Odhiambo suggests that the only escape from the influence of Western philosophy and methodology, is to turn to the sages in African society – those “individuals who are philosophical, notwithstanding the fact that they have not had contact with the so-called Western philosophy” (*Ibid*., 93). However, he acknowledges the question posed by Bodunrin (*Ibid*., 104) who asks "how will the philosophy they provide be different from the traditional worldview already recorded by the ethnophilosophers?" It seems that the professional philosophers also cannot escape Western influence, and Ochieng-Odhiambo concludes his *'Introduction to African philosophy'* by saying that there is still no agreement regarding the definition of African philosophy.

For the purposes of this study, which seeks insight from African philosophy to illuminate epistemological issues faced by students in a course in basic astronomy, the ethnophilosophic worldview approach is at least available, and seems to provide useful insight. However, in reaching this decision, it is recognized, firstly, that there are probably as many objections to “African” being used as a catch-all phrase as there are support for its functionality - and secondly, that culture is dynamic: all the ‘degrees’ of African culture are represented in South Africa – from ancient *gogos* (grandmothers) in deep rural villages to modern urban youngsters who identify more with American soap opera life than African culture, and don’t even speak an African language. The background to African philosophy and religion available from the literature needs to be understood in this light, but it also needs to be understood that it is dynamic and that it is current. Wrong, as part of a special focus on religion in the world today in ‘The New Statesman’, April 2006, 38, writes:

> “Magic permeates modern African society. MP’s use it before elections, football teams apply it to psyche out their rivals, students resort to it before exams. Shop owners use it to destroy rivals, Aids sufferers in a desperate attempt to survive. Founded on the philosophical conviction that everything happens for a purpose, it satisfies a spiritual craving … “Here in Africa it is much more obvious than in the west that we cannot control the universe or even understand it,” says Professor Cyrus Mutiso, a development consultant. “Magic seems to explain the unexplainable, and that is why people feel they need it.”

> But for Professor Mutiso, what he calls the "new magic" differs fundamentally from the traditional variety practised in African villages before Europe's missionaries arrived; this involved an entire community and aimed at maintaining a subtle harmony between man and the natural world. The new magic, in contrast, echoes life as it is experienced today by millions of Africans, with all its crushing economic pressures and solitary anxieties. "Magic is changing to fit the urban mess. It's now about the individual: the community doesn't come into it, and it tends to focus on money"."

The purpose of Western science has been to demythologize and demystify nature, and for those steeped in the content, philosophy and practice of Western science, traditional ways of knowing can seem quaint, unbelievable or bizarre. Consequently it is important to be made aware of the widespread reality of other ways of knowing and acknowledge that ignoring their existence is counter-productive in terms of education. This may be especially true in Africa, where Abimbola (1977) said that that African children may see science as a 'pack of lies' and where, in referring to the 'sacredness of science' as one of the major socio-cultural influences on the teaching and learning of science in Africa, Jegede (1997, 10) has indicated that "there is a pervasive view held by a large proportion of African society that the study of science is something special in that it requires magical explanations incompatible with the thoughts of someone from a non-Western society". It is clear that it is vital to recognize the existence of competing truths, particularly in South Africa with its multicultural population, and its new curriculum which highlights the importance of recognizing the different ways of knowing associated with these different cultures. These different ways of knowing and their appropriateness in terms of this new curriculum forms the focus of the next section.

2.6 THE SOUTH AFRICAN CURRICULUM AND THE RECOGNITION OF INDIGENOUS KNOWLEDGE SYSSTEMS

Slay (2002) indicates that culture has been defined in two domains: firstly in anthropology and ethnography, and secondly in political empowerment. In the first domain, the definition most frequently used in science education literature is that of Geertz (1975), who used the analogy of a web to represent the complexity and context of all those things that are significant and provide reality to the individual and the group. Keesing's definition (in Ogawa, 2002, 3) is also helpful: that culture is "a system of shared ideas, conceptual designs and systems of meaning". Both allude to the complexity of factors that are involved in trying to define culture. Humans have a deep seated need for identity and belonging, and in recent history, the demand for the recognition and acceptance of pluralism on a world wide basis has resulted in the acknowledgement of cultural diversity in many different dimensions, including art, language and music (Spaling and Dekker, 1996). It has been suggested that science should be included in this list, with school science being recognised as a culture in its own right, alongside other types of science, such as African Science or Chinese Science (Maddock, 1981; Thijs, 1984; Aikenhead, 1996; Cobern, 1998). It has even been suggested that science should be regarded as a 'foreign' culture, because it is a 'micro-culture' of Western civilization and because it is a 'sub-culture' of Western culture (Ogawa, 2002; Dzama and Osborne, 1999). In the science education literature, science is commonly referred to as "Western Modern Science" (WMS), where the 'Western' refers to the geographic location of the origin, development and practice of this body of knowledge, and the 'Modern' serves to distinguish it from Ancient or Medieval science (Snively and Corsiglia, 2000). It is regarded as

> "…the most dominant science in the world…..(the) officially sanctioned knowledge which can be thought of as inquiry and investigation that Western governments and courts are prepared to support, acknowledge, and use" (*Ibid*., 8, 9).

However, to those outside of the culture of WMS, it is hegemonic, with a particular epistemological and ontological basis. Okere (2005a, 4) points out that the terms 'Western' and 'science' have become "triumphalistic, jingoistic and exclusionary", and suggests that in the same way that 'west' cannot only be understood as a geographical term, since places as disparate as North America and Australia can be described as Western (although the term would not apply to the Navajo or the Aborigines), science needs to be understood at three levels: first, as knowledge in general, which he describes as "many knowledges" since this basic knowledge is "supremely historical in a supremely pluralist world"; second, as systematic or organised knowledge, which consists of the "ever-growing creation of bodies of truth that for centuries has constituted the matter of formal education"; and thirdly, as separate disciplines with their own methodologies - the science of practising scientists.

It is at Okere's second level, i.e. at the level of formal education that the second domain of culture becomes apparent, i.e. where culture is linked to political empowerment, and where it is seen to be organized around the transmission and practice of moral and political regulation (Giroux in Slay, 2002). School science has not, in South Africa, had a long history of availability to all of its citizens. Christian National Education is infamous in not having offered Mathematics and Physical Science routinely in all schools in South Africa. Where it was offered, the curriculum was based on the 'standard account' of Modern Western Science, described as "mythical science" by Jegede (1997) because it is so far removed from everyday life. Acknowledgement and recognition of 'other ways of knowing' only came with the publication of the Revised National Curriculum Statement (RNCS, DoE 2002(a) and the National Curriculum Statement (NCS, DoE, 2003). Statistics from the recent census show that 80% (representing 37.2 million people) of South Africa's population is Black (South African Statistics, 2006). It has already been pointed out that nearly 80% of all South Africans regard themselves as Christian. Of these Christians, many are fundamentalist in their belief, particularly the adherents of the African Independent Churches. However, the recognition of 'other ways of knowing' in the principles underpinning the new South African curriculum is a reference to Indigenous Knowledge Systems (IKS), which are not understood, especially in terms of science education, as including religious beliefs. Definitions that try to capture the 'essence' of IKS by referring to academic disciplines as well as the ontological, epistemological and axiological basis of the knowledge system, do not provide sufficient guidance for science teachers who are left trying to interpret how they should ‘value these other ways of knowing’. Difficulties range from whose knowledge is it that must be valued (remembering that there are multiple languages and tribal groupings in South Africa)? What specifically about this knowledge is it that must be valued? Where can this knowledge be found and who owns it? How do you value it if you fundamentally disagree with it, and what about knowledge that may be regarded as 'secret' - for example, remedies or treatments for particular illnesses?

In order to answer these questions, it is helpful to use the ontological framework suggested by Mbiti (1969) and recognize a number of different aspects to IKS, which fit at Okere’s first level of science knowledge, but which are not necessarily clearly distinct from each other. One of these is what is also described as ‘traditional ecological knowledge’ (Snively and Corsiglia, 2000) or ‘non-Western nature-knowledge’ (Lewis and Aikenhead, 2001). This includes the use of herbs for medicinal purposes, traditional building and farming methods, and traditional technology and customs in which science is embedded, for example putting a lump of charcoal into soup as an overnight preservative. Another aspect of IKS is that of traditional folk-lore, comprising taboos, myths and fables. The myths and fables comprise stories that may have some moral or cultural meaning, for example stories that explain why water should not be brought into the home after dark, where the sun goes at night, and why the hyena has a sloping back. Setiloane describes these as the stories that

> “…were passed on from generation to generation. Their depositories were the oldest members of the extended family, especially the grandmothers who would, on an evening, after the meal… be surrounded by grand-children hungry for tales about life, humankind and the origins of things” (1998, 65).

Taboos, which have already been mentioned as an obstacle to learning, may have a different function to myths and fables. Taboos would be invoked when there was no suitable answer to a question, or when the answer was intentionally withheld, or in relation to coming of age initiation customs (Kudadjie and Osei, 1998). A third aspect is related to those areas which could be categorized as metaphysical – issues relating to superstitions (Adeyinka, Kyeleve and Yandila, 1999; Emereole, Munyadzwe, Ntingana and Mosimakoko-Mosalakgoko, 2001), witchcraft (Mbiti, 1969; Marwick, 1966) and the veneration of ancestors (Mbiti, 1969).

The three categories of IKS identified (i.e. indigenous knowledge in which science is embedded, traditional folklore and ‘indigenous metaphysics’) are not necessarily separated in practice, but rather are part of the whole essence of African spirituality. However, the IKS that is probably of most interest to science educators is that which falls into the first category. A number of studies, for example Jegede and Okebukola, 1991; Moji, 1998; Manzini, 2000; Naidoo, 2001; Brown, Muzirambi and Pabale, 2006; and Khwinana, 2006, have shown that reference to examples of indigenous science results in increased interest and participation by African learners. In the same way that Fakudze and Rollnick (in press) point out that in the Southern African region, learners' first languages need to be affirmed while recognizing that "English is the language of power", worldviews different to science need to be acknowledged, while recognizing that the 'cold, hard logic of explanation that has shifted human thinking from the grip of superstition' (Holland, 2001) also needs to be affirmed. Adeyinka *et al.* (1999, 131) state that it is essential for schools to act as "critical agents of change to disengage the minds of students from such erroneous beliefs" and Egunjobi (in Burkhardt, 1999, 7) "cautions that 'it's not every IKS or traditional way of life that is desirable". The third category of IKS mentioned above is thus likely to suffer the same relegation as religion in the science classroom. A Masters study which involved comparing three types of African healers (*inyangas*, who work mainly with herbal medicines, *sangomas*, whose approach involves the spiritual and psychological as well as physical, and *umthakathi*, who work primarily with spells and spirits) was conducted by Maharaj among students in an urban township (in Malcolm and Alant, 2004). She found that they were hesitant to talk about the role of African diviners or *umthakathi*, to the extent that she was advised during trial interviews not to talk about them. Despite this, Malcolm and Alant claim from this study that "to the extent that border crossings were involved, most students seem to cross them without fuss" (*Ibid*., 69), brushing aside the fact that border crossing was impossible as far as ideas or understandings about *umthakathi* were concerned – there was no engagement. The strong opinions and feelings that are expressed in relation to different ways of knowing and the place of the metaphysical in the science classroom range from the pronouncement of the Judge[10], who passes a ruling that the teaching of intelligent design in public schools in Pennsylvania breached the First Amendment separation of church and state, and called it a "breathtaking inanity that fails the test as science" (Ridley, 2006, 52), to science educators who advocate recognizing the worldviews of students, including their religious beliefs, in order to facilitate learning in science.

The IKS that is relevant to this study falls into the folklore category and includes creation stories and stories that relate to natural phenomena that have reference to the diurnal cycle, seasons, Moon phases and eclipses. Again there are similarities to Greek mythology and ancient Greek philosophy, but Setiloane (1998, 66) notes that "by the time (Africans) had learnt to write, their (myths and stories) had already become victim to outside influences culturally and socially, through conquest, and taking on the religions of their overlords". However, understandings that are commonly held in Africa (see Mbiti, 1969 and Setiloane, 1998(b), and which may be "entrenched beliefs" (Sinatra *et al*. 2003), include: there is no beginning or end to the world; the sky is a dome over the Earth in which the stars are suspended; human beings emerged, male and female, with all their domestic animals, from a hole in the ground (or tree, or swamp) from a land underneath the Earth called "Mosima", to which they will return when they die. (Setiloane notes that "this is believed to this day, in spite of the new religions that people have acquired" (*Ibid*.,

[10] Judge John Jones, who was on the list of Time Magazine's 100 'Most Influential People in the World' in 2006

1998(a), 67). Other stories refer to a big snake (or snakes) which live underground or in large water bodies, which are responsible for earthquakes or other earth movements and which are seen as tornadoes when they move their place of abode (Thamae, 2004). Another is that of a crocodile which carries the sun from its place of setting to its place of rising every day, and the well known story of stars which are held to be the ancestors.

The question is how should this prior knowledge be accommodated in the new science curriculum at school level, and how should it inform the curricula and pedagogical practice in university Earth science courses?

The South African school science curriculum, which continues to be based on WMS, is developmental. For example, children learn about the seasons through what happens to deciduous trees and that it is colder in winter than in summer, years before they are presented with the concept of a dynamic, heliocentric solar system. However, by the time they are presented with the complete picture of the Earth as a cosmic body, they have been exposed to cultural input, and as in the case of the Nepali students in Mali and Howe's (1979) study, where the cultural belief is that of a flat Earth held up by a huge elephant, there is the likelihood that many people will hold similar conceptions, which then reinforces the belief. It is also clear that people develop their own causal conceptions of easily observable phenomena. In the absence of teaching, these will be ego-centric, Earth-based and pre-Copernican alternative conceptions. The literature on astronomy education clearly indicates that because the concepts involved are counter-intuitive and abstract, they are only accessible through teaching and the active construction of these concepts by the learners. If there has not been any cultural input, children will progress through developmental stages (which are age-related) in the construction of this knowledge through science-based instruction at school. However, Parker and Heywood's research in England indicated that "it is unlikely that existing primary teachers will have encountered basic astronomical concepts in their own education" (Parker and Heywood, 1998, 503), which means that misconceptions will continue to be rolled over. If this is true for England, it has to be expected that the teachers' knowledge levels will be far 'worse' in South Africa, especially among teachers who are un- or under-qualified, and who are teaching in classrooms that are poorly resourced.

But the content knowledge of the teachers is only one aspect. The prior knowledge of the learners has to be recognized in the context of constructivist pedagogy and Groome (1997, 209) has pointed out, with reference to First World classrooms, that "Western epistemology … poorly serves the purposes of religious knowing". The study by Roth and Alexander (1997) and Shipman *et al.* (2002), has shown that the conflict can be irreconcilable. Very little research in this field has taken place in South Africa, but it is likely that the findings regarding cognitive conflict associated with the science/religion debate will be the same in Africa as they are in the West: the science and the Christianity that have been imported are, after all, rooted in the same history.

However, it has been noted that African Traditional Religion and philosophy have shaped African thinking since before the time of Aristotle and before the importation of Christianity or science. In South Africa, the majority of the population do not subscribe to Western epistemological models. Cultural differences need to be taken into account in terms of education, and at the level of national curriculum development, belief in constructivism has meant that it has been used as the foundation for the new South African curriculum, where the existence of ‘other ways of knowing’ is recognized. The incorporation in the principles of the NCS of the need to value IKS as another way of knowing supports the concept of an African Renaissance, but as Groome (1997, 208) has also pointed out - “decisions about knowledge are as political as they are pedagogical”. In neither the RNCS nor the NCS are there guidelines for how IKS is to be included, or how its inclusion or content is to be assessed.

If the new South African curriculum is to achieve anything meaningful in terms of “The Earth and Beyond” strand at the GETC level, and learners are to graduate from school with a Copernican view of the Earth as a cosmic body (which is surely fundamental to an education in science, and does not preclude learning about other explanations of the Earth), research findings need to be made available to classroom practitioners and curriculum developers. Constructivism has proved to be very useful in explaining barriers to learning as well as in provoking suggestions to facilitate the crossing of those barriers. Collateral learning (Jegede, 1995) and Cultural Border Crossing (Aikenhead, 1996) have proved useful in focusing on issues of culture in the learning of science, despite Malcolm and Alant’s belief that there is “an epistemological weakness in border crossing research” because it “imposes a Western analysis on cultures that do not employ a Western epistemology” (Malcolm and Alant, 2004, 70). This argument is reminiscent of the sterile invoking of “special niche privileges” raised by Matthews (2004) and the problem associated with the conceptualization of an African philosophy outside of Western methodologies. In addition, the concept of border crossing is based on worldview theory, about which Malcolm and Alant state that “many … worldviews co-exist, with their own borders and crossings”, and that opening up discussions about the use of different worldviews “would likely find resonance with many African students” (*Ibid*., 71). These statements contradict their reservations regarding border crossing research. As with the selection of ethno-philosophy (despite its rejection by the “professional philosophers” who have not succeeded in replacing it with a usable philosophy) collateral learning and cultural border crossing have been selected as a potentially fruitful framework for this study despite Malcolm and Alant’s rather arrogant rejection of these theories. The theories are presented and discussed in the following section.

2.7 COLLATERAL LEARNING AND CULTURAL BORDER CROSSING

2.7.1 Research in science education in developing countries

In most of Africa, science as a subject only gained entry into the formal school system in the 1950’s and 60’s (Jegede, 1997). The curricula that were imported and adopted by countries all over the world following the curriculum changes in the west (- the result of the 'Space Race') and which were in use before and following independence in many African countries, carried the assumption that Western science was superior to other forms of studying nature (Abimbola, 1977; Kyle, 1999; Volmink, 1995; Kahn and Volmink, 1999). These curricula were not redesigned to take into account the socio-cultural and cosmological backgrounds of non-Western learners or issues of relevance – this perspective was only to emerge later, through the application of socio-cultural constructivist theory to teaching and learning in traditional situations. Cobern and Loving (2001, 52) were led to observe that "around the globe where science is taught, it is taught at the expense of indigenous knowledge…(which)…precipitates charges of epistemological hegemony and cultural imperialism". In Africa, the lack of relevance of Western science curricula to the everyday lives of African learners was generally not taken into consideration in the implementation of science curricula: Rollnick (1998(a), 80) points out that in Africa, irrelevance is considered a virtue in terms of science education, because "our colonial heritage has made us believe that education of necessity must be abstract and divorced from life". However, in the light of the understanding that "science has become an international currency for national and global technological development (and) that any nation that disregards this effect of science does so at its own peril" (Jegede, 1997, 15) the lack of "success" in science education in Africa has provoked a good deal of research, because as pointed out by Dzama and Osborne (1999), failure in science and technology education has not dogged all non-Western countries, Japan being a case in point.

Over the last few decades, much of the research in science education has focused on cognition, with the popular theory of socio-cultural constructivism also being drawn on to interpret and explain problems in learning in this field. Opposition to the idea of science as a 'culture' in its own right, with Aikenhead's (1996) reference to the difficulties of crossing "cultural borders", for example from a traditional worldview to one of Western science, tends to come from those who believe in the universality of science, and who for reasons either of lack of exposure to other cultures are unaware of its impact, or for reasons of gate keeping or issues of power, are not prepared to acknowledge it as a factor in the learning of science. Thijs's (1984, 43) comment on this is that those who are steeped in the 'mechanistic' and 'fragmentistic' history of Western science are limited by not being able to adopt a more holistic approach. Most research into the multicultural aspects of science education comes from areas where there is a great discrepancy between the indigenous culture and the culture of science, and thus where the impact is the most obvious (Aikenhead, 1996). Examples include the work of Ogunniyi *et al*. 1995 (Botswana, Indonesia, Japan, Nigeria and the Philippines), Ogunniyi 1996 (Africa), Ogunniyi and Fakudze, 2003 (Swaziland), Ollerenshaw and Lyons, 2001 (Native America), Aikenhead, 2000 (Aboriginal Canada), George and Glasgow, 1988 (the Caribbean), Waldrip and Taylor, 1999 (South Pacific Islands), Gado and Verma, 2002 (Africa and India), Linkson, 2002 (Aboriginal Australia) and Pauka *et al*., 2005 (New Guinea).

In southern Africa, much of the work in this area is reported in the Proceedings of the annual conference of the Southern African Association for Research in Mathematics, Science and Technology Education (SAARMSTE, formerly SAARMSE - 'Technology' was included in 2000) and in the African Journal of Research in Mathematics, Science and Technology Education. Malcolm and Alant (2004, 53) note that “almost all research in South Africa, whether eventually published or not, is aired at SAARMSTE conferences”. In their review of Science Education Research in South Africa, they are critical of the nature of Science Education, which they compare unfavourably to Mathematics and Technology Education, stating that

> “Mathematics Education researchers have been more attuned to the political dimensions of education, such as critical pedagogy … and Technology Education (which) has added a further perspective, with its clear concerns for ‘human wants and needs’ and hence for politics, equity, economics, environment and culture. Science Education research, in comparison, is seen as having been linked to “the less radical movements of constructivism, STS and multiculturalism” (*Ibid*., 53).

They complain that “in spite of its claims of personal and social constructivist frameworks, the research is often mechanistic in its epistemology” (*Ibid*., 59) and “lacking in critique or extension of the theories” (*Ibid*., 65). This indicates an intolerant generalization, particularly in the light of their recognition that much of the work presented at SAARMSTE conferences represents small empirical studies – often the result of Masters and Doctoral research reports or theses. Malcolm and Alant also express their concern that worldview theories “remain largely limited to a cognitive ideology centred on the psychology of the individual and learning science” (*Ibid*., 65) – a view that does not acknowledge that worldviews, while being grounded in culture and society, are constructed in the individual, and it is through the individual that the worldviews and their impact can be studied. Their response to the perceived paucity of politically acceptable research in science education is to recommend the use of two social research theories as “providing frameworks in which traditional cognitivist views of … learning … can be conceived anew”. These are firstly, phenomenography, which they say presents itself as “non-dualistic: there are not two worlds, i.e. an objective world and an internally constructed subjective world, but one world, the world as experienced by the individual learners” (60), and secondly, actor network theory (ANT), which they say draws on the notion of spatiality and “represents a clear move away from the notion of an individual mind that ‘does the thinking’” (61). While these methodologies may be alluring to researchers looking for alternate frameworks to study learning in science, it needs to be noted that the same criticisms that have been leveled at Marxism have been leveled at phenomenography and ANT, i.e. to be so accommodating that they do not allow for contradictory evidence: they simply adapt interpretations to take all possibilities into account (Thompson, 2001). Thompson supports his criticism by referring to Popper and Lakatos’s criticisms of Freud and Marx’s theories, i.e. that their broadness rendered them pseudo-scientific and consequently worthless (*Ibid*.). While the use of qualitative research methods in science education have proved their value, it is clear that methods such as phenomenography and actor network theory also require critique and extension before being recommended over established research methods.

The focus here, however, is not a critique of Malcolm and Alant's review, but rather that it should provide some background to the choice of a theoretical framework for the current study. They point out, with reference to Laugksch's Bibliography of Science Education Research in South Africa, that Earth Science/Geography has received “meagre attention” in terms of Science Education research in South Africa (Malcolm and Alant, 2004, 53). The reason for this could lie in the dual focus of Geography, i.e. its humanist and science components, which means that it commonly draws from the methodologies of both the sciences and the humanities. For some “hard core” scientists, particularly in fields that overlap with Geography, Geography is hardly regarded as ‘Science’. Consequently, the use of scientific rather than simply social science methodologies can be seen as important in legitimizing research in Geography Education, especially if there is to be potential for applying the findings in the broader field of science. Science education research reinforces the human element through its focus on teaching and learning, but in the case of the current research, the content area fits into physical Geography – an area regarded as 'science' rather than social or human geography. Consequently, a framework that would allow both qualitative and quantitative methodologies would help to satisfy the demands of both aspects: qualitative methods would allow concepts to emerge from the data gathering process, while the use of some quantitative analysis would provide for the emergence of trends. The qualitative methods to be used were based on the theories of collateral learning and cultural border crossing.

2.7.2 Collateral learning

In 1995, Jegede presented his theory of ‘collateral learning’ at the annual SAARMSTE conference. It was published in the same year in the journal ‘Studies in Science Education’, at about the time that Malcolm and Alant (*Ibid*.) record a change from “White dominated” Science Education research to research mostly concerning Black students and teachers, with much of this research being conducted by Black Masters and Doctoral students. Jegede's theory, which was an expansion of Ogunniyi's 1988 “Mental Dualism Theory” (Ogunniyi, 2002), was proposed to explain the link between a learner's context and prior knowledge (grounded in their worldview) and their ability to integrate and appropriate new knowledge through holding different (and sometimes conflicting) ideas and patterns of behaviour in different contexts. Jegede (1998) used the analogy of a chameleon being able to survive by responding to its environment to illustrate how traditional (in this case, African) learners adapt to conflicting concepts and contexts. However, this capacity to hold different ideas is not a new one: it has also been called a “duality of belief and understanding” by Ogunniyi (2002), “conceptual proliferation” and “anthropological learning” (Aikenhead, 1996, 1997); “cognitive apartheid” and “epistemological dualism” by Cobern (1996), and “compartmentalization” by Waldrip and Taylor (1999). Jegede's theory is an appealing framework in terms of examining learning in traditional or multicultural classrooms, and consequently it has been widely used in South Africa (as well as abroad) in research in this context. Jegede's main contribution to the idea of compartmentalization lies in his development of the four levels of collateral learning, which he described as follows:

parallel collateral learning (where the student constructs incompatible ideas from two worlds in separate compartments in their mental schema)
simultaneous collateral learning (where the student connects ideas from two worlds at the same time)
dependent collateral learning (where the student uses ideas from one worldview to challenge or understand the views from another)
secured collateral learning (where the learners resolve any conflict, and convergence towards communality is achieved) (Jegede 1998, 166).

He also suggested that learners could move progressively through the levels, from compartmentalization at the beginning of the process, to a situation of integration – where the knowledge was 'secured' and where any conflicts had been resolved. Secured collateral learning was seen as the desired outcome, however. Jegede had noted that an African student

> "…might perform excellently well in a western science classroom without imbibing or being enthusiastic about displaying the associated values and attitudes. This 'good' scientist at school can at home be a 'traditionalist' without any feeling of cognitive perturbation or dissonance" (Jegede, 1997, 11).

This sustained ability to 'live in two worlds' was also noted by Rollnick (1998 (b), 86) who said that African learners could be 'two people'- the person at home and the person at school. However, Jegede suggested that the prior knowledge of African learners could be a stumbling block in the construction of new knowledge: instead of leading to secured learning, the conflicting or contradictory concepts presented in the science class could simply lead to compartmentalization. Jegede, through his experience in teaching and research had seen this happen, and described collateral learning as representing

> "the process whereby a learner in a non-western classroom constructs, side by side and with minimal interference and interaction, western and traditional meanings of a simple concept (and that) collateral knowledge … is the declarative knowledge of a concept which such a learner stores up in long-term memory with a capability for strategic use in either the western or traditional environment" (Jegede 1997, 11).

Jegede indicated that this was typical of the situation where the learner first came into contact with new information, i.e. while he/she was still "trying to make sense" of the ideas which had been presented (1995, 119), and noted that at this level, the learner experienced no visible cognitive dis-equilibrium or confusion, "except perhaps to readjust memory to accommodate the different view presented in the science classroom" (*Ibid*.).

Jegede indicated that this position could be followed by the process of dependent collateral learning, which could lead to a resolution of the conflicting knowledges, with integration of knowledge being the most desirable outcome, i.e. secured collateral learning. Secured collateral learning was regarded, then, as the final product of a gradual and incremental acquisition of Western science knowledge, which would be achieved through dependent collateral learning (and possibly even simultaneous collateral learning) leading to secured collateral learning.

Conceptual change theory (Posner, *et al*., 1982), building on the Piagetian idea of assimilation and accommodation, posited that conflict was necessary in order to challenge prior ideas and bring about conceptual change, an idea in line with Jegede's process of dependent collateral learning. However, Senghor, among others, has pointed out that because Africans "think with their soul" (in du Toit, 1998, 24) they do not feel intellectually uncomfortable even when knowing that there are contradictions in what they believe (Eze in du Toit, 1998, 24). Malcolm and Alant support this idea by indicating from their analysis of border crossing research in South Africa that studies have shown that "the students were all keen to learn science and be successful in it, and at the same time the great majority maintained traditional beliefs" (2004, 69). Is this an indication of compartmentalization, or should it be seen as the ability to think holistically? In terms of science education, the question is whether compartmentalization comprises effective learning, especially if the compartmentalization is maintained in the long term. Compartmentalization may prevent conflict – but it also prevents constructive interaction (Barbour, 2000, 2). In the context of traditional cultures being challenged by 'successful learning' in Science, should science educators in South Africa be aiming for secured collateral learning as suggested by Jegede, or should they explicitly be promoting compartmentalization in recognition of multiple ways of knowing?

2.7.3 Problems with collateral learning

The issue of definitions

Collateral learning is an attractive concept because it is an articulation of a common human experience: while Jegede conceived the idea in relation to people with a traditional worldview being faced with having to learn Western science, collateral learning can be experienced by anyone faced with having to learn concepts that may conflict with their prior knowledge. However, there are a number of problems associated with the theory of collateral learning, two of which will be discussed here. The first concerns some of the details of the theory, and the second raises some moral problems in the context of one worldview usurping another.

As far as the details are concerned, one of the biggest difficulties with regard to the theory of collateral learning is how to conceptualize the different levels. For example, dependent collateral learning is said to occur

> "… when a schema from one worldview or domain of knowledge challenges another schema from a different worldview or domain of knowledge, to an extent that permits the student to modify an existing schema without radically restructuring the existing worldview or domain of knowledge." (Aikenhead and Jegede, 1999, 11)

However, they also stated that

> "… a characteristic of dependent collateral learning is that students are not usually conscious of the conflicting domains of knowledge and consequently students are not aware that they move from one domain to another (unlike students who have achieved secured collateral learning)" (Aikenhead and Jegede, 1999, 11)

The question that arises from these explanations of dependent collateral learning is whether it is realistic to accept that the 'challenge' or 'modification' that takes place when one worldview or domain of knowledge challenges another, can happen without the learner being 'conscious' of either the 'mental battle' that is going on or the realization that they have modified their understanding. Aikenhead and Jegede (1999) also explained that

> "… dependent collateral learning occurs when a student's preconception of indigenous belief is: (1) contrasted with a different conception encountered in the science classroom, (2) given a tentative status, and then either (3) altered by reconstructing the original schema under the influence of the newly encountered schema, or (4) rejected and replaced by a newly constructed schema. In other words, students modify or reject their original schema because it makes sense to do so" (Aikenhead and Jegede, 1999, 12)

It must be asked how the student can go through all the cognitive activities mentioned (contrasting, giving something status, altering, rejecting or modifying), without being aware of doing any of this, especially in the light of the further comment that:

> "dependent collateral learning is similar to the Piagetian accommodation-assimilation model of information processing associated with Posner, Strike, Hewson and Gertzog's (1982) conceptual change model" (Aikenhead and Jegede, 1999, 12)

Assimilation and accommodation, in the Piagetian sense, involves the conscious acceptance or rejection of an idea. The conceptual change model also suggests that unless the student finds the new conception to be intelligible, fruitful and plausible, no conceptual change will take place. This would seem to require some metacognitive effort and conscious decision making. Ingle and Turner (1981) maintain that if children are able to give different explanations of the same phenomena, this is evidence that accommodation has not been achieved. They describe this as "dualistic thinking", which is closer to the idea of parallel collateral learning than it is to dependent collateral learning.

As far as secured collateral learning is concerned, it was first conceived as a state of resolution of conflict – a convergence towards commonality - through the integration of ideas from two worldviews (Jegede, 1995, 1998). It was then expanded to incorporate the idea that this could be achieved, not necessarily through convergence or integration of the ideas, but simply through “the person (having) developed a satisfactory reason for holding on to both schemata even though the schemata may appear to conflict” (Aikenhead and Jegede, 1999, 278). Consequently, secured collateral learning appears to have been conflated with parallel collateral learning. The only difference is that in a state of secured collateral learning, they would know that they were moving from one domain of knowledge to another, while in parallel collateral learning this shift would be unconscious. However, this characteristic is given above (see Aikenhead and Jegede, 1999, 11) as the difference between secured and dependent collateral learning.

Another area of confusion relates to the constraint of collateral learning occurring only if the conceptions are held in the ‘long-term memory’. ‘Long term memory’ was used by Aikenhead and Jegede (1999) as the distinguishing criterion between parallel collateral learning and “Fatima’s rules” (Larson in Aikenhead and Jegede, 1999, 10). Larson described the tactics used by students to pass exams but avoid meaningful learning as “Fatima’s rules” after an articulate high school student who explained that one of the most common of these ‘rules’ was learning for exams to secure a pass and then forgetting or rejecting the learned conceptions after the exam. This tactic could be described as ‘short term parallel collateral learning’, but any form of Fatima’s rules was considered by Jegede and Aikenhead as mutually exclusive with collateral learning. However, short term parallel collateral learning could be a realistic and useful way of understanding parallel collateral learning, especially if this type of learning preceded the onset of dependent collateral learning.

The discussion so far serves to indicate the lack clarity with regard to the specific, i.e. detailed conceptualizations of each of the different types of collateral learning.

The issue of the Pyrrhic victory

The second area of concern mentioned above lies in the context of one worldview usurping another. Parallel collateral learning is considered by Jegede to describe the situation where two conflicting schemas are held side by side in the long-term memory and no progression is made towards resolution (Jegede, 1995, 1998). Cobern (1995) challenged this by questioning whether it was actually possible to hold two conflicting schemas in the long term. He suggested that collateral learning could be seen as a Wittgenstein Language Game, where “the idea is that one can simultaneously hold two or more contradictory views of a phenomenon because the different views are separated by the different “language games” from which the views are derived” (Cobern, 1995, 7). Cobern pointed out that this can only work in the short term. In the long term, he said, one “game” will overcome the other(s). He claimed that this was what had happened in traditional societies in the west as they had been exposed to science, as “scientific literacy at any non-trivial level will bring about changes in one’s basic understanding of the world" (Cobern, 1995, 8).

Jegede’s response was that “to make learning meaningful, there must be integration of science knowledge with the learner’s worldview” (Jegede, 1998, 165). He argued that the problem lay in “the hegemonic hierarchy of the knowledge structure of science” and that science “should not be seen as a single path but as an evolving map of ways to cope with the world” (*Ibid*.). Jegede's concern was that “any western science curriculum in a non-western classroom which does not take particular consideration of the traditional worldview of the learner risks destroying the framework through which concepts are likely to be interpreted” (Jegede, 1997, 10). Yet, rather confusingly, he also seemed to claim that it is necessary to integrate the knowledge systems for learning to be meaningful in the long term. This is what Jegede termed “secured collateral learning”.

The problem seems to boil down to the question about whether it is possible (or perhaps even desirable) to integrate knowledge from two worldviews. Cobern suggests that domination and replacement, not integration, is the likely outcome of conflict between traditional and scientific explanations. Lewis and Aikenhead (2001, 4) also question integration as a real possibility. They claim that integration represents a Pyrrhic victory (i.e. a victory gained at too great a cost), because this 'integration' would have the same long term outcome as a Wittgenstein language game: the traditional knowledge, which would be subsumed by modern Western science, would simply lose its identity.

The disagreement outlined here may be related to different understandings of the relationship between knowledge and belief or understanding and acceptance. According to Sinatra *et al*. (2003) there are two responses to this relationship: those who believe that failure to accept an idea precludes developing an understanding of it, and those who believe that it is necessary to first understand the idea before it can be believed. Sinatra *et al*.’s investigations led them to conclude that it is possible to understand and work with something (for example a concept or a theory), but still not accept it, a view that is shared by Ogawa (1995) and one that seems to fit Jegede’s concept of parallel collateral learning. The ability to operate in the long term in two ‘worlds’ fits the African ability to hold contradictory views, but as already pointed out, this does raise the question of meaningful learning. Can conflicting knowledge, held in parallel in the long term, be considered to represent *meaningful* learning?

Cobern argues that science explanations are “exhaustive and … marginalize all other ways of knowing” (1995, 9), including traditional, ethnic, racial, gender, or religion based ideas. If, on the one hand, external constraints (for example community or religious constraints) demand that knowledge should be held in parallel, because the price of secured collateral learning is too high, then parallel collateral learning would seem to be the only kind of 'learning' that could be entertained. In situations like this it would be unrealistic to strive for or demand integration. However, the question remains: is this the kind of transformative learning that is being sought in science education? If, on the other hand, the process of dependent collateral learning results in the tension being resolved in favour of Western Modern Science, the other ways of knowing, including religious or traditional ideas may be rejected. It has been recognized by many, including Aikenhead and Jegede, that this loss of belief in traditional or religious ideas is potentially very damaging socially and culturally, as these ideas and beliefs are the "glue" that hold society together (Gray, 1999). This understanding is supported by Cobern (1995), who also points out that the new science ideas fail to replace the moral support that used to be part of traditional understandings. He argues that unless there is some form of deliberate mediation or integration (as suggested by Jegede's model of "Two worlds – one science" 1998, 164), there could be two unacceptable outcomes. The first is that the traditional understanding maintains its integrity and school science 'will never be applied to real problems' (Hawkins and Pea, 1987). Marin, Bennaroch and Gomez (2000) suggest this may be because the new ideas are just too novel and the students' ideas too deep-rooted. The second is that the Western science "eventually undermines the traditional culture by virtue of its sheer physical effectiveness" (Cobern, 1995, 11). Empirical research that supports this concern has been carried out by Janotta (1986), Waldrip and Taylor (1999) and Ollerenshaw and Lyons (2001).

Aikenhead and Jegede (1999) acknowledge that some researchers disagree with their favoured outcome of secured collateral learning. These include, for example Linkson (2002), who sees parallel collateral learning as a more useful strategy. The benefits of the compartmentalization seem to apply not only to those students who do not intend a career in science (and where parallel collateral learning provides a means to maintain different understandings with respect and dignity) but even to those who pursue a career in science. Ogawa stated

> "Even scientists can, in principle, understand, work in, and contribute to modern science without believing in the truthfulness of modern science. This is one reason why non-westerners can be scientists without losing their identity" (Ogawa, 2002, 5).

Ogawa's (2002) idea of categorizing science into "personal science", "western modern science", and "indigenous science" could be used to support the long term existence of parallel collateral learning, but it could also be used to dispute Jegede's preference for secured collateral learning as the most desirable outcome of science teaching and learning.

The problem regarding compartmentalization or integration remains unresolved. Snively and Corsiglia (2000), Stanley and Brickhouse (2001), and Cobern and Loving (2001) indicate that the resolution hinges on clarifying a universally accepted definition of science, but agree that this will be a very difficult issue to achieve. Aikenhead predicted that the controversy between those who believe in the universalism of science and those who do not would continue, because treating science as a cultural enterprise "represents a radical shift in thinking for some science educators" (Aikenhead, 1996, 6).

Another and possibly even more radical shift for science educators is to come to terms with the idea that religion in its own right is part of the cultural enterprise. In terms of African culture, Mbiti (1969) has made it clear that there is no separation of the physical from the metaphysical world - that “to be African is to be religious”. This stands in stark contrast to the logical positivist view which sees Western science as the only source of ‘true’ knowledge, and where religious knowledge, because it is unverifiable, has been “relegated to the limbo of the unreal” (Edwards, 1998, 86). Africans by nature are religious, and it has been noted that in South Africa, a very large proportion, especially of Black South Africans, align themselves with the Christian faith. Consequently, any scientific theories that oppose religious ideas may cause problems for substantial numbers of people.

While the idea of compartmentalization is supported by many, and is of special relevance to this study, there are problems with Jegede's conception of the different types of compartmentalization, or as he refers to it, collateral learning. Consequently, a typology developed specifically in the context of the science/religion debate was 'borrowed' from the discourse of religious philosophy and education. This is Barbour's Typology, which is outlined below.

2.7.3 Barbour’s Typology

In 1990, Barbour proposed a fourfold typology in his book “Religion in an Age of Science” as “an aid to sorting out the great variety of ways in which people have related science and religion” (Barbour, 2000, 2). While Barbour’s typology comes out of the Science/Religion debate, it can be usefully applied to IKS and Science as well as Science and religion. While this and other typologies, for example that of Haught (in Koul, 2003) which is very similar to Barbour’s typology, have been criticized for failing to allow for “the subtlety, complexity, and diversity of relationships between science and religion” (Ibid, 105), the categories - conflict, independence, dialogue and integration - can be usefully linked to Jegede’s theory of collateral learning.

1. Conflict:

This category contains the ‘extreme’ groups: those for whom “science and religion are enemies” (Barbour, 2000, 2). Barbour suggests that people likely to fit into this category are Biblical literalists at one end of the spectrum and atheistic scientists at the other. While both groups agree that it is not possible to believe in both God and evolution (which here includes Big Bang Theory, Nebula Theory and Plate Tectonic Theory as well as the evolution of species), they disagree about which is true. Barbour points out that these are the groups that receive the most media attention, since “conflict makes a more exciting news story than the distinctions made by persons between these two extremes who accept some form of evolution and some form of theism” (*Ibid*.). An example of this is contained in the 1996 special edition of *Science & Education* in 1996, where Mahner and Bunge presented a 'conflict' position with regard to science and religion, resulting in a lively response from a number of people who disagreed with their view. People who fit at either end of Barbour's 'conflict' category, i.e. atheistic scientists and Biblical literalists, could be described as 'secured collateral learners' in terms of Aikenhead and Jegede's 1999 conception of secured collateral learning, as these people would have specific reasons for why they hold the knowledge or beliefs that they do. 'Conflict' as a category is clearly distinct from the fourth of Barbour's types, i.e. 'integration', which also rather confusingly fits Jegede's description of secured collateral learning (which was originally given only as the 'convergence or integration of conflicting knowledge' before the rider was added regarding 'valid reasons for holding conflicting beliefs'). The distinction between 'conflict' and 'integration' is crucial in terms of the science/religion debate, as these responses have very different consequences. As a result, Barbour's category of "conflict" represents a more useful concept to describe the position of people who hold one belief and exclude another. Jegede's reconceptualisation in 1999 of the definition of a secured collateral learner can be seen in this context to have been unhelpful as it precludes the difference between conflict and integration.

2. Independence:

This category corresponds with the concept of compartmentalization or parallel collateral learning: Barbour says that "according to this view, there should be no conflict because science and religion refer to differing domains of life or aspects of reality" (Barbour, 2000, 2). Woolnough (1996), in one of the response articles to Mahner and Bunge (1996) presents this view. Science and religion are seen as serving different functions in life and answering different questions. Consequently, they are held as mutually exclusive. They only come into conflict when one domain tries to make claims that 'belong' in the other. Intelligent Design (ID), which according to Staver (2003) advocates itself as a scientific theory in opposition to evolution, but which in his opinion is a religious concept, has resulted in a lot of conflict in the United States through demands by supporters of ID that it should be included in the science curriculum. Those in opposition are categorical that *because* there is no empirical evidence to support it, it has no place for it in the science curriculum. Those in opposition can be seen to want to keep the knowledges separate, while those in support of its inclusion are causing conflict. Barbour (2000, 2) states that the independent position claims that "we can accept both science and religion if we keep them in separate watertight compartments of our lives". However, he also points out that "compartmentalization avoids conflict, but at the price of preventing any constructive interaction" (*Ibid*.). This position of independence is the recommended option of many people, including scientists such as Stephen J. Gould and theologians such as P.F. Forsthoefel. It is the easiest way to avoid conflict while allowing participation in both worlds.

3. Dialogue:

This can arise when both scientists and theologians engage in reflection on the methodologies, analogies or models of the different domains. It may also arise when science "raises at its boundaries limit-questions that it cannot itself answer" or when God is "conceived to be the determiner of the indeterminacies left open by quantum physics, without any violation of the laws of physics” (*Ibid*., 3). Dialogue can be seen to be the equivalent of dependent collateral learning, where ideas from one worldview are used to understand or challenge the views from another. Dialogue, or dependent collateral learning, is thus a process which may lead to integration. Settle's (1996) response to Mahner and Bunge (1996) is an example of this position.

4. Integration:

Barbour refers to the approach that seeks to reformulate religion in the light of science as a “theology of nature”. This is the position of the “secured scholastics” referred to in section 2.4.2. This position is only achieved by individuals who are as well versed in one domain as the other, and who are able to reconcile and integrate knowledge from both domains without any loss of integrity. Very few people achieve this status as it involves very ‘hard’ intellectual work. A summary of the links between collateral learning and Barbour's Typology is given in Table 2.2.

While Barbour’s categories were especially conceived in relation to the interaction between science and religion, these categories could also be applied to the inter-relation between science and IKS or any other knowledge system. An understanding of these categories of responses could also be helpful to teachers trying to respond to the imperative in the South African curriculum to acknowledge and value other knowledge systems.

Table 2.2: A summary of links between collateral learning and Barbour’s typology:

Barbour’s Typology	**Jegede’s Collateral Learning**	**Explanation**
Conflict	Secured collateral learning	While only one view or way of believing is ascribed to under Barbour’s ‘conflict’ category (i.e. religion or science), good reasons can be given for why this particular view is held. ‘Being able to give good reason or explanation as to why you hold a particular view’ was added as a condition by Jegede to his original concept of secured collateral learning, resulting in a changed meaning for ‘secured’.
Independence	Parallel collateral learning	Science and religion are held in separate “compartments”
Dialogue	Dependent collateral learning	Interaction or challenge between different forms of knowledge, leading to questioning and grappling with the conflicting ideas
Integration	Secured collateral learning	The conflicting knowledge is able to be meshed or integrated without loss or subjugation of one to the other

2.7.4 Cultural Border Crossing

The second theory that forms part of the framework used in the present study is “cultural border crossing”.

In 1996 Aikenhead proposed this theory as a metaphor to describe the difficulties he saw being experienced by students as they struggled with the meaningful construction of Western science concepts. The basic assumption made by Aikenhead in transferring this metaphor to the science classroom was that science should be regarded as a culture in its own right. He justified this by establishing the attributes of culture (e.g. communication, attitudes, values, beliefs, practices) and showing how science fulfills these criteria (Aikenhead, 1996, 5). Drawing on the work of Costa (in Aikenhead, 1996) and Hawkins and Pea (1987), he proposed that if the learner's life-world generally harmonized with the subculture of science, and if the transition between the two was not difficult, there would be an "enculturation" into what he called the 'subculture' of science. If, however, there was disharmony between the learner's life-world and that of school science, the learner would struggle to 'cross the border' into the subculture of science, and the learning would be less meaningful. Aikenhead envisioned four types of transitions between the different social contexts or worlds of the students. These were:

Smooth transitions (where the worlds were congruent)
Managed transitions (where the worlds were different)
*Hazardous transition*s (where the worlds were diverse) and
Impossible transitions (where the worlds were highly discordant).

Aikenhead linked these transitions to five categories of students identified by Costa. The importance of the differences in students' responses to science is also noted by Sinatra, *et al.* (2003), who point out that the "disposition" of students is critical to how they deal with controversial theories. The 'dispositions' identified by Costa are presented in Table 2.3, along with Aikenhead's interpretations of how each of them would respond to 'crossing the borders into science'.

Aikenhead also used his concept of border crossing to link Costa's categories of students with Phelan *et al.*'s (in Aikenhead, 1996) categorization of transitions. He said for example, that 'potential scientists' would experience 'smooth' border crossings between their life-world and that of science, because there was not a great deal of difference between them (noting that they would also need the necessary academic ability to do so). By contrast, an 'other smart kid' may have to 'manage' the crossing into the subculture of science, or they may even experience it as 'hazardous', depending on how strong the conflict was between their life world and the sub-culture of science. Aikenhead also referred to work by Lugones (*Ibid*.) to develop the idea of what qualities may be involved in ensuring successful border crossing. These were 'flexibility', 'playfulness' and 'being at ease', which included a cluster of factors such as being a fluent speaker, having a shared sense of history and being humanly bonded with people in that culture.

Aikenhead also introduced the idea of teachers acting as "culture brokers" and 'tour guides" or "travel agents" (Aikenhead, 1996, 22), or as described by George (1999) "bridge builders". Aikenhead suggested that this perspective could provide science educators with a "new vantage point from which to analyze familiar problems” (Aikenhead, 1996, 1).

While Aikenhead has provided a new and useful ‘vantage point’ from which to try to analyze some of the difficulties and complexities of learning, it is important to note that Costa based her categorization on data obtained from 43 high school students in two schools in the United States of America (Costa, 1995). While her sample included culturally diverse students, it is important to recognize that in contexts outside of the United States, new categories of students may need to be established.

Table 2.3: Categories of students according to their ability to ‘cross cultural borders’ into the culture of science.

Category of Student	Characteristics (according to Costa, 1995)	Aikenhead’s interpretation (1996)
Potential Scientist	Students whose life-worlds were congruent with science as a school subject and the school as an institution, who enjoyed the challenges of subject matter	These students would be open to ‘enculturation’ into the scientific community. These students present themselves as academically ‘able’.
Other Smart Kids	Students whose life-worlds were congruent with school, but not with science as a discipline. They would not find science to be personally meaningful or useful, but would use it for their own ends (to pass)	These students (who also present themselves as academically ‘able’) would understand the concepts, but refuse to be enculturated into the subculture of science.
I Don’t Know Students	Students whose life-worlds were inconsistent with that of school science. They would have difficulty in finding a connection with school science.	These students would ‘play the school game’ of learning to pass without understanding the content, a phenomenon captured by Larson (in Aikenhead, 1996) as “Fatima’s Rules”
Outsiders	Students whose life-worlds were discordant with that of school and school science.	These students don’t know anything about science and don’t care about knowing about it.
Inside Outsiders	Students whose life-world was irreconcilable with school, but potentially compatible with science.	These students, though potentially able, were prevented from participating in science.

2.8 SUMMARY OF THE LITERATURE REVIEW

Constructivism is a widely accepted theory of learning which posits that new knowledge is constructed on what learners already know. This already held knowledge, against which new ideas are assessed, is a product of the worldview of the individual learner, which in turn, is shaped by the socio-cultural environment in which the learner has been raised. This theory of learning is very useful as a framework for understanding problems associated with learning in basic astronomy, where socio-cultural factors combine with everyday human experience to create unique learning difficulties in this field.

The science explanations for phenomena such as day and night and the seasons require the ability to construct mental models and to understand processes that appear counter to normal daily experience. Studies in astronomy education have shown that the difficulties experienced in understanding the scientific explanations are irrespective of culture. However, it has also been shown that explicit teaching can result in learners moving from a naive flat-earth experience of the world, to a scientifically based understanding of cosmic phenomena.

This progressive development echoes that of the history of Astronomy as a scientific discipline, from ancient Greek ideas of an eternal Earth, shaped like a disc and enclosed with a dome of sky, to our Big Bang understanding of the Universe, populated by billions of galaxies in the vast expanse of Space. The development of this understanding has been linked to the Judeo-Christian worldview: the desire to understand the workings of nature, in relation to Biblical beliefs and in order to glorify God, was a driving force among early Western astronomers. However, as science grew ever more powerful in explaining the apparently mechanistic processes of nature, beliefs associated with scientific and religious explanations came into conflict. Science developed its own worldview, with its own brand of ontology and epistemology

The history of colonization of the New World by the Old indicates that Western belief systems were imposed on already existing belief systems. In Africa, Christian missionaries introduced Western religion. This was followed by Western-style schooling and Western curricula - including Western science and its history of conflict with Christian beliefs. African children learning Western science are thus confronted by a complex mesh of information, which they are required to learn and understand in a meaningful way.

Constructivism highlights the role of prior knowledge in this process, while the concept of cultural border crossing highlights the difficulties that are experienced in the context of a mismatch of worldviews. For African learners who hold a belief system shaped by both Christian and African beliefs, the presentation of 'facts' in the science classroom, unmediated in terms of either of these belief systems, can result in enormous cognitive and psychological conflict.

In South Africa, there has been progress in the new education framework in terms of recognizing the importance of prior knowledge and the existence of other ways of knowing with regard to learning. The historical background and overview of different worldviews in the literature review has served to illustrate the complexity of the construction of scientific concepts in the context of South Africa, where there is a multiplicity of ways of knowing.

The following section presents the theoretical framework that was used in this study to investigate the nature and effect of these different ways of knowing on learning in a course in basic astronomy.

2.9 THE THEORETICAL FRAMEWORK FOR THE STUDY

The theoretical framework used in this study is a synthesis of three typologies: Cultural Border Crossing, Collateral Learning and Barbour's Typology of conflict responses in terms of science and religion. These are presented in tabular form in Tables 2.4 and 2.5

Table 2.4: Synthesis of the concepts of cultural border crossing and collateral learning

Type of student (according to Costa, 1995)	**Level of congruence between life world and WMS**	**Type of border crossing (Phelan *et al*., 1991 in Aikenhead 1996)**	**Process of learning**	**Result**	**Numbers of students**	**Success at learning science**
"**Potential scientists**" (note: found in all cultures)	High (but for some WMS students WMS can be just as foreign as for those with low levels)	Smooth (but not all levels of high congruence result in smooth border crossings)	No border crossing, but 'enculturation' (Hawkins and Pea, 1987) is likely	Possible enculturation; Possible use of Fatima's rules. Possible 'deep learning' (Ramsden, 1992)	Usually few	Can be very successful
"**Other Smart Kids**"	Can be anywhere on continuum, but probably less congruence than "potential scientists"	Managed	Dependant or no collateral learning. Assimilation and consequent disruption from indigenous life world culture can lead to social problems	Possible use of Fatima's rules. Possible 'surface learning' (Ramsden, 1992). Possible secured collateral learning.	Usually many	Can be successful, but use passing science to further their own ends.
"**I don't know Students**"	May be high or low	Hazardous	Possible 'acculturation' (Spindler, inAikenhead1996) – selected modification of existing ideas	Dependent collateral learning. Possible use of Fatima's rules. 'Surface learning' (Ramsden,1992)	Usually many	Could be successful, but unlikely to be interested in learning science
"**Outsiders**"	Very low	Impossible	No learning	No collateral learning. Drop out of science	Usually many	Will not do science as a school subject

The purpose of a typology is to distill recognizable categories or 'portraits' of traits (or groups of responses) in a particular situation or context. The portraits are usually intended as an organizer for the purpose of characterization and understanding. The three typologies presented in this chapter were selected for the purpose of building a framework for understanding the effects of worldview on learning in a course in basic astronomy at the University of the Witwatersrand. The intention of the study was not to probe *how* the learning happens (a criticism leveled at border crossing and collateral learning by Ogunniyi, 2002, and Fakudze and Ogunniyi, 2003), but rather to try to understand what implications an African worldview may have on learning in this area while taking into account the problems of positionality (see Chapter 3).

Table 2.5: An African Typology of student learning in basic astronomy (adapted from Aikenhead, Jegede and Barbour's Typologies)

Type of student	**Congruence between life world and science**	**Type of border crossing**	**Result**	**Numbers of students**	**Success at learning science**	**Barbour's Typology**
"**Potential scientists**"	May be high. May also live in multiple worlds, where congruence may be high between relevant worlds.	Smooth or managed very well. Well supported in efforts to learn	* Possible enculturation into science (Hawkins and Pea, 1987); * Possible use of Fatima's rules. * Possible 'deep learning' (Ramsden, 1992)	Usually few	Can be very successful	All categories: could justify conflict or independence or move towards dialogue or integration
"Other smart kids"	Can be anywhere on continuum, but probably less congruence than "potential scientists"	Managed	* Possible use of Fatima's rules. * Possible 'surface learning' (Ramsden, 1992). * Dependant or no collateral learning. * Assimilation and consequent disruption from indigenous life world culture can lead to social problems.	Usually many	Can be successful.	Likely to be conflict or independence
"**Fighters**"	Low	Managed	* Possible acculturation. * Probably dependant or parallel collateral learning	Usually few	Will persist, often against all odds	Possibly all categories
"**I don't know Students**"	May be high or low	Hazardous	* Parallel or dependent collateral learning. * Possible use of Fatima's rules. * 'Shallow learning' (Ramsden,1992)	Usually many	Often not successful	Likely to be conflict or independence
"**I don't know disad-vantaged Students**"	Very low (with very poor secondary school education)	Hazardous	* Parallel or dependent collateral learning. * Possible use of Fatima's rules. * 'Shallow learning' (Ramsden,1992)	Relatively many in the context of South Africa where there are many students with a disadvantaged educational background	Often not successful	Likely to be conflict or independence
"Drop outs"	Low	Impossible	* No collateral learning. * Drop out of science	Relatively very few	Often not successful	Likely to be conflict

In his 1996 paper "Border Crossing into the Subculture of Science", Aikenhead described Jegede's concept of collateral learning as "a progression that appears to move from anthropological instruction to acculturation" (Aikenhead, 1996, 21). Collateral learning was seen as a cognitive explanation for cultural border crossing, resulting in several collaborative papers between Aikenhead and Jegede (Aikenhead and Jegede, 1999 and Jegede and Aikenhead, 1999). The connection between these theories, which was given in Table 2.4, is a schematic synthesis of information drawn from Aikenhead (1996), Aikenhead and Jegede (1999) and Jegede and Aikenhead (1999).

However, the emergence of the science/religion conflict in the data collection phase resulted in an adaptation of the synthesis of Jegede and Aikenhead's categorizations (Table 2.4) in order to be more appropriate to the context of this study. Barbour's Typology was thus incorporated to provide an additional facet to the framework, and resulted in the creation of an “African Typology of student learning in basic astronomy”, provided in Table 2.5.

The value of the tabulation of the different theories in this way was that it provided a framework for analysis. This framework allowed an overview of connections between the typologies, although there was not always a perfect fit. Each of the typologies was useful in the analysis, with each providing unique insight into the problems of learning in astronomy.

The concepts that form the foundation of astronomy cannot be divorced from their connection with the purpose and meaning of life. Learning in this field is thus multi-dimensional and very complex, particularly when worldview issues are involved. However, the synthesis of typologies, while also complex, offered a guide to the interpretation of the data.

2.9 CONCLUSION

Ogawa said “science educators should be always sensitive to another kind of wisdom than modern science” (2002, 8). The problem is that shifting from a universalist to a cross-culturalist perspective represents a paradigm shift (Lewis and Aikenhead, 2001) – and one that is not easily accepted by science educators who subscribe to a positivist philosophy. However, one of the nine principles in South Africa’s new National Curriculum Statements (Department of Education, 2002(a) and 2003) states clearly the importance of the inclusion of Indigenous Knowledge Systems in the curriculum. This means that the South African curriculum officially recognizes the importance of acknowledging different worldviews and other ways of knowing in the science classroom.

This study began with collateral learning and cultural border crossing as the theoretical framework. However, the truth of Blutreich’s caution that

> “…the collateral learning concept is probably too nebulous for scientific analysis… we’re left with the daunting option of accumulating a boggling amount of data to obtain anything remotely resembling anything statistically significant” (Blutreich, 2003, 2)

was soon apparent, and served to confirm Jegede’s own admission that "collateral learning is difficult to explain or confirm" (Jegede, 1997, 11). Barbour's Typology was thus brought in as a support to the framework, resulting in the formulation of an 'African Typology of learning in basic astronomy'. While Ogunniyi has long been of the opinion that none of the hypotheses that have been posited to explain the concept of border crossing have “gone deep enough to unravel this complex cognitive process” (Ogunniyi, 2002, 68), the appeal of the African Typology is that it has the potential to highlight the cognitive difficulties faced by students in the science classroom, through the consideration of traditional philosophy and religious beliefs. This could also provide a useful framework for teachers who may like to contribute to more meaningful learning in their classrooms through understanding and responding to their students, but who have no idea of the existence or legitimacy of other worldviews or the impact they may have on learning.

It needs to be noted in the conclusion of this chapter, that there are other extremely important issues that are involved in the success or otherwise of learning science, for example, the availability of resources and the role of language. However, beyond brief mention, these are beyond the scope of the present research. The analysis of the data will consequently be linked to the framework provided in Table 2.5.

This chapter has presented the literature that informs the current study, as well the theoretical framework on which the study was based. The next chapter explains the research methods that were used to gather and analyze the data.

CHAPTER 3

POSITIONALITY STATEMENT

“Positionality” refers to race, gender, class experience, levels of education, sexuality, age and ability, all of which “have an impact on the ways we do our research and how the people we work with perceive us” (Skelton, 2001, 89). Harding (in Groome, 1997, 211) has approached the problem of positionality by referring to what she calls “standpoint epistemology”. She says that this refers to recognizing the fact that

> “…all knowing is from some perspective – from a context, interest, and politics – in other words from a standpoint. Then knowledge engages critical self-reflection, to realize and name its own perspective – where one is “standing” in constructing knowledge – and then to recognize why and how this standpoint shapes what is known.”

Standpoint epistemology or positionality thus involves recognizing the influence (on me) of my social, cultural, political and historical context. I need to be aware of how my sex, race, gender roles, ethnic background, economic condition, political structures…all have a profound influence on what (I) know and how I know it. The need then is to “call (my) cultural context and perspective into question, to recognize its sins as well as its graces” (*Ibid*., 19).

I was born in 1954, the year after the then Minister of Education’s statement to Parliament:

> “Natives will be taught from childhood to realize that equality with Europeans is not for them…People who believe in equality are not desirable teachers for Natives…What is the use of teaching the Bantu mathematics when he cannot use it in practice? The idea is absurd.” (House of Assembly Debates, Aug-Sept, 1953)

Who am I? What is there in my worldview and my life experience that may affect the way I understand and present what I perceive? How does it affect my ability to be objective in terms of data collection and analysis? How does the way my students see me and respond to me affect what they will and will not share of their experience and their thoughts? I am middle-class, middle-aged, White and female, with post-graduate qualifications and many years of teaching experience - seemingly as opposite as possible to the students who comprised my research samples, who were mostly ‘economically-challenged’ (i.e. on financial aid), young, male and Black, at the beginning of their university career.

I was born and grew up on a farm in the province of Mpumalanga. Farm animals, snakes, raging bush fires and drums pounding through the night are amongst my earliest memories. I was named *Mamkwaleni,* after a locally famous *sangoma*. Before going to school, my time was spent with a series of Tsonga nannies, who preferred to practice their English on me than follow my mother's instructions to teach me Tsonga. During my primary school years I attended a small local farm school, Whites only, mostly Afrikaans-speaking, where my siblings and I thought it the norm to go to school barefoot. As I grew up and graduated from the local school to go to a state boarding school, my situation on the farm changed. Interactions with the local people became narrowed to conversations in Tsonga about what goods they wanted to buy in my mother's trading store. An annual highlight was attending the 'coming out' ceremonies of the initiation school held on the farm, where over the course of two days, the children - ranging in age from as young as 10 years old to their early twenties- would be reintroduced to the community as men and women. These days were celebrated with much organized whip and stick fighting among the men, beer brewing and ululating among the women, and strictly gender-segregated dancing by the young initiates. This all came to an end in 1980 with the expropriation of the farm by the government for inclusion into one of the Homelands.

My most defining teaching experience was over a period of seven years at a multi-racial independent school which was started as an outreach project in Mpumalanga by a big independent school in Johannesburg. The school, Penryn College, developed its own outreach project which is one of the largest of its kind in the world, reaching thousands of children through regular teacher workshops (www.penreach.org). The children attending this predominantly Black school represented a cross-section of society: from the children of wealthy Black and White local business people and professionals to individual Black children who were selected for their potential and supported by their wider family as the one to 'have the chance at a better life'. While my association with independent schools continued when I was employed at Wits, the experience I had gained over the years was not only that of privileged education. I had taught extra lessons to township children in Port Elizabeth in the evenings, and the diversity of children at Penryn and teachers in Penreach (the outreach project) had exposed me to different worldviews. However, it took reading for a Masters degree in Science Education to provide me with the language for something that I had always been aware of, but which had not, in my experience, been articulated or formalized. This was the existence of 'other ways of knowing'.

I was aware during the period of data collection for this study, and particularly in the interview situations, that my position as a university lecturer placed me in a position of authority over the students in several different ways. The first of these was as a subject or 'content' authority: Aitken (2001, 78) has pointed out that "we need to recognize the importance of the politics of difference that constitutes our relationship with interviewees – we are part of the academy and scholarly research". As described in the literature review, teachers or lecturers have traditionally been highly regarded by Africans - they have historically been accorded a similar authority to elders (Ogunniyi, 1983), although in recent South African history, this authority and respect has diminished. However, my position as their lecturer would no doubt have had some effect on the nature of the student's responses to the questions. Aitken (2001) refers to this as the impact of "power relations", pointing out the necessity of being aware of how these might impact on the kind and depth of information that respondents might be willing to share. This is connected as well to the problem of expectations: it is possible that the students were driven or directed in their answers by what they thought I expected of them, despite my careful explanations of my interest in their knowledge and that the questionnaires were not tests.

The second issue of authority that probably would have affected the students in their responses is grounded in South Africa's history and in the racial differences between the students and myself. Skelton has said that there are:

> "…particular configurations of power that frequently emerge in cross-cultural and cross racial research (and that) if we work in a post-colonial geographical context, being white….may have an important impact upon the relationships we can establish during our research. It might mean that people feel they have to talk to us out of an enculturated sense of deference; it might mean that people do not want to talk to us, because we represent a negative and exploitative past" (Skelton, 2001, 89).

I knew that it was important, particularly for the interviews, that there should be as much trust and honesty as possible between the students and me, and that the maintenance of an 'aloof academic position' would not facilitate understanding between us (Aitken, 2001). For this reason, the interviews were conducted towards the end of the year, after there had been considerable contact through one-on-one interactions in practicals, tutorials and field-trips. I was aware that because of the cultural differences between White Africans and Black Africans, I had a very different background to that of my students. Skelton, commenting on her experience as a young, White, British woman conducting research in the Caribbean, said:

> "Being black and doing research with white people will raise very different questions from those I have thought through in relation to being white and doing research with black people. The same is true for research and researchers across the 'Third World/First World" boundary" (Skelton, 2001, 94).

Because I had grown up on a farm, I felt I had at least some sensitivity to traditional Black culture that would help me to respond to the students in a way that would facilitate or enable the generation and collection of relevant data. I was also really interested in hearing about their prior knowledge. However, the problem of positionality was only made really clear to me at a conference at the beginning of 2003, when I attended the presentation of some research in a closely-related field, which had also used cultural border crossing and collateral learning as a theoretical framework. The person who presented the research was also female and 'mature', but she was Black and of the same cultural group as the students in her research sample. The responses to her questions and the results she had recorded were more revealing of the power of positionality than I could have imagined. It would seem that because the students knew she had the same cultural background as they did, there was a freedom of speech and expression of thinking that led to a different picture of collateral learning than was emerging from my research. This was probably also deeply affected by the fact that the students in her research sample were based in a predominantly rural area, and so were closer to their traditional roots than the students with whom I was interacting. My students were predominantly from township schools and had thus undergone at least some ‘cultural distancing’. Her research was conducted under conditions of intersubjective (common) understanding of culture and knowledge, while in my case, there would have been no expectation by the students of such ‘taken for granted’ understanding. While I was aware of the potential of many factors that could create barriers, I clearly had not been aware of how much of an impact they might actually have. Skelton comments that

> “…cross cultural research is difficult, particularly if we think through and acknowledge the complexities, sensitivities and dilemmas that are implicated within it…we have to constantly think about what we are doing, why we are doing it and what the research we do means to other people” (Skelton, 2001, 96).

The problem of being an ‘outsider’ (Mohammad, 2001) and how this may have impacted on the generation and analysis of the data is acknowledged as probably one of the severest limitations of the current study. This is exacerbated by the fact that

> “(u)nder Apartheid, inequities were systematically increased through laws strenuously implemented, including the restriction and abuse of individuals and communities, carried into the allocation of education resources and indoctrination (in schools and teacher education) through Christian National Education and Fundamental Pedagogics” (Naidoo in Malcolm and Alant, 2004, 50)

However, there is an alternative view that needs to be inserted here, stemming from Matthew’s (2004) indictment of ‘epistemological niche privileges’, and what may be referred to as the ‘academic right’ to do cross cultural research. Naidoo’s comment (in Malcolm and Alant, 2004) does not take into account that Apartheid also created restrictions from the opposite perspective: as a White child growing up, my experience was also of restriction: entrenched economic inequalities and the pervasive acceptance of Western superiority did not encourage White people to participate in Black culture, and in contrast to the opportunity, albeit limited, for participation in Western education by Black people, no similar formal opportunities were provided to Whites to learn about Black culture, Black science or Black education. Naidoo’s comment (in Malcolm and Alant, 2004) therefore does not acknowledge indoctrination from the opposite perspective i.e. the indoctrination that came from the view that ‘what was European was superior’. The desire by Black people for Western education and life styles reinforced that superiority. At a school where I taught in the 1990's, Black parents rejected the introduction of SiSwati as a school subject. Their comment was "Don't teach our children SiSwati – SiSwati is rubbish! Teach them English!" Most of the technology that shapes the life styles of people all over the world - including radios, cell phones, cars, computers – is the product of Western science. The research methods that are used to improve learning in science education have their roots in methods developed in the 'west'. The problem with an approach such as that taken by Malcolm and Alant when they commend the 'change in colour' of Science Education supervisors in South Africa (Malcolm and Alant, 2004, 53) is that it invokes special niche privileges and entrenches racism. The recognition that cross cultural research is difficult must be stated, and critical reflection is essential, but that should not preclude or devalue the contribution that has and can be made by researchers with a different worldview than their respondents. It can, in fact, be argued that an 'outsider' may be exposed to thinking that is articulated specifically because the researcher is an outsider. The most critical point to be noted, however, is that neutrality is elusive, if not impossible.

As the research progressed, and religious conflict, provoked by the teaching of some of the theories in the 'Earth in Space' course emerged as a 'surprise' finding, another positionality problem was brought to the fore. Religion, in my Western understanding of the term, had not been perceived as a possible issue in border crossing before it was raised by the students in relation to the post-instruction questionnaire. Here, one of the questions was: "was there anything in the course you found hard to believe?" The students' responses precipitated the need for me to read about and try to understand African Traditional Religions and the history and effect of the Christianization of Africa. This is a huge field in philosophy and theology, a field which was unknown and foreign because my background is in Western understandings of botany and physical geography, and my understanding is a work in progress. The students responses to what they had found difficult to believe also placed me, again particularly during the interviews, in a difficult position, since I am a Christian. The focus of the research, guided by the science education literature, had been on the impact of 'cultural' issues on the learning of basic astronomy. Religion had not been highlighted as a critical part of culture. This changed between the first and second phases of data-gathering as noted in the section on Research Methodology: in the second phase, the post-instruction questionnaire included, in the question "What will you teach your children?" three options: Science; traditional understandings; or religious understandings, in response to the students' answers in the first phase of data collection. Apart from this, religion was not mentioned in the questionnaires at all.

During the interviews, some of the students would talk 'up front' about the issues they had with the perceived conflict between their religious beliefs and Western science. Others were so uncomfortable with what they understood as my apparent 'un-religious' or even atheistic approach to the content of the course that they struggled to tell about their religious problems with it. In a few cases their discomfort was so great that I felt compelled to tell them that I was also a Christian. For some this was a huge relief, and they were then able to speak about their confusion more freely. Did this compromise the collection of data? Did it facilitate it? Skelton's comment regarding "…what our research means to other people" also points to the role that the reader plays in interpreting what has been interpreted by the researcher: their understanding, for example, of the role of culture or religion on science education will impact on the credibility and value that they will ascribe to the research.

Despite the threats identified to the objectivity and trustworthiness of the present study, every effort has been made to maximize its trustworthiness. This has been done through discussions with colleagues; validating the questions in the questionnaires; recording the interviews and after transcription, having them verified by the interviewees. The collection of data from several different groups of students over a period of three years also served to verify the findings from each of the groups.

Problems of positionality, however, can only be dealt with by carefully examining one's standpoint and reflecting as transparently as possible on how this may have impacted on the research process. This reflection has been applied to the gathering of the data and to its analysis, as well as to the recommendations made as a result of the study.

CHAPTER 4

RESEARCH METHODOLOGY

CHAPTER 4

RESEARCH METHODOLOGY

This section on the research methodology is presented as five sections. The first sets the scene by introducing the choice of a research paradigm for the study and describing the different groups of students making up the research sample. It also provides a brief introduction to the research instruments to give an overview of the methods that were used to gather the data. Tables are provided in the text and in the Appendices to illustrate the development of the research instruments and methods of analysis over the period of the study. Section 2 describes the pilot study. Section 3 describes the pre-instruction questionnaire and the coding methods used for the analysis of the data that was gathered. Section 4 describes the post-instruction questionnaire and its evolution from an instrument to record conceptual change to an instrument to investigate barriers to learning. Section 5 describes the interviews, and the use of vignettes to portray the most common difficulties associated with border crossing.

4.1 BACKGROUND

4.1.1 The choice of a research paradigm

The focus of this research was to extend understanding through the use of methods that are reliable, credible and valid. While the discipline of science has been defined through its rigorous methodologies which emphasize *quantitas* (Erickson, 1998), science *education* has benefited not only from quantitative methods, but also from methods which lend themselves to revealing and understanding human behaviour and thinking. The move towards qualitative research methods, which originated from the research methods of social anthropology (Bryman and Burgess, 1999), has grown out of debates regarding the nature of science, the development of different forms of constructivism, and the shift towards postmodernist views regarding educational research.

Cohen and Manion (1994) have stated that qualitative research methods used to be regarded as 'quaint but quirky' by researchers who favoured a 'nomothetic' approach[11]. However, scientifically acceptable (i.e. quantitative) research methods are now seen as lacking in the account they are able to provide of the social world, especially with regard to research in education, where the focus of the research is people, and the objective is to illuminate human understanding behaviour and attitudes (Thompson, 2001; Fraenkel and Wallen, 1990; Foddy, 1993; Lindsay, 1997).

A nomothetic approach is one based in a positivist epistemology where quantitative research methods are seen as the only means of obtaining objective, reliable and valid results[11]

Qualitative research methods encompass a variety of approaches to interpretive research (Leedy, 1989), including methods that are used to "investigate the quality of relationships, activities, situations or materials” (Fraenkel and Wallen, 1990, 368).or to “describe and analyze people’s individual and collective social actions, beliefs, thoughts and perceptions” (Schumacher and McMillan, 1993, 372). They are thus appropriate to situations requiring strategies that will “obtain as holistic a picture as possible of a particular society, group, institution, setting or situation” (Fraenkel and Wallen, 1990, 374. Dwyer and Limb capture the defining qualities of qualitative research methods as follows:

> “(q)ualitative methodologies do not start with the assumption that there is a pre-existing world that can be known, or measured, but instead see the social world as something that is dynamic and changing, always being constructed through the intersection of cultural, economic, social and political processes. The emphasis in using qualitative methodologies is to understand lived experience and to reflect on and interpret the understandings and shared meanings of people’s everyday social worlds and realities. Qualitative methodologies are characterized by an in-depth, intensive approach rather than an extensive or numerical approach. Thus they seek subjective understanding of social reality rather than statistical description or generalizable predictions” (2001, 6).

The methodology chosen for this study was thus based on the idea that qualitative methods would provide the flexibility required to allow free responses to questions designed to provide insight, firstly into the prior knowledge of students, and secondly into the barriers to learning experienced by students in the context of the study. However, the use of qualitative methods for data gathering does not preclude the value of some ‘number crunching’ in the analysis. Erickson (1998, 1166) points out that even in qualitative research “the researcher must pay careful attention to frequency of occurrence, especially to relative frequency”. Consequently a mixed methods approach was chosen for this study. The data gathering followed qualitative methods, while some simple quantitative methods were used in the analysis.

As far as the data gathering was concerned, three of the characteristics of ethnographic research provided by Fraenkel and Wallen (1990) indicated the suitability of ethnographic methods for this study. First, they are useful when you want to get as complete a picture of something as possible; second, ethnographic techniques are a viable approach for use in schools and classrooms because of the opportunities they provides fin gaining an insight into the processes of education; and third, they have the potential to reveal areas of interest that may not have been detected by other forms of research. Schumacher and McMillan’s indication that ethnographers begin their research with ‘foreshadowed problems’, which, they state “may arise from intuitive questions based on a working knowledge of facts, issues, concepts and theories that guide the decisions for an emergent design” (1993, 408). These recommendations fitted well with the conceptualization of this particularly study, particularly in the light of Hammond and Brandt's recommendations for their use in the “examination of bounded cultural settings” (2004, 3).

The research questions that were posed to guide this study grew out of the lived experience of African students struggling with the content of an Earth Science course in basic astronomy. The intention of the study, which was to investigate what the reasons behind these difficulties might be, was guided by my understanding of socio-cultural constructivism. The first step, therefore, was to establish the prior knowledge of the students in this field. This would provide insight into their worldview and indicate the prevalence of cultural or traditional ideas in contrast to the ideas of Western science. Establishing their prior knowledge would also allow me to benchmark the results of this study against the findings of other similar studies. The second step was to establish their post-instruction knowledge and also to probe the effect of their prior knowledge on their responses to the course. Some of these questions were metacognitive, for example, 'what did you find hard to believe or understand and why?', while others were biographical in nature, to provide some data on the background of each student.

The theoretical framework selected for this study ascribes to the understanding that "science learning is a cultural as well as a cognitive activity" (Hammond and Brandt, 2004, 2). The theories of cultural border crossing and collateral learning, proposed respectively by Aikenhead (1996) and Jegede (1995) to describe and explain the difficulties experienced by students with different worldview beliefs than those of science, were used as a framework for analysis of the students' responses. The application of these theories provided the opportunity to find out whether and how culture could be acting as a barrier to learning. The analysis of the responses to the questions was intended to illuminate any costs that might be associated with border crossing and collateral learning, and how these could have affected the quality of learning that was taking place.

4.1.2 The Research Sample

The research sample was made up of several convenience groups of first year University students, where the common factor was their attendance of an Earth Science course called 'The Earth in Space'. The breakdown of these groups is given in Table 4.1, but the final sample number in terms of data gathering was as follows:
Pre-instruction Questionnaire: n = 191
Post-instruction Questionnaire: n = 163
Interviews: n = 25

Foundation students in Geography and Earth Science and first year Geology students at Wits University are required to do a course in basic astronomy called 'The Earth in Space'. The content and length of the course differs according to the student group: for first year mainstream Geology students, and the Earth Science (or 'College of Science') students, the course extends for one university block (approximately 7 weeks). For the Geography students, the course is only 3 weeks long and is less content-intensive than for the other groups.

Data were not collected in terms of the age, sex or race composition of the groups, as this information was not critical in terms of the focus of this study and the request for students to record this information may have been offensive. However, the general trend for students in all of the groups was that they ranged in age from about 18 to 23. In each group there was a predominance of males; and each group contained only a small proportion of White and Indian students. The characteristics of these groups are as follows:

Geography Preliminary (changed in 2004 to '**Geography Foundation**') is a bridging course into the Geography mainstream course. It is open to Faculty of Humanities students who would like to major in Geography, but who do not have Geography as a matric subject, and/or who do not have English as their home language. Matric Mathematics is not a requirement for this course, nor is Physical Science. The classes are usually quite small (less than 20) and are predominantly made up of Black students from township or rural schools.

The **College of Science** is an access course into the Faculty of Science. Students who do not achieve the required number of matric points to gain automatic entry into the Science Faculty are offered places through a series of selection tests, and successful candidates can opt to do Earth Science as one of three courses that they have to take, the other courses being Mathematics and Physical Science. The course extends over two years, and the students who are successful gain entry into second year mainstream courses. The classes are usually small (20 to 30 students) and tend also to consist of Black students from township or rural schools.

Geology 104 is the mainstream first year course for students who would like to major in Geology. These students have achieved sufficient matric points to gain automatic access into the Faculty of Science, and are required to have passed Higher Grade Mathematics. The sample class of 2004 was fairly large, with over 100 students. The demography of this group reflects a broader range of backgrounds: students may come from rural, township, urban or even independent (private) schools. While usually a number of Indian, coloured and White students take this course, the class of 2004 consisted predominantly of Black students (approximately 65 – 70 %).

The data were gathered in two phases: the first phase comprised the pilot study, which was conducted in 2001, and two sets of data collected in 2002. This was followed by a second phase of data collection in 2004. Consequently the final sample is made up of six different groups of students, each of which represents a 'convenience' sample (Fraenkel and Wallen, 1990; Schumacher and McMillan, 1993).

Qualitative research typically involves samples that are small, and where the main aim is to gain a holistic understanding of a particular situation or activity in its natural setting (Fraenkel and Wallen, 1990; Schumacher and McMillan, 1993; Dowler, 2001; Dwyer and

Limb, 2001). Table 4.1 shows that most of the sample groups were small, with only the Geology mainstream group providing the opportunity to gather data from a larger sample.

Table 4.1: Summary of the sample groups and numbers of students who participated according to the different research instruments i.e. questionnaires and interviews

Year and phase	Student Group	Abbreviation	**Questionnaire**	**Questionnaire**
Phase 1			Pre-instruction	Post-instruction
2001(Pilot study)	Geography Preliminary	G*	11	12
2002	Geography Preliminary	G	16	17
2002	College of Science	COS	22	20
Phase 2				
2004	Geography Foundation**	G	17	16
2004	College of Science	COS	33	23
2004	Geology Mainstream	MS	92	75
Total			191	163
Phase 1			**Interviews**	
2002	College of Science	COS	9	
Phase 2				
2004	Geography Foundation	G	6	
2004	College of Science	COS	10	
Total			25	

*The abbreviations in this column have been used in all the quotations of student responses to the two questionnaires. Each quotation is given a source, where the first two numbers indicate the year of data collection, (01, 02 or 04), followed by the sample group using the abbreviations in the table, followed by the student number, and finally whether the quote came from the pre (PRE) or post (POST) instruction questionnaire, e.g. (04.MS.12.PRE) indicates 2004, Geology mainstream student 12, pre-instruction questionnaire.
**The name of the Geography course was changed from 'Geography Preliminary to 'Geography Foundation' in 2004 to be in line with the naming of other foundation courses offered at Wits. For reference in the quotations, both are referred to simply as 'G'.

4.1.3 Introductory overview of the research instruments

As noted, I wanted to record the students' prior knowledge of specific phenomena or events related to basic astronomy, unaffected by the content of the course they were to embark on. I then wanted to find out what difficulties they may have had in understanding or accepting what they had learned. Open-ended response questionnaires were selected as research instruments, one to be completed at the beginning of the course and one at a time after the course had been complete. A 'pre-instruction questionnaire' was devised to establish the knowledge base of the students regarding a few key concepts in basic astronomy. These questions were also used in the post-instruction questionnaire to establish any change in ideas. The second questionnaire also contained a few additional questions which were directed at finding out about any difficulties the students may have experienced in learning the content of the course. The information from both questionnaires was then available for the formulation of the questions that were used to probe areas of interest during the interviews with students who volunteered to be interviewed. The breakdown of the different groups, each with the number of students participating in each of the data collection strategies (i.e. the questionnaires and interviews), can be seen in Table 4.1.

4.1.3.1 The pre-instruction questionnaire

A 'pre-instruction questionnaire' (see Appendix 2) was developed for this study because a literature search for a suitable example on which to base the questions was not successful. The empirical research that I was able to find linking collateral learning with indigenous cosmology was very limited. The only studies that had been done in Africa, at the time of the creation of the first questionnaire in 2001, were those by Ogunniyi (1987), Jegede and Okebukola (1991) and Ogunniyi *et al*. (1995). The closest possibility at that stage was the questionnaire used by Ogunniyi and his colleagues in their 1995 study on ‘Worldview Presuppositions of Science Teachers’. However, it did not contain any questions related to basic Astronomy. A study by Lemmer, Lemmer and Smit, which contained similar questions to those devised for this study, was, however, published in 2003 in the *International Journal of Science Education*. This was very useful for comparative purposes as some of the questions they had used were similar to the ones used in this study. However, at the time of the creation of the first pre-instruction questionnaire for this study, the Lemmer *et al*. paper had not been published.

The pre-instruction questionnaire was thus devised to consist of six open-ended response questions based on key concepts[12] in basic astronomy. These questions focused on concepts which should, according to school curricula, have been covered at school level. However, they were also the kinds of questions - for example, ‘what is a star?’ and ‘where do the stars go in the daytime?’- that are often asked by children when they are young. Consequently there was the possibility that the students would have been exposed to cultural explanations during their formative years, perhaps before, or in addition to the science they should have learnt at school. The questions therefore provided the opportunity to investigate the existence of different worldviews through asking the students to record what they thought the scientific explanation to the question might be, and what their own personal understanding was. This enabled me to gather a record of their prior knowledge. It also allowed me to establish their knowledge and understanding against the benchmark of ‘typical’ school science. The students were also asked to record (if they could remember) the source of the information they were giving me, as an additional means to try to establish whether the information had a cultural or school origin.

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[12] Listed in the American Association for the Advancement of Science: Atlas of Science Literacy, Project 2061, 2001, pages 42 - 49.

4.1.3.2 The post-instruction questionnaire

Part of the intention of the first research question was to find out whether there had been any change in the students' understanding or ideas after the course, and what effect their prior knowledge might have had on these ideas. I also wanted to find out what they might have found difficult about the course in order to establish whether they were engaging in any collateral learning, and whether there were any issues of cultural border crossing. Consequently a post-instruction questionnaire (see Appendix 3) was formulated, which contained the same questions as the pre-instruction questionnaire, but with a few extra questions added regarding what they had found difficult to understand and believe in the course. This questionnaire was given to the students several months after they had completed the course. This time lapse was necessary to comply with Jegede's constraint that collateral learning only applies to concepts that have become part of the long-term memory.

The post-instruction questionnaire thus consisted of two parts. The first was to enable the comparison of ideas with reference to content, while the second part, containing the metacognitive questions was to provide insight into border crossing and collateral learning.

4.1.3.4 The interviews

On completion of the post-instruction questionnaire, the students would be invited to participate in an interview. Here I hoped to find out how their prior knowledge and world view may have affected their learning, as well as what concepts they had found difficult to understand or accept and why. This was in keeping with the recommendations for research in this field as set out by the Joint Research Project Report (Jegede, Aikenhead and Cobern, 1996, 7), where at the 'Mito Meeting', the suggestion was made "for case studies or vignettes of collateral learning, illustrating how a student moves (or does not move) from "parallel" to "secured" collateral learning". The present study thus comprises a vignette, defined as a character sketch or word picture in the Chambers Twentieth Century Dictionary (1975).

4.1.3.5 The data collection timeline

The data were collected over a period of three years (see Tables 4.2 and 4.3). This meant that there was time for reflection between the data collection sessions, particularly between the first phase of data collection, involving the pilot study in 2001 and two groups of students in 2002, and the second phase of data collection, involving three groups of students in 2004. The effect of this was that while the questionnaires remained basically the same over the years, a few changes were instituted, particularly in the post-instruction questionnaire and in the interview questions. These changes reflect my ongoing discussions with my supervisors and colleagues in Earth Science, and with family and friends involved in education. The changes also reflect my growing understanding of the barriers to learning experienced by the students as I extended my reading in response to issues raised in the questionnaires and interviews. Practical (or opportunistic) issues also had an effect: in Phase 1, one of the pre-instructions questions was about eclipses, as there were several eclipse events during that time. This question was substituted in 2004 (i.e. in Phase 2) for a question about the Universe, to probe the students' understanding of space beyond the solar system.

An overview of the research methodology used for each phase of both the pre-instruction and post-instruction questionnaires is provided in tables 4.2 and 4.3 (also provided as Appendix 2 and 3 for easy reference). These tables summarize the phases of data collection, the instruments used, the methods of analysis and the presentation of the results.

Table 4.2 Summary of research methodology: Pre-instruction questionnaire

Phase 1

Sample groups	Instruments that were used	Focus of analysis	Method of analysis	Presentation of results
Pilot study G 2001 COS 2002 G 2002	Pre-instruction Questionnaire Appendix 4.1 Pre-instruction Questionnaire Appendix 4.2	Prior knowledge	Manual coding (also computer coded in Phase 2: see below)	Table 5.16 showing conceptual change: responses to six content questions from pre- and post- instruction Questionnaires

Phase 2

Sample groups	Instruments that were used	Focus of analysis	Method of analysis	Presentation of results
G 2004 COS 2004 MS 2004	Pre-instruction Questionnaire Appendix 4.3	Prior knowledge related to worldview	Computer coding of data from **all** sample groups, i.e. from Phase 1 and Phase 2: Method 1 (numbers of students involved with each issue) and Method 2 (frequency of reference to the issues involved)	Tables 5.1 to 5.15. These tables show numbers of students with different worldview positions; and details of the prior knowledge given as "code statements"

Table 4.3 Summary of research methodology: Post-instruction questionnaire

Phase 1

Sample groups	Instruments that were used	Focus of analysis	Method of analysis	Presentation of results
Pilot study G 2001	Post-instruction Questionnaire Appendix 4.4	Barriers to learning	Manual coding	Table 5.16 showing conceptual change: responses to six content questions from pre- and post-instruction Questionnaires
COS 2002	Post-instruction Questionnaire Appendix 4.5.1			
G 2002	Post instruction Questionnaire Appendix 4.5.2	Conceptual change and barriers to learning		

Phase 2

Sample groups	Instruments that were used	Focus of analysis	Method of analysis	Presentation of results
G 2004 COS 2004 MS 2004	Post-instruction Questionnaire Appendix 4.6	Barriers to learning	Computer assisted coding of data from **all** sample groups from Phase 1 and Phase 2; Method 1 (numbers of students involved in each issue) and Method 2 (frequency of reference to each issue)	Tables 5.17 to 5.37: numbers of students who responded to the issues in different ways. Figures 6 to 13: pie charts showing the relative frequency of "code statements" to a number of issues.

4.2 THE PILOT STUDY

The pilot study was conducted in 2001. It involved the implementation of the pre- and post-instruction questionnaires to a group of 12 Geography Preliminary students (class of 2001) in an effort to test the questions and expose any unforeseen difficulties (Novak and Gowin, 1984). The function of the pre-instruction questions was to gain an understanding of the students' prior knowledge and worldview about key concepts in basic astronomy. The six questions, which were simply stated questions about the Earth as a cosmic body, were developed, in consultation with my supervisors, to make them as clear and unambiguous as possible before the 'test run'.

The questions were:
What is a star?
What happens to the stars during the day?
What causes day and night?
Why is it generally colder in winter than in summer?
Why does the Moon appear to change its shape?
What is a solar eclipse and what causes it to happen? (changed in Phase 2 to 'What is the Universe?')

The post instruction questions were the same as those in the pre-instruction questionnaire, but a few questions were added which asked the students to explain what they had found difficult to understand and believe in the course. Copies of the questionnaires may be found in Appendix 3.

4.2.1 Testing the questionnaires

Before handing out the questionnaire to the group of thirteen Geography Preliminary students at the beginning of the course, I explained that I was doing some research in the area of learning. I told the students that I was interested in any of the explanations, stories or ideas they could tell me from their background (school or home) about certain natural phenomena. I explained that the kinds of questions I was going to ask them were usually asked by small children, and that it was likely that if the questions had been answered to their satisfaction at that stage, they probably would not have asked them again or even thought about them again until they encountered them at school. I explained that all cultures had their own stories about phenomena like the Moon and the stars and the seasons, and gave them some examples (e.g. Stonehenge, Mexican seasonal calendars and Greek mythological stories). The questionnaires were then given to the students who were encouraged to write down all they could remember or think of in relation to the questions. They were reassured that the questionnaire was not a test, that I had no expectations in terms of 'right' answers and that I was interested in anything they were able to tell me. They were also assured of anonymity by being asked not to write *their names* on the questionnaires, but rather the first names of their mother and father. This was to enable me to match up the pre- and post-questionnaires without compromising the anonymity of the responses. Once the questionnaires had been completed and handed in, I explained that while the 'Earth in Space' course was going to present them with the Western science view of basic astronomy, I told them I was interested in other views and would be glad to talk about any other conceptions they had. We then proceeded with the course, beginning with the meaning of geological time before moving on to the Earth as a cosmic body, the Earth/Moon system, the Solar System and Universe, and theories such as the Big Bang, Solar Nebula and Plate Tectonic theories.

The post-instruction questionnaire was only administered after a lapse period of about five months, after the students had written off the ‘Earth in Space’ course in their midyear exams. This time lapse had specifically been built into the research process in order to try to avoid the influence of rote or ‘shallow’ learning (Ramsden, 1992), because collateral learning, according to Jegede (1995, 1998), only relates to learning that has gone into the long-term memory. It was also anticipated that the lapse period would help in avoiding the situation of the students playing Fatima’s rules (as explained in the literature review) which, according to Jegede and Aikenhead (1999), does not comprise collateral learning.

4.2.2. Issues of trustworthiness in qualitative research

The pilot study was carried out as a first response to the need for any academic research to “respond to canons that stand as criteria against which the trustworthiness of the project can be evaluated” (Marshall and Rossman, 1989, 144). This is particularly pertinent in terms of qualitative research, which is still viewed with suspicion by positivist scientists, who are tied to what Cohen and Manion (1994) refer to as a ‘static view’ of the nature of science and a nomothetic approach to research.

There have been many responses to the problem of how to deal with issues of trustworthiness in qualitative research. Marshall and Rossman (1989), for example, have provided a list of questions which they suggest can form the basis for ensuring rigour in any research. These are:

1 how truthful are the findings? (this addresses the question of internal validity);
2 how applicable are they to other situations? (this addresses the question of external validity);
3 can the findings be replicated (i.e. are they reliable?); and finally,
4 how can the researcher be sure that the findings reflect the respondents’ views and are not a product of the researcher’s bias?

Other suggestions which are helpful as a guide to ensuring rigour are those from Fraenkel and Wallen (1990), who suggest that the ‘appropriateness’, ‘meaningfulness’ and ‘usefulness’ of the inferences can serve as criteria for checking validity. They also suggest that consistency of the inferences over time can be used to answer questions with regard to the reliability of the research. Lincoln and Guba (1985) suggest using the following as criteria for judging the soundness of qualitative research:

1 ‘credibility’ (the extent to which the subjects find the researcher’s interpretations to be believable),
2 ‘transferability’ (the extent to which a judgment can be made about the generalizability of the results),
3 ‘dependability’ (the extent of stability of the results, once unpredictable changes are discounted) and
4 ‘confirmability’ (i.e. is the data confirmable?)

The nature of ethnographic research precludes exact replication because it is focused on providing a detailed description of a particular situation (Lindsay, 1997).However, as has been described, the different groups making up the full sample were sufficiently similar so as to provide a form of replication, which would contribute to establishing the internal and external validity, or in the terminology of Lincoln and Guba, the transferability, dependability and confirmability of the findings. The question of researcher bias is addressed in the section on positionality which can be found in Chapter 3.

A different and interesting response to the issue of reliability and validity in qualitative research has been given by Mohammad (2001). She has posited that objectivity and neutrality are myths, and that “all knowledges are embedded, situated, specific, and hence partial, with an inevitable bias” (*Ibid*., 103). Consequently, all knowledges produced are always ‘versions’: they represent but one out of other possible truths.

However, any research needs to be subjected to careful scrutiny, and in this study, the first step was to check that the questions used in the pilot study had been well phrased and structured, that they were unambiguous and not suggestive of an answer, i.e. that they were not ‘leading’ questions. This criterion seemed to be met by the responses that were given by the students in the pilot questionnaire: there seemed to be little confusion as to what they were expected to do, and their answers were beyond any expectations I might have had in terms of the richness of data they provided. However, in an effort to improve, and as far as possible ensure the dependability of the questions, the questionnaire was taken for face validation to a highly experienced academic researcher before being administered to the 2002 sample groups. Face validation seeks to ensure that the questions elicit the information they were designed to elicit, that they do not ‘lead’ or suggest an answer, and that they are free of bias or ambiguity (Cohen and Manion, 1994; Fraenkel and Wallen, 1990; Lindsay, 1997). This attempt at improving the dependability of the questions proved to be very interesting, because it revealed how very difficult it is to ask good questions.

The changes suggested resulted in a significant change in emphasis in the questions (the various forms of the questionnaires may be found in Appendix 4): the explicit distinction between ‘scientific’ understanding and ‘personal’ understanding that had been made in the pilot questionnaire was removed, in order that there should be no suggestion that the students could have, or should have, more that one explanation. The separation of ‘scientific’ from ‘personal’ understanding in the pilot questionnaire was seen by the expert to be too directive in terms of the framework of collateral learning. The second part of each question was thus phrased to ask if the student “had heard of or read any other explanations”. The effect was that instead of the students informing me what *they* thought the scientifically correct answer was by comparison to an alternative explanation, I had to try to make that distinction. Consequently the phrasing was changed back to the original form in the 2004 pre-instruction questionnaires.

Another suggestion made by the expert was to simplify one of the background questions. The question

> "When you were a child, can you remember asking questions such as "what is the sun?" - How did your parents/grandparents respond? How do you think they gained this understanding?"

was changed to

> "When you were a child, can you remember asking questions such as "what is the sun?"

This suggestion led to the development of a more fruitful question about what the students would teach their *own* children.

The pilot study group, as noted, consisted of the 2001 "Geography Preliminary" class. This group was similar to the other groups making up the research sample in that they were predominantly Black English Second Language (ESL) students from township or rural schools (the historically disadvantaged 'Black schools'), and they were all doing foundation courses. One of the biggest differences between the Geography groups and the College of Science and Geology first year groups, is that the Geography students register in the Faculty of Humanities, while the other two courses are registered in the Faculty of Science. The Faculty of Science requires that students should have Matric Mathematics and at least one science subject to be eligible for acceptance. However, because the content of the Geography 'Earth in Space' course is very similar to that of the other groups, it was decided, on the advice of two experienced science education specialists, Rollnick and Lubben (2002, pers. comm.), that the questionnaire results from the pilot sample could be incorporated into the results of the study. The responses made by this group of students were meaningful, and their contribution warranted inclusion with the main body of data.

4.3 THE PRE-INSTRUCTION QUESTIONNAIRE

4.3.1 Administration of the questionnaire

The process of administration of the pre-instruction questionnaire for the sample groups of 2002 and 2004 was the same as that for the pilot study. However, I asked a co-lecturer in the course to sit in and take notes of what I said to the students in the introduction before handing out the questionnaire (the notes are available in Appendix 5). This was seen as important in enabling 'progressive focusing' (Boaler, 1998), as reflexivity is a critical feature of ethnography. It was thus important to have a record of what I had said, and to know that I had assured the students of anonymity and the fact that the questionnaire was not a test. These students were also instructed *not* to write their names on the questionnaires, but to write the names of their mother and father (information only identifiable by themselves) on the front of their questionnaire. The use of the parents names as a means of identification was explained by saying that if I wanted to ask them about something interesting they had written, I would be able to use these names to invite them to talk to me. However, as noted, these names were also to serve to link the pre- and post instruction questionnaires in preparation for the interviews. This technique was later found to not have been particularly successful: sometimes the students would only give the name of only one parent, and in terms of African culture where aunts are regarded as mothers, decisions about who should qualify as parents changed from one questionnaire to the next! There was thus a match difficulty that could have been avoided by giving the students pre-numbered questionnaires.

In the same way as in the pilot study, once the questionnaires had been completed and handed back, we commenced with the course.

4.3.2 Coding the data: content questions

The data were coded both manually and using a computer software programme (*ATLAS.ti 5.0, 2nd Edition, 2004*) designed for coding qualitative research. The coding categories that were created were checked for reliability by a colleague, also working in the field of basic astronomy, as well as by an education specialist. While their work served to confirm the categories that were used for coding, both were White males. The nature of this research - with its focus on the impact of culture on learning - indicates that it would benefit enormously from the input of a team of researchers, particularly if they reflected the diversity of the research sample.

4.3.2.1 Phase 1

I wanted to be able to distinguish, in terms of the prior knowledge of the students, the prevalence of alternative conceptions compared to conceptions based on Western Modern Science (WMS). An initial study of the responses to the pre-instruction questions from the first phase of data collection (i.e. the data collected in 2001 and 2002) indicated that there were five basic categories of responses to the content questions:

1. A correct (Western science) conception.
2. A misconception (of Western science).
3. An alternative belief (i.e. a conception not based on Western science).
4. No answer given (blank), or the student stated “I don’t know”.
5. The response could not be categorized.

The basic worldview distinction involved the first three responses, while category 4 provided information regarding the extent of the lack of content knowledge. Table 4.4 shows the categories that were developed for analyzing the responses that fitted into categories 1, 2 and 3 for the six content questions in the pre-instruction questionnaire.

Table 4.4 : Coding system for answers to Questions 1 to 6 in the pre-instruction Questionnaire (Phase 1).

Answer based on Western Modern Science (WMS) 1: Answer based on WMS 1.1 comprehensive and clear scientific explanation 1.2 partially correct answer, based on WMS, needs fuller explanation 1.2.1 solar system perspective 1.2.2 Earth based perspective 2: Science misconception (i.e. answer based on WMS, but is not correct) 2.1 guess/made up answer 2.2 observation-based answer
Answer NOT based on Western Modern Science (WMS) 3. Alternative belief or personal understanding, not based on science 3.1 based on own observations 3.2 linked to an alternative framework 3.2.1 traditional understanding or IKS 3.2.2 religious basis
4. No answer given, or student states “I don’t know” 5. Statement makes no sense or cannot be categorized

A few examples are given to illustrate the coding of the answers.

Example 1 (from question 1: “What is a star?”)

> “A star is a ball of gas that is burning and giving off light. It is millions and millions of kilometers away from the earth” (02.COS.6. PRE)

This response was coded as 1.1 i.e. it represented a WMS conception which was clear and definitive.

Example 2 (from question 4: “Why is it generally colder in winter than in summer?”)

> “The earth is a sphere spinning on an axis which is tilted. As it rotates around the sun, the (*sic*) is some areas which the sun’s rays hits a lot and some areas which it hits very little. The place with the most rays is hotter” (02.COS.6.PRE)

This response was coded 1.2.1 i.e. the answer is based on a WMS perspective, and has a ‘solar system’ perspective. However, there is a problem with terminology (i.e. rotation instead of revolution) and clarity of explanation (i.e. the effect of the angle of insolation is explained as places where the Sun’s rays “hit a lot” or “very little”). This meant that this answer could not be given a rating of 1.1)

Example 3 (also from question 4: "Why is it generally colder in winter than in summer?")

> "In winter the sun migrates north towards the equater (sic) therefore resulting in cooler conditions" (02.COS.1.PRE)

This response was coded 1.2.2 as the answer is based on WMS, illustrating the view taught in Climatology to explain the movement of the heat equator, but it does not give a full account of the cause of seasons, and is limited to an 'Earth bound' or geocentric perspective.

Misconceptions included the widely held understanding that seasons are caused by the distance between the Sun and the Earth, that the Earth was closer to the Sun during summer than in winter, and observation based answers included ideas such as the Sun being hotter in summer.

As far as the alternative beliefs were concerned, it also became obvious very quickly that if students did not know of a 'formal' explanation, they either 'created' an answer based on their own observations or they drew on traditional knowledge systems or religious knowledge. The following serve as examples:

Examples 4 (from question 1: " What is a star?")

> "A star is a heavy round globe which often appears at night and gives the light to the earth" (02.COS.20.PRE), followed, in response to the question "where/how did you get this information?" by "I didn't get this information from no-one, is (*sic*) just came. Truly speaking, I never heard or read about it. Is something I'm just thinking about it."

This was coded 3.1 i.e. an alternative conception, based on the student's own observation or thinking)

Examples 5 (from question 1: " What is a star?")

> "A star is a rock which is found on space which shines during the night mostly in summer" (02.COS.16.PRE), followed, in response to "where/how did you get this information? by "from my Grandmother."

This was coded 3.2.1 i.e. an alternative conception, possibly based on traditional knowledge. (The problem of 'discovering' what constituted traditional knowledge will be discussed under issues of accessibility of information)

Example 6 (from question 3: "What causes day and night?")

> "The book of life tells us that God create day and night" (02.COS.3.PRE)

This was coded as 3.2.2 as it clearly was based on the Biblical account of creation.

The students were told in the introduction, before the questionnaires were handed out, that the questionnaire was *not* a test, and that I was interested in whatever they knew at that stage. However, if they did no't have an answer, that was "also OK" and they could either leave the question blank or tell me that they did not know the answer. This may have helped to reduce the answers that could not be categorized, as several students stated that they had "no idea" rather than just try to make up an answer. Others, however, stated that this was the first time they had thought about certain questions and that their answers were based on their own observations. Sometimes this resulted in answers based on everyday or common observations or explanations, for example, in answer to the question "What happens to the stars in the day time?" many students wrote answers similar to the following:

> "I think the stars often appear at night, so they maybe disappear because of the sun" (02.COS.20.PRE).

The coding system given in Table 4.2 was used for the analysis of the data collected in Phase 1. It was useful for comparing the pre- and post instruction knowledge of the students, but as Schumacher and McMillan (1993) point out, ongoing refinement takes place in qualitative research as a consequence of its 'emergent nature'. During the course of this study, the coding system was refined in two different ways: the first involved the inclusion of 'everyday' or 'common' ideas, and 'personal ideas' as categories under 'Ideas not based on Science', while the 'Ideas based on Science' were changed to 'correct', 'simple' or 'problem' ideas. The second 'refinement' was to use a computer based coding system, "*Atlas.ti",* created by Thomas Muhr (2004), instead of manual coding. Consequently, once the data had been collected in 2004, all the questionnaires (from Phase 1 and Phase 2) were converted into 'primary documents' (PD's) in the computer programme's 'hermeneutic unit' or workspace, where coding could take place.

4.3.2.2 Phase 2

Coding Method 1

The method of coding described under Phase 1 is a 'top-down' approach, in which each student's response to each question was categorized according to whether it represented a Western Modern Science worldview (WMS) or whether it was based on Alternative Beliefs (AB). This coding method, using the slightly different categorization scheme noted above, was repeated on all the pre-instruction questionnaire data using Atlas.ti (for an example see Appendix 6). The students' responses were now coded as representing a *correct*, *simple* or *problem* WMS understanding, or as AB *personal, everyday*, *IKS* or *religious beliefs.* Any student who gave two different answers – one based on science and one on alternative beliefs - would be coded as having some form of combination of worldviews.

The following examples are illustrative of this method of coding, where example 1 shows a student who was categorized as having a 'WMS correct' worldview; example 2, where the student, who did not provide a scientific answer, was categorized as having ‘AB everyday and AB religious’, and example 3, where the student gave a combination of WMS and AB, was categorized ‘WMS simple and AB IKS’:

Example 1

1. What is a star?
1.1 A giant ball of burning hydrogen gas (scientific explanation)
1.2 Books; Discovery channel (source of this information)
1.3 A giant ball of burning gas (personal explanation)
1.4 Discovery channel (source of this information) (04.COS.32.PRE)

Example 2

1. What is a star?
1.1 - (scientific explanation - no answer given)
1.2 - (source of this information - no answer given)
1.3 Star is small and bright objects which during the dark nights shine on sky. It is there to decorate the sky and protect the sky against Satan (personal explanation).
1.4 My childhood memories (source of this information) (04.G.1.PRE)

Example 3

1. What is a star?
1.1 It is the sun in many other planets, for example the sun is the star (scientific explanation).
1.2 School (source of information)
1.3 I believe it is the people who died ages ago and they look up for us (personal explanation).
1.4 Grandparents (source of this information) (04.COS.27.PRE):

While it was found that there were relatively few responses that could be linked to indigenous or cultural knowledge, it was common for students to hold either partially correct scientific conceptions (listed as either *simple* or *problem* ideas), or *everyday* beliefs, which were categorized as ‘AB’ because they did not contain any reference to the scientific explanation about the phenomenon.

Method 1’s deductive approach, where the *whole* answer (i.e. .1, .2, .3 and .4 of each question, i.e. the scientific and personal explanations for each question) was taken into consideration in the categorization of each student’s response in terms of a worldview position, is presented in tables in Chapter 5: Results and Analysis. In these tables, for the sake of clarity, the number of students whose responses were based on Western Modern Science (WMS) is given in blue; the number whose responses were based on Alternative Beliefs (AB) is given in green, and where students gave a combination of WMS and AB answers, the numbers are given in yellow. An example is given in Table 4.5, below, where three numbers have been inserted to serve as an illustration:

10 students have a ‘WMS correct’ view (i.e. single worldview based on WMS);
4 hold a WMS correct and AB religious view (i.e. multiple worldviews: WMS and AB (religious); and
6 hold AB – which includes *everyday* and *personal* beliefs (- while this represents a combination of beliefs, only *one* worldview belief system (i.e. Alternative Beliefs) is displayed by these 6 students.)

TABLE 4.5 : Example:
METHOD 1: Frequency of occurrence of single and multiple worldview concepts

WMS Correct	**10**						
WMS simple							
WMS problem							
AB everyday							
AB personal				**6**			
AB IKS							
AB religious	**4**						
WORLDVIEW CONCEPTION	**WMS correct**	**WMS simple**	**WMS problem**	**AB Everyday**	**AB personal**	**AB IKS**	**AB religious**

(WMS in blue; AB in green and a combination of WMS and AB in yellow)
n = x (blank/I don’t know/unclassifiable: n = y)

While this type of coding was useful in indicating the predominance of different worldviews and combinations of worldviews, it did not allow for the emergence of detailed patterns of knowing. It did not show, for example, what the everyday ideas were, nor did it show the slight variations in understanding or multiple views that were often expressed by individual students. It did not reveal the kinds of explanations that were categorized as ‘IKS’, nor the interesting ‘problem ideas’ of WMS. Consequently, a second method of coding was used, which *would* allow for the emergence of the detail missed by this first method of coding.

Coding Method 2

The second method, also carried out in *Atlas.ti’s* hermeneutic unit, provided the opportunity for capturing the detail and frequency of the students’ ideas (for an example see Appendix 7). This method drew on some of the ideas of Grounded Theory (Glaser and Strauss, 1967; Glaser, 1998; Muhr, 2004) in that themes were allowed to emerge from the data. This was achieved by creating extracts of ideas from the students’ responses, which were later sorted into the appropriate categories.

Extraction of discrete ideas: the 'code statements' (Tier 1)

The first step of processing in Method 2 was the creation of 'code statements' from the responses given by the students. The creation of these code statements was directly guided by the students' wording in their answers. In this way, descriptions of stars such as "burning gas", "exploding gas", "made of gas", "burning ball of gas" and simply, "gas", were all recorded as 'code statements' rather than being immediately listed as representing a worldview position. The creation of these extracts meant that it would be possible to see exactly what the students had written, and to see how many students made reference to each idea. The '*code statements*' were so named because *Atlas.ti* referred to the process undertaken as being the creation of 'codes'. However, these extracts did not represent preconceived codes into which the students' ideas were being slotted. The code statements were simply extracts from the students' written responses, which would be sorted into themes at the next stage of the process.

Sorting into concept codes (Tiers 2 and 3)

Once all the responses in all the pre-instruction questionnaires had been processed into code statements, the code statements for each question were sorted in *Atlas.ti*'s 'network views' facility (for an example see Appendix 8) into ideas based on Western Modern Science (WMS), and those that were not connected with the often abstract and counter-intuitive explanations which are the hallmark of basic astronomy, i.e. alternative beliefs (AB). The code statements were then grouped according to the worldview categories already established by Method 1, i.e. correct, simple and problem ideas in WMS, and everyday, personal, IKS and religious ideas in AB. Table 4.6 serves to clarify the categorization of the responses to the questions in the pre-instruction questionnaire.:

Table 4.6: Categorization of the students' responses to the pre-instruction questionnaire

TIER 3 Worldview concepts	TIER 2 concept codes ('minor' concepts)	TIER 1 code statements (examples from 'what is a star?')
WMS	WMS correct (answer is correct and contains good detailed information)	(a star is a….) "burning ball of gas"
	WMS simple (answer is correct but little descriptive or explanatory detail is given)	(a star is made of…) "gas"
	WMS problem (answer is based on WMS but is wrong in some way)	(a star is a …) "meteor"
AB	AB personal (unique, personal, intuitive description or explanation)	(a star is a…) "small rock"
	AB everyday (common intuitive description or explanation)	(a star…) "appears and shines at night"
	AB religious (alternative beliefs based on religious teaching)	(a star…) "is created by God"
	AB IKS (alternative belief based on culture or tradition)	(a star…) "is our ancestor"

In some cases, the Tier 2 groups were subdivided. For example, in the responses to the question 'what is a star?' the ‘WMS correct’ group was broken down into ‘composition’, ‘location’ and ‘process’. While this sorting brought order to the massive variety of code statements, the detail of the code statements was not lost. In addition, the frequency of reference to code statements was captured. Method 2 thus provided for the emergence of the ‘student voice’ through the frequency of occurrence of code statements: the voice was ‘loud’ when there was a ‘chorus of support’ i.e. many references to a particular issue, and ‘quieter’ when only a few students or individual students mentioned a particular issue or idea.

The example given in Table 4.7 is an extract from Chapter 5 on ‘Ideas about seasons’ This example serves to clarify the coding according to Method 2: It can be seen in this table (highlighted in blue) that there are 15 different Tier 1 code statements for WMS ‘correct ideas: astronomy perspective’. The examples of the code statements provided in the final column show the *three most commonly referred to* of these 15 code statements: ‘revolution’ was mentioned 55 times; ‘Earth moves around the Sun’ 19 times; ‘angle of axis’ was mentioned 10 times. The remaining 12 of the 15 code statements are not listed in the table for the sake of brevity. In each case *usually* only the three most commonly referred to code statements are given. However, occasionally more or less than three examples are given, either if there are for example, only two code statements available in a particular category, or if there are code statements that are particularly interesting - in which case more than three are included.

While it can be seen in Table 4.7 that there were only 15 code statements for ‘WMS correct ideas: astronomy perspective’ the total number of references to these code statement was 120 (see column 4 in Table 4.7). This indicates that there was a commonality of ideas - that many students were giving the same (few) ideas. By way of contrast, the Alternate Beliefs ‘personal ideas’ (highlighted in yellow), shows 14 code statements and 19 occurrences or references: this indicates that there was a great variety of ideas, but only a few were given more than once, and many were mentioned by individual students. (‘time causes the seasons’ was mentioned 5 times, ‘every 3 months the seasons change’ was mentioned twice; ‘different activities cause different seasons was mentioned by only one student, as were the other 11 code statements that were grouped under Alternate Beliefs ‘personal ideas’).

While this process was very valuable in capturing the detail that was unavailable using Method 1, there were also difficulties in the coding, the most important of which are described in the section that follows the table.

TABLE 4.7: METHOD 2

Example: (taken from "Why is it generally colder in winter than it is in summer?")

Tier 3 Concept Category	Tier 2 Concept Category	No. of different Tier 1 code statements	Total number of occur-rences	Examples of the 3 most common code statements in each concept category (number of occurrences for that particular statement given in brackets)
Western Modern Science	Correct ideas: Astronomy perspective	15	120	Revolution (55) Earth moves around the Sun (19); Angle of axis (10)
	Correct ideas: Climatology perspective	18	48	Sun moves between the Tropics (12); Sun moves or migrates North (5); Seasons caused by meteorological conditions (5)
	Simple ideas	18	92	Position of the Earth relative to the Sun (13); Movement of the Earth (10); Earth moves (9)
	Problem ideas: Distance	5	52	Earth close to Sun= summer, far = winter (17); close and far positions relative to the Sun (11); distance away from the Sun (11)
	Problem ideas: Location on orbit	5	7	Seasons are located along the orbit (2); Earth moves into different climatic zones (2); Earth moves into different climatic areas (1)
	Problem ideas: Terminology	6	62	Earth rotates around the Sun (52); Fixed axis rotation around the Sun (3) Rotation around the Sun (2)
WMS TOTAL	**Ideas based on science**	**67**	**381**	
Alternative beliefs	Personal ideas:	14	19	Time causes the seasons (5); Every 3 months the seasons change (2); Different activities cause different seasons (1)
	Everyday ideas	17	61	Seasons are weather related (10); Climate or climatic factors cause the seasons (9); Winter is cold summer is hot (7)
	Ideas based on IKS	6	11	Seasons are for agricultural purposes (5); Seasons are to keep the balance and fairness in nature (2) Sun moves to hide somewhere
	Ideas based on Religion	2	6	God's plan (5); God's command (1)
AB TOTAL	**Ideas which are not based on science**	**39**	**97**	

Difficulties in coding

These included:

1. Deciding on the limits for each Tier 2 category so that a balance could be created between the categories being too broad or too narrow: if too broad, the category would not allow for the emergence of detail such as the various ideas regarding the composition of rocks, if too narrow, meaningful themes would not emerge from the mass of detail. This difficulty was also related to the next one, which was:

2. Choosing an appropriate descriptive phrase for each category that would meaningfully indicate the range of ideas contained in that category. These problems were solved by sometimes adding subcategories to the minor concept codes (Tier 2), such as adding, for the question ‘what is a star?’, the subcategories ‘composition’, ‘location’ and ‘origin, process and function’.

3. Problems related to language: almost all the respondents in the samples were English Second Language (ESL) students, which makes it particularly important that the role of language should be recognized. However, it is beyond the scope of the present study to include a discussion on the role of language in knowledge construction beyond saying that its importance cannot be underestimated (see for example Inglis, 1993; Rollnick, 2000). The students often used an incorrect term in their explanations – the interchangeable use of ‘rotation’ and ‘revolution’ being a case in point. This problem was solved to a certain extent by asking the students to draw diagrams to illustrate what they were trying to explain, following the example of other research done in the field of astronomy education (for example, Baxter, 1989). The problem was also minimized by creating suitable subcategories, for example, in the question ‘why is it generally colder in winter than in summer’ (the question about seasons) a subcategory of ‘WMS Problem Ideas’ was created, called ‘Problem ideas: terminology’.

4. Issues of positionality: an illustration of the difficulties arising in relation to positionality can be seen in the description by one student of the *nuclear* reactions taking place in the Sun as ‘*chemical*’ reactions. From a Geography perspective, the fact that a first year (Foundation) student knew anything at all about reactions taking place in the Sun (which in the context of Geography is related to the idea of radiation, global warming and the hole in the ozone layer) was more important than the error regarding the naming of the kind of reaction. This would, no doubt, be unacceptable in the context of Physical Science.

5. Another issue related to positionality made the allocation of responses to the category “IKS” tentative for me: for example, one student said that an eclipse is caused by the “moon and the Sun passing through each other….every thad (third?) year … is that the moon and Sun meet for passing through each other” (02.COS.10.PRE). Other students wrote that eclipses happen “when the sun meets the moon” (02.COS.17.PRE) and “when the sun and Moon meet” (02.GP.15.PRE).The fact that Student 10 (02.COS.10.PRE) – quoted above) cited his/her grandmother as the source of this knowledge alerted me to the possibility of it representing traditional knowledge, but he/she had also cited television as a source (which may have indicated a television story about eclipses). However, a story in the newspaper (see Appendix 5) that was part of a teaching supplement published in anticipation of the total eclipse of the 4th December 2002, indicated that these ideas did have a cultural origin, and that the use of the word “meet” or “passing through” was intentional and very significant. It is thus likely that someone with personal knowledge or a background in social anthropology would recognize certain statements as belonging to IKS, which here, because of my background, were not identified as such and consequently were not allocated to that category.

6. Issues related to the nature of science: there has been much literature devoted to discussions around the nature of science (for example Zeidler, Walker, Ackett and Simmons, 2002; Lederman, 1992; Pauka *et al*., 2005). The debates centre on the legitimacy of referring to traditional (or ecological or cultural) knowledge as science, as opposed to the a-cultural or universal explanations known as Western Modern Science. In this study, Western Modern Science has been taken to refer to the kind of knowledge taught at school, while alternative beliefs refer to the knowledge that is gained through personal observation or experience, or from social or cultural sources.

Validation of the coding system

Once the categories, or ‘code families’ as they are known in the programme, had been created for each question, they were given to a colleague who is also working in the field of learning in basic astronomy, and an education specialist, for checking. The categorization of students into the different worldview categories was checked and confirmed, as was the allocation of code statements into the various categories (e.g. everyday/ common explanations and personal explanations, compared to explanations based on science or religion or culture). This cross-checking confirmed the categories that were used, but it was necessary to refer on occasion to Mohammad’s advice, that “all knowledges are embedded, situated, specific, and hence partial, with an inevitable bias” (Mohammad, 2001, 103). It is inevitable in educational research, particularly in a multicultural context, that positionality will play a role, and that the analysis may result in a ‘version’ of truth. The critical requirement then is that there should be consistency in the handling of the data. This is where the beauty of using computer software became apparent: while the data were presented as a unit or whole, it was also possible to compare the results for the different samples. This provided a means of verification from the different sample groups, and provided evidence of the reliability and validity of the research instruments and the coding that was used. An example of the breakdown of the results in the different sample groups can be found in Appendix 9.

Summary of advantages of using two methods of coding for the pre-instruction questionnaire:

Method 1 is a deductive approach, with students being allocated to preconceived categories. These categories are presented in the form of a table which indicates the predominance of worldview positions, which are either single worldview positions (WMS *or* AB), or a combination of worldview positions (WMS *and* AB).

Method 2 is more of an inductive approach, where the students’ ideas are first captured as code statements (Tier 1), and then only grouped into concepts at a worldview level (Tiers 2 and 3). Here the results are also presented in the form of a table, which demonstrates the variety of ideas given by the students in response to the pre-instruction questions.

The two methods can be seen to confirm and support each other in that the emergence of the categories in Method 2 supported the categories that were used in Method 1, but that the two different methods yielded different kinds of information. In this way, the analysis of the pre-instruction questionnaire results was enriched.

4.3.3 Coding the data: source of information

The content questions had been set up not only to elicit what the students thought the scientific answers were, and what their personal understandings were for each question - They were also asked to identify the source(s) of this information. It is acknowledged that it cannot be assumed that everything learnt at home or in the community would fit into the category of knowledge based on alternative conceptions, and anything learnt at school or through the media into the category of Western science. However, despite the possibly ambiguous nature of this data, it had the potential to provide some insight into the sources of the different kinds of prior knowledge of the students.

The coding for the ‘source of information’ responses is presented in Table 4.8: All the source of information questions were coded using the system of numbering given in Table 4.6. The results were then tabulated and converted into a pie graph to show the relative importance of each of the different sources of information.

Table 4.8: Coding system for sources of information

Possible source of Western Science conceptions 1. School 1.1 School teachers 1.2 Books (e.g. school text books/encyclopaedias) 2. Media 2.1 television 2.2 newspapers/magazines
Possible source of alternative conceptions (traditional or religious) 3. Family 3.1 parents 3.2 grandparents 3.3 siblings or other family 4. Community (including religious input)/friends 5. Own thinking/reasoning/understanding/observation

4.4 THE POST-INSTRUCTION QUESTIONNAIRE

4.4.1 Evolution of the post-instruction questionnaire

The post-instruction questionnaire underwent a few changes as the study progressed. These changes are summarized in the flow chart provided in Appendix 3, and examples of each of the different questionnaires may be found in Appendix 4. This is common in qualitative research, with Schumacher and McMillan (1993, 385) describing this particular characteristic of qualitative research as “the continual intermeshing of data collection and analysis”. The purpose of the post-instruction questionnaire shifted, as the study progressed, from investigating conceptual change, border crossing and collateral learning, to investigating the barriers to learning with reference to border crossing and collateral learning in association with Barbour's Typology.

In the pilot study (2001), only three questions were added to the six 'content' questions of the pre-instruction questionnaire to create the post-instruction questionnaire. These three questions involved asking the students if there had been anything they found hard to understand; if there had been anything they found hard to believe; and if there had been any replacement of knowledge. In 2002, an enlarged set of questions were asked in addition to the six content questions of the pre-instruction questionnaire. These questions (which are listed on the following page) were to elicit information about whether the students were engaging in border crossing and collateral learning. In addition, a few biographical questions were included, where the students were asked, for example, to identify who their primary care-giver had been when they were growing up, what type of school they had been to, and whether or not they would teach their children traditional as well as scientific explanations for natural phenomena. The purpose of the biographical questions was to try to establish what I had termed their 'cultural distance', an idea that referred to the level or depth of influence of traditional culture on the student. Cultural distancing tends to occur with urbanization and exposure to Western culture because Western science and Western ways of life are viewed as more desirable, and superior, to cultural knowledge (Wiredu, 1980; Addo, 1997; Pauka *et al*., 2005). This results in a lack of interest on the part of younger generations to learn traditional ways and customs, resulting in the gradual loss of this worldview.

Ethnographic research has been described as a 'process', where the generation and reformulation of research questions is encouraged and where there is a concern not only with the product, but also with the actual process of research (Schumacher and McMillan, 1993, 406). Consequently, another change in the 2004 post-instruction questionnaire was the inclusion of *religion* as an option, along with *traditional understandings* and *Western science,* to the question where students were asked what kind of 'understanding or knowledge' they would teach their *own* children. This change was instituted as a result of the students' responses in the first phase of data collection, where it had become clear that religion was an important issue in terms of border crossing.

It has also been pointed out that ethnographic research is very difficult to do well: this stems from the fact that it is subjective and highly dependent on the researcher's skills (Fraenkel and Wallen, 1990). Consequently, while the decision to work ethnographically allows for a more flexible frame in which to work, it may mean that the research seems 'messy', 'uncoordinated' and 'unproductive' (Parr, 2001), with the researcher wondering if the method chosen will reveal anything of value. The most important questions in the post-instruction questionnaire were those which sought to elicit evidence of collateral learning and border crossing. These questions were difficult to phrase, and while they were discussed with several colleagues to try to ensure that they were unambiguous and clear, they remained rather ‘messy’. These questions (as used in 2004) are listed below, with the specific purpose of each question given in brackets in italics:

1. Was there anything in the Earth in Space course that you found <u>hard to understand?</u> Please explain your answer by telling me what and why. (- to provide insight into the student’s ease of construction, related to their worldview and prior knowledge)

2. Did any of the things you were taught conflict with ideas or beliefs you already had before you started the course? Was there anything that you learnt about in the Earth in Space course that you found <u>hard to believe</u>? Please explain why. (- *to provide insight into worldview/traditional thinking/epistemology in relation to border crossing*)

3. Did any of your ideas change as a result of the course? Please explain what changed and why. (In 2002 this was phrased: “Was there anything that you learnt about in the Earth in Space course that <u>replaced</u> any understanding or belief that you had of natural phenomena before you did the course?”) (- *to provide insight into collateral learning and border crossing)*

4. Do you think the science that is taught in the Earth in Space course (e.g. Big Bang theory, Nebula theory, Plate Tectonic theory) is the real truth about natural phenomena and how the world and the Universe works? (- *to provide insight in terms of the student’s epistemology*)

5. Do you think that the scientific explanations taught in the Earth in Space course are true for all situations and for all people or do you think that there are other explanations that are also valid or useful or true? Please answer as fully as you can (- *to provide insight in terms of collateral learning and the student’s epistemology*)

6. Did you find that any of the things you learnt about in the Earth in Space course suddenly made something that you had either
previously wondered about –
maybe not understood before –
maybe not thought about before –
become more clear to you or suddenly make sense to you? Please explain and if possible give an example. (- *insight into simultaneous collateral learning*)

These questions, unlike the simple content questions, had been very difficult to formulate. The issue was how to try to find out whether the students had different ways of thinking without directly asking them. Consequently, some of the questions, particularly question 5, could be seen as “leading” questions. Jegede (1997) did not explain why he said collateral learning was difficult to confirm, but part of this difficulty could be related to the problem of being able to establish its use without direct questioning.

The biographical questions (which were mainly tick-box in format) were as follows:

7. While you were growing up, who was your primary caregiver?

Parents	Grandparents	Other (state)

8. How would you describe the type of school(s) you attended while growing up?

Urban	Township	Country	Other (state)

9. Who are the people who most influence the way that you think?

Parents	Other family	Friends	Teachers	Other (state)

10. Does your family think it is important to follow traditional customs (eg marriage, coming of age ceremonies etc) (Tick your choice)

Yes	No

11. When you have children, will you teach them traditional/religious/scientific explanations for natural phenomena? (Tick those appropriate to you) Please explain your choice.

Traditional	Religious	Scientific	Not sure

……………………………………………………………………………………………………

……………………………………………………………………………………………………...

4.4.2 The use of diagrams in explaining concepts in basic astronomy

In Phase 1, none of the students had made use of a diagram to complement or support their answers in either of the questionnaires. This may have been because they were not asked to use diagrams, or because the layout of the questionnaire had not been conducive to this. Consequently, in both the pre- and post-instruction questionnaires of 2002 and 2004, space was specifically included for diagrams, and the students were explicitly invited to include diagrams in their answers to the content questions. Despite this, only a few students included diagrams in their responses.

Consequently, in Phase 2, a question specifically dealing with the drawing of a diagram was included in response to international research (for example Baxter, 1989; Sharp, 1996). The diagram was purported to allow insight into the students' concept of gravity, and their understanding of the relative spatial location of the Sun, Moon and stars. The diagram involved asking the students to draw (very simply) the Earth in space, with 'stick' people standing on it at the 4 points of the compass; to indicate the position of the atmosphere; and to draw in the relative positions of Sun, Moon and stars. It was anticipated that these diagrams would be useful in revealing conceptualizations that may not be available through written descriptions, and that the diagrams would indicate the level of development of each student's 'Earth concept' (Nussbaum and Novak, 1976). However, subsequent research (for example Schoultz *et al*. 2001 and Trundle *et al*. 2002), of which I only became aware after the collection of the data in 2004, has argued that many of the conclusions drawn from research based on diagrams are, in fact, a consequence of the two-dimensional nature of such diagrams, and that when three dimensional models are used in conjunction with diagrams, the misconceptions turn out to be a consequence of the methodology of the data collection, as the misconceptions 'disappear' with the use of the models. When I tested this informally on a small class of pre-service teachers in 2005, pencil and paper tests showed a lack of gravitational understanding by several students, but when they were asked to explain the same concepts with the use of a model, the 'misconceptions' disappeared. As a result, it was decided to omit the data from this specific question (involving the 'formal' drawing of a diagram) from the present report.

However, the diagrams that the students used to supplement their explanations to the six content questions were often very helpful in clarifying the description given by the students, and some of these have been included in the results.

4.4.3. Administration of the post-instruction questionnaire

The post-instruction questionnaire was given to the sample groups several months after completion of the course. Difficulties in administration meant that in Phase 1, only data from the 2002 College of Science sample could be used for the establishment of conceptual change from a comparison of the six content questions from the pre- and post-instruction questionnaires. They were the only group for whom a sufficiently long lag time could be arranged before completing the post-instruction questionnaire, after the pressure of examinations on this topic was over.

In Phase 2, administrative difficulties with the Geology mainstream students (the biggest sample) also prevented the collection of post-instruction data in terms of the content questions. Time constraints meant that the students would not be able to complete the whole post-instruction questionnaire, so the decision was taken to direct the 2004 groups to concentrate on the additional questions related to barriers to learning, as these were more important for the purposes of this study. This decision was facilitated by the fact that conceptual change had already been established – on paper at least – with the results from the 2002 College of Science group (presented in Table 5.2.1 in the results), a finding which was in accordance with Bishop's (1996) view that students need to be developmentally ready to understand the abstract explanations of Astronomy, and that learning in this field can only be acquired through explicit teaching (Mali and Howe, 1979; Parker and Heywood, 1998; Trumper, 2001; Kelfkens and Lelliott, 2006). The conceptual change that had been shown in this early analysis of the data is possibly due to Astronomy being taught at school (if it is taught at all) before students are developmentally ready for it.

The post-instruction questionnaire was introduced by reminding the students of the pre-instruction questionnaire they had already completed. I explained that the current questionnaire was also part of my ongoing research into learning and that their response would be helpful in terms of future cohorts of students. After handing out the questionnaires and asking them to again write the names of their mother and father on the first page, and not their own, as they had done for the pre-instruction questionnaire, I read through the questions with them. I especially wanted to highlight the distinction between what they had found difficult to *understand* and what they had found difficult to *believe*. A 45-minute period had been set aside for the College of Science and Geography Foundation groups, but less time was available for the Geology mainstream group as I had not taught them the course, and had to negotiate time with the lecturer concerned. However, the students were very co-operative, and most handed in detailed responses, despite the fact that some of them were unable to finish the questionnaire.

4.4.4 Coding the data

4.4.3.1 Phase 1

As noted, the analysis to establish conceptual change was done using the data from the 2002 College of Science group (n =20) after the first round of data collection. The responses to the post-instruction 'content' questions (i.e. 'What is a star?', 'What happens to the stars in the day time?' etc) were coded using the same coding system as for the Phase 1 pre-instruction content questions, in order that there should be consistency in the interpretation of the responses (Lindsay, 1997). Each response was thus judged according to whether it was based on Western Modern Science (WMS), or whether it was an 'alternative conception'. If it was based on WMS, it was classified according to whether it was 'correct', 'partially correct' or a 'misconception'. The results for the pre-instruction questionnaire were then tabulated with the results for the post-instruction questionnaire. This enabled a comparison of the pre- and post-responses to the questions, making it possible to see if the students had maintained or changed their ideas.

4.4.3.1 Phase 2

As noted, after the second phase of data gathering, the focus of the study shifted to an interest in what the students had found difficult to understand and believe, and why. The 11 questions that were used for the analysis of collateral learning and border crossing comprised two different types of questions: those that probed barriers to learning in terms of knowledge construction and epistemology (Questions 1 to 6 from the second section of the questionnaire) and those that were biographical (Question 7 to 11)

These two different types of questions were handled differently: Questions 7 to 10, because they only required the ticking of response boxes, were simply tallied and tabulated. Questions 1 to 6, and the second part of Question 11, were more complex. They were coded using the two methods described for the pre-instruction questions in section

4.3on: Method 1 was used to record the numbers of students who responded in particular ways to selected criteria, while Method 2 provided for the recording of the detail of the students' responses through the use of 'code statements'. These code statements were grouped, where applicable, under 'Issues related to content', 'Issues related to epistemology' and 'Issues related to learning', with examples of the various code statements in each group, for each question. The relative frequency of the code statements was then presented as a pie chart, providing a visual overview of the relative weight of the different responses. As with the pre-instruction coding, all the responses to Questions 1 to 11 (from both phases of data collection) were coded using *Atlas.ti*.

The results and analysis of these post-instruction questions are presented as 'reflections' on issues of learning in the following way:

Reflections on understanding: Question 1
Reflections on believing: Question 2
Reflections on border crossing and collateral learning with reference to the typologies presented in the theoretical framework: Questions 3, 4, 5 and 6
Reflections on influences on learning: Questions 7, 8, 9 and 10
Reflection on values: Question 11

4.5 THE INTERVIEWS

In order to enhance the credibility of any research, it is important that data should be collected in multiple ways – a strategy called 'triangulation'. Here the responses to the questionnaires formed a 'stand alone' set of data, but also provided the basis from which to develop questions for the interviews. The data from both questionnaires and interviews would be used to develop what Geertz (1975) described as a 'thick description' - one of the tactics used in qualitative research to enhance the credibility of the data (Atkinson and Hammersley, 1994).

All the students who were interviewed during Phase 1 were volunteers from the 2002 College of Science sample, while those in the second round (2004, Phase 2) were volunteers from both the College of Science and the Geography Foundation classes. Since I did not teach the Geology mainstream students, access to these students was limited, and because of the timing of their course, and the completion of the post-instruction questionnaire very close to the end of the year, they were not invited to volunteer to be interviewed.

4.5.1 Setting up the interviews

Once the post-instruction questionnaire had been completed by the Geography and College of Science students, they were invited to volunteer to be interviewed about their responses. They were again informed that the purpose of the research was for me to gain an insight into learning and that the hope was that this would be of benefit to future cohorts of students. The response from the students in these classes was encouraging. They almost all wanted to be interviewed.

The selection of interviewees turned out to be somewhat randomized as it was based on the mutual availability of time. Unfortunately, time constraints meant that only nine students from the 2002 College of Science sample and ten and six students respectively from the 2004 College of Science and Geography samples were actually interviewed, before the time got too close to their final exams and interviews had to stop. This timing situation was unavoidable, as I only wanted the interviews to take place after I had had time to build a relationship with the students, in order to try to minimize the problem of positionality (explained in Chapter 3). By the time the students came for the interviews, I had taught them several courses and had been on field trips with them. Limiting the interviews to taking place towards the end of the year was inevitable because of the time lag required before administering the post-instruction questionnaire, but it also allowed for the development of a level of trust, which I hoped would translate into a greater freedom and honesty in the students' responses in the interviews. In all, 25 interviews were conducted.

4.5.2 Preparing for the interviews

Cohen and Manion (1994) describe a particular type of interview where the distinctive feature is that it focuses on the interviewee's responses to a known situation. This is the so-called "focused interview", which grew out of the 'non-directive' or 'informal' type of interview. Merton and Kendall (1946) modified the focused interview from its original 'therapeutic' form, to make it more suitable for use in research in Science Education. They identified four aspects, which they claimed make this type of interview unique:

1. The persons to be interviewed are known to have been involved in a particular situation.
2. The researcher analyzes the content of the situation in 1 above and constructs a set of questions relating to the meaning and effects of this situation.
3. Using the analysis as a basis, the interviewer constructs an interview guide which determines the relevant data to be gathered in the interview.
4. The actual interview is based on the subjective experiences of the respondent.

These four aspects made this type of interview seem appropriate to this study: in terms of the first aspect, most of the students had completed the pre- and post- instruction questionnaires (in a few cases, students had completed one and not the other as a result of absence during the administration of the questionnaires), and had been through the "Earth in Space' course.

The second and third aspects listed by Merton and Kendall were met as follows: the students who had volunteered to be interviewed made an appointment with me to identify their pre- and post-instruction questionnaires, which meant that each interview could be specifically tailored to the individual student, thus meeting the last of Merton and Kendall's criteria.

It has been explained that only the 2002 College of Science sample was used for a formal investigation of conceptual change. However, in preparation for the interviews, an analysis of the answers in the content section of both questionnaires for each interviewee also gave me some insight into possible conceptual changes that had occurred for those particular students. An examination of all their answers to both questionnaires allowed me to formulate questions around those changes, and especially around the comments they made in Section 2 regarding the barriers to learning.

While the interview guide contained some questions which were common to all the interviewees, each interview guide was composed of unstructured questions so that the students had ‘free rein to answer in any way they chose’ (Tuckman in Cohen and Manion, 1994). Most of these unstructured questions were individually tailored according to the responses the student had given. The prepared questions were followed by probes such as 'can you tell me more… ' or 'can you explain that in a bit more detail…' to try to elicit as much information about the student’s thinking or understanding as possible.

The questions about the difficulties students had had with the course proved to be very fruitful in the formulation of interview questions, despite my original misgivings about how these questions had been worded. One of the most helpful questions, and one which provoked a lot of insight, was the question regarding what the students would teach their own children. The basic schedule which guided the interviews can be found in Appendix 11. Something which proved helpful during this time was the fact that I had undergone training in interviewing prior to doing the actual interviews. This training had made use of a micro-teaching facility, where ‘practice interviews’ were video-taped and critiqued. However, there is no doubt that good interviewing is a skill which can be developed with practice.

4.5.3. Ethics

It has become University research policy, particularly with regard to research involving people, that ethics procedures need to be carefully followed. This involves scrutiny of the research proposal and research instruments by the University Ethics Committee. The relevant documents were submitted when this policy was introduced during the course of 2003 and clearance was gained for the second round of data collection in 2004 (see Appendix 10). One of the biggest concerns in terms of ethics is confidentiality, and the steps taken to protect the identities of the respondents are outlined in the relevant sections that follow.

4.5.4 Conducting the interviews

The students had been informed, prior to choosing to come for an interview, that the interview would be audio-taped and transcribed, and that they would be given the transcription to verify. It was explained to them that this was important in preventing misrepresentation (Dowler, 2001). It was also explained to them that the interviews would take place in my office, and that they would be on an individual basis. Because I was involved in teaching the students over this period of time, it was reasonably easy to be able to arrange times for the interviews.

On arrival for the interview, the student was again informed of the purpose of the interview and asked if they had any questions. They were given a demonstration of how the tape-recorder worked and asked to read a small introductory portion from the questionnaire, which was then played back to them, so that they could hear what they sounded like on the tape. We then proceeded with the interview, most of which were between 50 minutes and an hour long.

Each interview was transcribed as soon as possible so that its content would still be relatively fresh in the mind of the student. As soon as the transcription had been completed, a copy was made for the student, which they took away and read, and then returned. It was again made clear to them that the transcriptions and the contents of their questionnaires were confidential and would only be used for the purposes of my research. The students had been invited to add in any more comments they might like to make before handing the transcription back, and in a few cases were asked to fill in words that had not been clear on the audio-tape. Several of the students did add in more comment, and some asked for copies of their transcript to keep.

The interviews were very interesting, not only because of what the students had to say, but because it was clear that they were very keen to have their voice heard. Most hardly had to be encouraged to talk, and some, in answering the questions, ventured into personal territory that they asked should be omitted from the transcripts. This was done. Several came back to ask me about my research and several commented on how much they had enjoyed having the chance to talk about their ideas. One student added in the following comment on the transcription which was returned to me, which I found touching and encouraging:

> "My last comment. I would like to wish you a good luck for your research. It been so great to me, I mean I learn a lot from it. I think this is the best way of increasing our understanding in terms of, are we learning to pass at the end of the day, or to increase to what other scientists have. So Ma'am, keep it up for the good job you are doing"

4.5.6 Analyzing the interviews

The data obtained from the interviews indicated that many of the difficulties in border crossing could be related to prior beliefs based on indigenous culture, which in this study, comprised IKS and ATR on the one hand, and imported, but indigenized religions, Christianity and Islam, on the other. The interview data thus supported the data obtained from the questionnaires, but was far richer. The analysis of the pre- and post-instruction questionnaires had led to the creation of tables which indicated how *many* of the students in the sample were affected by issues such as poor background knowledge in science, as well as the difficulties experienced by the students in dealing with conflicts that arose when the content of the course was seen to be threatening to religious or cultural beliefs.

The purpose of the interviews was to ‘flesh out’ the difficulties that had been alluded to in the questionnaires. The interviews were to provide a space which would allow for the voice of the students to be heard, where they were not constrained by time, or by having to write down their ideas. The data obtained are presented in the form of vignettes (character sketches), following a suggestion made for research in this field by members of the international Joint Research Project on the ‘Effects of Traditional Cosmology on Science Education’ at their meeting in Mito, Japan, in 1996[13]. The term 'vignette', as it is used in social research, refers to a method of data collection in which respondents are asked to respond to stories which make reference to particular points (Finch, 1987; Hughes, 1998). In the more general sense of the term, a vignette is used as a character sketch which gives a portrayal of a particular situation or event. Marshall and Rossman (1989), in their book, 'Designing Qualitative Research', use this technique for describing or demonstrating the different methods of research that they present. Similarly, in the cases presented here, a vignette has been interpreted as a 'consolidated' character sketch or portrait, in that more than one student has been drawn on to make up the 'sketch'.

A criticism which has been leveled at the use of portraits, and which has relevance to the vignettes presented here, is that there can be no way for the reader to "unmake the omelet (portrait) once it is cooked (constructed); what remains shrouded in portraiture is the politics of vision, that is, the uncontested right of the portraitist researcher to situate, centre, label, and fix in the tinctured hues of verbal descriptive prose what is professed to be "real". (English, 2000). A response to this criticism is to make as much room for the 'voices' of the respondents as possible. Consequently, the vignettes contain substantial, unedited extracts from the interviews, rather than small selections which would be more susceptible to English's criticism. In addition, the vignettes do not claim to present a 'whole truth': their function is to provide a sketch of the most important issues to have arisen in relation to the impact of culture on learning, where data from the interviews has been supported by data from the questionnaires. The vignettes thus serve not only as a means of triangulation[14] - they serve to ‘flesh out’ the findings of the pre- and post-instruction questionnaires which were limited, by their nature, in terms of the data they were able to capture.

Three vignettes are presented, where the best examples from the interviews have been selected to illustrate the issues involved in border crossing. The first vignette focuses on difficulties in border crossing in relation to traditional culture, while the second focuses on difficulties in relation to religious beliefs. Where possible, some background information is given of the students whose quotes were selected from the interview transcripts, in order

[13] (http://www.ouhk.hk/cridal/misc/report.htm accessed 2002.

[14] Triangulation refers to "using more than one source of data to confirm the authenticity of each source" (O'Leary, 2004, 115)

to give a personal context to the ‘voice’. The third vignette does not focus on epistemological difficulties, but rather on the attitude of a special group of students in this sample who were dubbed ‘fighters’.

'Fighters' was a special brand of the ‘I don’t know: disadvantaged’ students category that I had created to align Costa's typology with a special type of student encountered in the sample: while their life-world was discordant and incongruent in relation to science, and their background in science was very weak, they were absolutely determined to succeed. They put in extra time with reading, questioned what they had done wrong in assignments and made appointments for extra ‘lessons’. Despite the fact that they might not find science (or more specifically the Earth in Space course) personally meaningful at this stage, they were determined to try to make it meaningful in order to succeed at university. Most were the first members of their family, and sometimes their community, to succeed in getting accepted into university. They knew very little about basic astronomy when they began the course, but they were absolutely determined to ‘learn’ and to pass. Their attitude was admirable and humbling as an example of determined border crossing.

4.6 CONCLUSION TO CHAPTER 4

Chapter 4 has presented the background to the choice of a research paradigm for this study, and has given the details of the research instruments that were used, the methods of collection of the data, and the composition of the research sample. The methods of coding have been explained, as have the methods of presentation of the results and analysis of the data.

Chapter 5 presents the results and analysis of the data in three sections: the first deals with the pre-instruction questionnaire, the second with the post-instruction questionnaire, and the third with the interviews.

CHAPTER 5

RESULTS AND ANALYSIS

CHAPTER 5

5.1 THE PRE-INSTRUCTION QUESTIONNAIRE: PRIOR KNOWLEDGE

5.1.1 INTRODUCTION

The purpose of the pre-instruction questionnaire was to record the prior knowledge of the students with regard to some of the fundamental concepts of basic astronomy, such as rotation and revolution and dimensions in space. The science education literature that had shaped my understanding on issues around the construction of scientific knowledge by people from traditional cultures had led to the expectation that many of the students in the sample would respond to questions such as ‘what is a star?’ and ‘what causes day and night?’ by referring to alternative beliefs based on Indigenous Knowledge Systems (IKS). The answers given by the students could then be taken an indication of whether there were indeed different worldviews held by the students. The intention was to gain an insight into the nature of the students’ knowledge before they started the course, and to establish the extent to which they held alternative beliefs, which could be acting as a barrier to learning in this field, in comparison ideas that were consonant with the explanations of Western science.

The questionnaire involved six simply phrased questions to gain insight into the students’ worldview. These were

- ‘**what is a star**?’ and ‘**what happens to stars in the daytime**?’ to gain an insight into their concepts of stars;
- ‘**what causes day and night**?’ and ‘**why is it generally colder in winter than in summer**?’, to see how well students understood the concepts ‘rotation’ and ‘revolution’;
- ‘**why does the Moon appear to change its shape in the course of a month?**’ to establish their understanding of Moon phases and the operation of the Earth-Moon system;
- ‘**what is the Universe**?’ to gain an insight into their knowledge and understanding of the nature and dimensions of space. (This question was introduced in 2004 to replace an earlier question about eclipses, which, because of the eclipses that had occurred at that time, had been relevant in the 2001/2002 data collection phase.)

In the presentation of the results, each question is be introduced by giving some background information regarding the choice of the question. This introduction will be followed by the results and analysis of each question using the two methods of coding described in Section 4. The results are provided in the form of two tables: the first, following Method 1 coding, shows the number of students whose ideas are based on science, compared to those with alternative beliefs rooted in a socio-cultural worldview. The second table, (Method 2) provides the frequency of reference to particular ideas, providing the detail of the students' prior knowledge. The tables are followed by a discussion of the findings. The chapter concludes with a table showing an overview of the responses to the six questions.

5.1.2 RESULTS AND ANALYSIS OF THE CONTENT QUESTIONS

5.1.2.1 IDEAS ABOUT STARS

Stars are familiar to all of us as part of our everyday experience. For the ancient Greeks, they were the epitome of unchanging perfection and therefore the domain of the gods. In many cultures, the appearance or disappearance of particular heavenly bodies were - and in some contexts, still are - used to mark important ceremonies or the beginning of annual events. In many sub-Saharan cultures, for example, the appearance of the Pleiades heralds the beginning of the ploughing season (Snedegar, 1995). In addition to their importance and mystery in tradition and culture, the 'heavens' also represent the context of some of the most important advances in modern science, and consequently in modern thinking and living. Questions about stars thus had the potential, in this study, to draw on different forms of knowledge.

Basic astronomy is part of the school curriculum, but other than to pass exams, for many people the abstract and counter-intuitive explanations that science provides does not have deep relevance or significance in their lives, and they do not need to know 'how they work'. This is in contrast to some of the cultural or folklore knowledge related to stars, which can be deeply personal. The questions "what is a star?" and "what happens to the stars in the daytime?" were selected to provide an indication of 'base' knowledge, providing a window through which to glimpse the worldview of the student through recording their prior knowledge about the everyday, immutable phenomenon of stars – brilliantly present in the night sky, absent during the day.

Because the focus of the research was to investigate how different worldviews could affect border crossing and the learning of science in the field of basic astronomy, the questions that were asked in the pre-instruction questionnaire were intended to 'benchmark' the students' responses to a few questions about everyday phenomena, against the definitions of Western science. For the first question, i.e. "what is a star?", the simple scientific explanation is that a star is a burning ball of gas, radiating heat and light as a result of internal nuclear reactions which commonly involve the conversion of hydrogen to helium. The questions were phrased very simply in order to invite as wide a response as possible: they did not, for example, ask for students to specifically comment about the composition or size or location of stars. However, the students *were* asked to distinguish between what they thought may be the scientific answer as well as any other explanations they had or may have heard of, and what the source(s) of that information might be. All the answers that are drawn from the questionnaires to be used as examples in the analysis and discussion are quoted verbatim, including spelling and grammatical errors.

Many of the students gave fairly detailed answers to the questions. As noted in section 4.3, the criteria used for categorization started with the following question: *Did the response refer at all to the concepts or explanations of Western science?* If so, was the explanation correct, but more importantly, was it clearly based on the kind of science taught at school? If there was evidence to support this, the response would be categorized as being part of the 'WMS' worldview, either as a **correct** conception (for example, 'a burning ball of gas', with the possible addition of information such as hydrogen being converted to helium); a **simple** description (for example a 'body' or 'object found in space'); or as a **problem** idea (for example a star being described as a planet or meteor). If the response was *not* based on WMS, it was recorded as an 'alternative belief' (AB). Here common or everyday descriptions (for example that stars appear and shine at night and disappear during the day) were distinguished from more personal explanations (for example that a star was a rock in the sky, reflecting the light of the Sun). If the response made clear reference to a religious perspective, or there was an indication that it drew on traditional beliefs, it would be categorized as AB 'religious' or AB 'IKS'.

While I felt reasonably confident in distinguishing responses based on science from those that were not, it was sometimes difficult to decide where to assign a particular response at the Tier 2 level. As a result, the advice was sought of two educational experts with whom I discussed the categories, and who checked them and the allocation of statement codes. Despite this precaution, it is recognized that the allocation of responses remains a subjective process, and one that is dependent on the knowledge of the researcher. As noted in the positionality statement, this is especially true in terms of responses that are potentially part of traditional understandings or IKS. Clearly future research in this area would be strengthened if it could be collaborative, with participation by as many of the different cultural groups in South Africa as possible.

5.1.2.1.1 "WHAT IS A STAR?"

The first of the two questions to be used to examine 'Ideas about stars' was "What is a star?". Table 5.1 provides the results of Method 1, i.e. the frequency of occurrence of Tier 3 (worldview) concepts, and Table 5.2 provides the results of Method 2, i.e. the concept categories with the number of code statements in each category, the frequency of occurrence of each of these code statements, and some examples of the code statements.

TABLE 5.1 “What is a star?” METHOD 1

WMS Correct	**34**						
WMS simple		**17**					
WMS problem			**17**				
AB everyday		**19**	**15**	**29**			
AB personal			**6**		**27**		
AB IKS		**5**		**3**		**2**	
AB religious	**2**		**2**	**2**	**1**		**0**
WORLDVIEW CONCEPTION	**WMS correct**	**WMS simple**	**WMS problem**	**AB Everyday**	**AB personal**	**AB IKS**	**AB religious**

(WMS in blue; AB in yellow and a combination of WMS and AB in green)

n = 191

(blank/I don’t know/unclassifiable: n = 10)

Students who showed evidence of one form of knowledge only:

Students who presented a WMS understanding only: (34+17+17) = 68 (36%)

Students whose knowledge was not based on WMS: (29+27+2+3+2+1) = 64 (34%)

Students who showed evidence of more than one form of knowledge:

Combination of alternative beliefs and science: (2+19+5+15+6+2) = 49 (26%)

Total students with at least some science in their explanation: (68+49) = 117 (61%)

Total number of students who referred to religion: 7 (4%)

Total number of students who referred to IKS: 10 (5%)

One of the striking findings from Table 5.1, in the light of all the students having passed matric, is that 64 of the students *only* gave answers based on alternative beliefs. This is almost as many as the 68 who only gave a WMS explanation. When the number of students who gave WMS answers (68) is added to those who gave a combination of WMS and AB (49 students), the total number of students who made some reference to science is 117. However, the group of 34 students who gave a *correct* WMS explanation represents only 18% of the sample, compared to the 61% (117 students) who indicated *some* knowledge of science. These results are not unusual in terms of the wider body of international research that has investigated both students’ and teachers’ conceptions of astronomical phenomena, and where a predominance of alternative conceptions has been found to be the norm, even in First World countries (e.g. Finegold and Pundak, 1991; Sharp, 1996; Parker and Heywood, 1998; Trumper 2000).

TABLE 5.2: "What is a star?" METHOD 2

Tier 3 Concept Category	Tier 2 Concept Category	No. of different Tier 1 code statements	Total number of occur-rences	Examples of the 3 most common code statements in each concept category (number of occurrences for each statement in brackets)
Western Modern Science	Correct ideas: Composition	10	66	Burning ball of gas (19); Made of gas (14); Burning gas (7)
	Correct ideas : Location	18	82	Stars are far/distant (25); In space (13); Centre of planetary system (8)
	Correct Ideas: Origin, process and function	24	144	Big Bang theory (36); Star is a Sun (27); Emits light and energy (26)
	Simple ideas	13	31	Star is a body (6); Star floats around in the Universe (5); Star is an object (4)
	Problem ideas	22	69	Star is a small planet (40); Stars are comets (4); Stars are asteroids (2)
WMS TOTAL	**Ideas based on science**	**87**	**422**	
Alternative beliefs	Personal ideas: Composition	17	44	Star is a rock (34); Fragments of planets (2); Star is solid material (2)
	Personal ideas: Location	4	24	In the sky (20); In the atmosphere (3); outside the atmosphere (1)
	Personal ideas: Origin, process and/or function	10	30	Stars reflect the light of the Sun (18); Stars shine on other planets (3); Stars shine with energy from the Sun (2)
	Personal ideas: Shape	3	9	Body with sharp endings (7); Star shaped object (1); Heavy round globe (1)
	Personal ideas: Size	8	20	Stars are very small (8); Stars are little objects (4); Small celestial bodies (3)
	Everyday ideas	29	198	Stars disappear or are invisible during the day (66); Visible at night (27) Shine at night (25)
	Ideas based on IKS	27	37	Stars are people (6); Spirit or soul of the ancestors (2); Stars are broken bits of the Sun (2);
	Ideas based on Religion	7	20	Stars are God's creation (9); Stars were created long ago (2); Stars protect the sky against Satan (1)
AB TOTAL	**Ideas not based on science**	**105**	**382**	

Table 5.2 shows the 'student voice'. Here it can be seen that answers based on science were a little more frequently given than those based on alternate beliefs (422 'mentions' for science compared to 382 for alternative beliefs). It can also be seen that alternative beliefs based on everyday and personal observations were far more prevalent than beliefs based on IKS (71 code statements compared to 27), a finding shared by Anamuah-Mensah (1998) in his study of beliefs among Ghanaian students. In his study, Anamuah-Mensah explained the dearth of beliefs linked to IKS by saying "the students seemed to have developed some non-native science beliefs (that are probably scientific) which made them reject the majority of native science beliefs" (*Ibid*., 120).

One of the ideas that was frequently mentioned, that was here categorized as a personal belief rather than an everyday understanding or IKS, was that stars were understood to be rocks: 34 students stated that ‘stars are rocks’, variously describing them as space rocks/crystal rocks/pieces of rock/shiny stones/millions of little rocks. There did not appear to be any link to African traditional stories or explanations, and one of the students who was of Portuguese extraction also explained his view of stars as rocks during one of the classes.

African folklore, however, is rich in terms of celestial phenomena, and the fact that out of a sample of 191, only 10 students gave answers that could be linked with IKS is probably an indication of the powerful effect of positionality, as well as the students’ perceptions of what was expected of them in answering a questionnaire in the context of a university course. This explanation for the lack of IKS-linked explanations in the questionnaires is borne out to a certain extent by information shared during the interviews: the students explained that they did not want to give "wrong answers" in the questionnaire. However, in the one-on-one environment of the interviews, the students were enabled to feel more comfortable about expressing their cultural and religious beliefs. Consequently, far more IKS-rich information was forthcoming during the interviews.

Despite the dearth of IKS-related answers in the questionnaire, two main ideas emerged in terms of the stars and IKS: the first was the link with the ancestors: the stars were referred to as ‘dead people’; ‘people who had died long ago’; ‘ancient warriors’; ‘ancestors’; and ‘light of the ancestors’, whose task it was to ‘look after’ or ‘watch over us’ at night, as explained in the following response:

> “Stars are ancient warriors and also people who have died and no space for them in heaven. They choose to look after their family from the sky instead of living in the clouds” (02.G.5.PRE).

The second idea was linked to climatology: that the stars were linked to different seasons, an idea consonant with revolution, and that it was possible to use them for weather prediction:

> “A star is a element thing of a planet that brings light at night that can also help to predict the weather stability of the following day” (04.G.5.PRE)

These cultural associations, while valuable and interesting in their own right as a way of knowing, were also useful as a guide for identifying conceptual difficulties in terms of Nussbaum and Novak’s (1976) ‘Earth concept’. Lemmer *et al*. (2003), drawing on literature regarding the worldview of the ancient Greeks, described the African Earth concept as ‘organistic’, in which the Earth is viewed from an animist perspective in terms of its process and functioning, and where observation is guided by teleology and causality. Animism refers to the world being perceived as a living being, an idea that finds resonance with the Gaia concept of John Lovelock. It has been established (Albanese *et al*. 1997) that without exposure to a mechanistic worldview, it is not possible to progress through to the highest of Nussbaum and Novak's levels of development. In their responses to the question 'what is a star?' the students indicated that the WMS concepts were foreign to many of them, and the image created by some of the students was reminiscent of the ancient Greek conception of the sky forming a dome, like an inverted bowl, over the Earth. However, instead of the dome being full of little holes through which the Sunlight falls as in the Greek conception, the students indicated that the dome was 'sprinkled' with little sparkling rocks, shining as a result of reflected light from the Sun. This image was never ascribed to grandparents or elders which would have helped to link it to IKS, but rather the source as given as 'my idea' or 'my own thinking', indicating typical development of the 'Earth concept'. This Notion II idea represents a stage between the flat Earth concept of young children and the cosmic concept which can only develop with teaching. However, Lemmer *et al*. (2003) do refer to a Motswana belief that

> "… the sky is a perforated sheet called the blue. In daytime, the sun travels below the sheet. At night it travels above it and the sunlight shining through the holes are perceived as stars" (*Ibid*., 568).

None of the students in the sample made reference to the idea of a sheet, but it would seem that even if the students knew of 'other explanations' of this kind, they were more comfortable with simply providing descriptions of a very general nature, such as that 'stars are shining/sparkling/glowing/bright objects that appear at night and disappear during the day'. However, the African traditional worldview was apparent in the teleological and anthropomorphic nature of responses such as:

> "When the sun die stars are born and replace it with the little light during the night" (04.G.9.PRE),

and

> "I think when there's light there's no use for them, they withdraw themselves, I think its actually a process they know when its time they are needed" (04.MS.43.PRE).

The organistic picture painted by many of the students is typical of Nussbaum and Novak's second level Earth concept, where the notion of unlimited space is lacking, and the sky is the limit to the space above the Earth. For example, the idea of a ceiling is inherent in the following:

> "The stars operate similarly to light bulbs, they turn on during the night and off during the day" (02.COS.11.PRE).

The standard scientific description of a star being a 'burning ball of gas' was only given by 19 students (i.e. 10% of the sample). The scientific conceptions that were the most commonly referred to were the Sun being a star, the association of stars with the Big Bang theory and the fact that stars emit light. All of these are standard text book responses. However, the 34 students who gave the correct WMS explanation did not include any alternative ideas, indicating that they held a WMS worldview only - although two of these students added that the stars were created by God. The most common problem in terms of WMS conceptions was the confusion of stars with planets, and to a lesser extent other celestial bodies. This is possibly linked to a theoretical understanding that there is a distinction between planets and stars which is not borne out through naked eye observations.

While 49 students were recorded as having a combination of WMS and AB, most provided a combination of simple or incorrect WMS conceptions and everyday or personal ideas. There were only five students whose ideas reflected two worldviews, as indicated in the extracts below, where 1.1 is the 'scientific answer'; 1.2 the source of this information; 1.3 the 'other explanation you may know' and 1.4 the source of this information:

> **1. What is a star?**
> 1.1 It is the sun in many other planets, for example the sun is the star.
> 1.2 First Geology lecture
> 1.3 I believe it is the people who died ages ago and they look up for us.
> 1.4 Grandparents (04.COS.27.PRE)
>
> **1. What is a star?**
> 1.1 Is a ball of gases that consist of helium and hydrogen
> 1.2 from Science
> 1.3 Is a fire that has been made by our loving God to give light to the planets
> 1.4 Granny (04.MS.41.PRE)

As is clear from Table 5.2, the most common response to the question was a simple observational description of stars, sometimes with fragments of science contained in it. While most of the students seemed to rely on their own observation or common knowledge to answer the question, only a few referred to cultural understandings which demonstrated the animism and anthropocentricism inherent in a traditional worldview. The overall picture of the students' prior knowledge in terms of 'what is a star?' is one of vague or no recollection of what they should have been taught at school with most answers giving a simple description of stars as little lights at night. Lemmer *et al.,* also working with South African university students conceptions in basic astronomy (but in their case, first year Physics students) described their lack of scientific understanding as "incredible" (2003, 578).

5.1.2.1.2 "WHAT HAPPENS TO THE STARS DURING THE DAY?"

This was the second question that was asked in the pre-instruction questionnaire that fits under 'Ideas about stars'.

During the course of conversations with students in 2001, I had learnt of the belief in African culture that stars are linked to the ancestors. The belief is that people who have died, variously described as 'ancient warriors' or 'ancestors' or simply 'dead people', appear at night to protect those on Earth, but during the day they disappear because that is when they sleep – an anthropocentric, practical solution to the disappearance of stars, based on the belief that during the day people can look after themselves.

The everyday experience is that of the stars fading as the Sun rises, and gradually re-appearing as the Sun sets, with the intuitive understanding that the bright light of the Sun obscures the lesser light of the stars.

The scientific understanding of the Universe, involving enormous spatial dimensions in which there are billions of galaxies, is not consonant with either traditional or everyday conceptions. According to the scientific explanation, the blue sky is the result of the scattering of the blue wavelengths of visible light which causes the sky to be blue and opaque, effectively preventing us from being able to ‘see through’ it. The scientific explanation is thus counterintuitive and has to be taught - it is unlikely to be arrived at through everyday observation.

TABLE 5.3: “What happens to the stars during the day?” METHOD 1

WMS Correct	6						
WMS simple		11					
WMS problem		1	3				
AB everyday		34		61			
AB personal		12		21	26		
AB IKS				4	3	2	
AB religious							0
WORLDVIEW CONCEPTION	**WMS correct**	**WMS simple**	**WMS problem**	**AB Everyday**	**AB personal**	**AB IKS**	**AB religious**

n = 191

(this includes blank/I don’t know/unclassifiable: n = 7)

Students who showed evidence of one form of knowledge only:

Students who presented a WMS worldview only: (6+11+3+1) = 21 (11%)

Students whose worldview was not based on WMS: (61+21+4+26+3+2) = 117 (61%)

Students who showed evidence of more than one form of knowledge:

Combination of alternative beliefs and science: (34+12) = 46 (24%)

NOT SHOWN ON TABLE 5.3: Students who showed evidence of 3 different types of knowledge (WMS simple and AB everyday and AB personal) = 3 (2%)

Total students with at least some science in their explanation: (21+46) = 67 (35%)

Total number of students who referred to religion: 0

Total number of students who referred to IKS: (4+3+2) = 9 (5%)

TABLE 5.4: “What happens to the stars during the day?” METHOD 2

Tier 3 Concept Category	Tier 2 Concept Category	No of different Tier 1 code statements	Total number of occur-rences	Examples of the 3 most common code statements in each concept category (number of occurrences for each statement given in brackets)
Western Modern Science	Correct ideas:	3	11	Blue sky (9); refraction of light in atmosphere makes blue sky (1); Sky is a mixture of gases (1)
	Simple ideas	11	147	Stars are still there (73); Stars are far distant (25); Stars stay where they are (14)
	Simple ideas linked to Climatology	4	9	Cloud cover can hide the stars (6); Stars are hidden by cloud and air pollution (1) Stars dissipate because of cloud and scattering (1)
	Problem ideas	3	5	Reflection of the sea (2); Reflection of Sun’s rays prevents us from seeing stars (2); Stars are same colour as the sky (1)
WMS TOTAL	**Ideas based on science**	**21**	**172**	
Alternative beliefs	Personal ideas	36	61	Stars reflect light of the Sun (15); Stars are in the sky (4); Stars move position (2)
	Everyday ideas	22	298	Sunlight bright and overwhelms light of stars (101); Sunlight is too bright (46); Stars are invisible during the day (33)
	Ideas based on IKS	6	14	Stars sleep during the day (4);Stars are ancestors: they watch over us at night (2); Stars are born when the Sun dies at night (2)
	Ideas based on Religion	0	0	
AB TOTAL	**Ideas which are not based on science**	**64**	**373**	

As with the first question, the wording of this question was selected as carefully as possible in order not to be directive. Unfortunately, this resulted in the fact that the response: ‘nothing happens – the stars are always there’ was an acceptable, if simple, observational rather than explanatory answer. However, what I had actually hoped for, through this question, was the emergence of other traditional beliefs, in addition to seeing how prevalent these beliefs might be.

The everyday experience of the stars fading at dawn and reappearing at dusk leads to the intuitive explanation that the Sun’s light is so bright that it overwhelms the light of the stars. The categorization into ‘simple ideas’ based on WMS and ‘everyday ideas’ was difficult here as the responses could have fallen into either category, reflecting an unfortunate ambiguity inherent in the question. Lemmer et al. (2003), who used a very similar question in their research (“Where are the stars during the day?” Ibid, 575) also reported experiencing difficulty with categorization as often the students’ responses could be categorized as organistic or mechanistic. In their study, the response that the stars were obscured by the Sun’s light was categorized as mechanistic, whereas here it was categorized as an ‘everyday’ belief. It needs to be recalled that in this study, the purpose of the question was to elicit culturally-based responses rather than to establish a geometric understanding. Consequently observational answers (such as ‘star light is overwhelmed by the sunlight causing them not to be visible’) were categorized ‘AB everyday’ since they were the most frequently given, common-sense reason for the absence of stars during the day. This categorization led to 61% of the students being listed as having a worldview not based on science (Table 5.3). The choice of different criteria for categorization can thus be held to account for the fact that the percentage of students in this study holding a WMS understanding (‘mechanistic’ in Lemmer *et al*.’s categorization) stands at 11% (see Table 5.3), compared to Lemmer *et al*.’s results, where 78% were said to hold a mechanistic perception. This is a clear example of Lindsay’s (1997) point that the perspective of the researcher drives categorization.

Another difficulty related to categorization is illustrated by the following. The statement that “the stars disappear during the day” was usually categorized as an ‘everyday’ explanation, but on occasion it was listed as ‘AB IKS’, if there was a supporting statement such as

> “…during the day stars get into the sun, whereby the sun becomes bright. The sun is bright because these stars that has entered are helping with the brightness” (01.G.9.PRE).

The “getting into the sun” and the fact that the student had recorded that the information came from a grandparent, resulted in the response being listed as ‘AB IKS’. Without the information about the source of the knowledge, the response would rather have been listed as ‘AB personal’. It can thus be seen that while as much care as possible was taken to ensure consistency, the choice was often subjective and tentative, but the advantage of using the two methods of coding can be seen in the fact that the categorization is made transparent. Despite these difficulties, the problem usually lay at the Tier 2 concept level, which means that at the coarsest level, i.e. at the worldview level, the relative predominance of worldview (i.e. Tier 3) concepts would not have been affected.

Students categorized as holding a combination of WMS and AB presented personal or everyday ideas containing fragments of science. A full scientific understanding was displayed by only a few students. In Table 5.4 it can be seen that while concepts regarding the scattering and refraction of light are taught in Physical Science, and may be referred to in Geography in connection with climatology, very few students referred to these concepts in their explanations. The majority of answers categorized as WMS were simple ideas, which were closely associated with AB everyday ideas, showing that for the majority of students, the full scientific explanation was unknown.

Only nine students (5% of the sample) referred to IKS. These were students who had linked the stars to the ancestors, and here presented the traditional, animistic view that during the day the stars (ancestors) were sleeping:

> "It is our ancestor's light or the star is their spirits and souls that are watching over us. That's why we see them only at night" (04.G.16.PRE).

The traditional worldview also comes across in the teleology of statements such as:

> "Star is small and bright objects which during the dark nights shine on sky. It is there to decorate the sky and protect the sky against Satan" (04.G.1.PRE),

which focuses on the perceived purpose of stars – to beautify and protect against evil, and in the anthropomorphism (inanimate objects being given human characteristics) and anthropocentricism (mankind being seen as the centre of existence) inherent in the following statement:

> "The stars sleep during the day and come out to watch over us at night because they are our guiding angels" (02.G.13.PRE).

5.1.2.2 IDEAS ABOUT DAY AND NIGHT (ROTATION)

> "And God said, "Let there be light" and there was light. God saw that the light was good, and he separated the light from the darkness. God called the light "day" and the darkness he called "night". And there was evening, and there was morning – the first day."
>
> Genesis 1: 3-5

These verses are among the best known in the Bible. As part of the creation account, they speak of God's power not only in creating day and night, but in confirming that what he created was good. The human desire to understand God's power, and through this to be able to praise his goodness, appears, for many people, to have had the opposite effect. The diminuition of the need to refer to a supernatural power to explain the origin and working of the Universe goes back, in Europe, to the time of Copernicus and Galileo, where the change in understanding from a geocentric to a heliocentric Universe undermined the literal translation of the Bible and role of God in the creation and maintenance of the Universe. As science has progressively explained the 'mysteries' of the physical world, so the Biblical creation account, has, for many people become a 'fairytale', a 'folklore' account which needs to be interpreted in the context of the time in which it was written and which has been used, in the light of the Big Bang theory, to discount everything else claimed by the Bible. However, for people with a literalist or fundamentalist Biblical understanding or who hold a traditional worldview, the claims made by science are equally viewed as 'lies' or 'fairytales'. This is especially true in Africa, where Christian beliefs are intertwined with African Traditional Religious beliefs.

The rotation of the Earth on its axis in 24 hours, with the profound impact this has on most living beings, is one of the most basic concepts of basic astronomy. It is introduced, along with the concept of the Earth as a sphere, in primary school. The biggest problem in learning the mechanistic explanations associated with heliocentricity lies in trying to connect what you see and experience every day in terms of sunrise and sunset with a concept that is not experientially true. The confusion is caused by what do you believe and who do you believe: your eyes and what you are told in Sunday school, or school science, which is hard to understand? By the time the learner reaches high school, they know that the Sun does not move – they 'know with their head' that it is the Earth that is moving. By the time they reach university, a pre-Copernican understanding should be shocking, yet it has been established that even in first world countries this is fairly common.

Table 5.5 shows the numbers of students holding different views, while Table 5.6 makes available the actual ideas held in terms of the different views

TABLE 5.5: "What causes day and night?" METHOD 1

WMS Correct	63						
WMS simple		9					
WMS problem	3*		62				
AB everyday	5		6	4			
AB personal		1	6	1	7		
AB IKS	3	1	6			0	
AB religious	6		2		5		0
WORLDVIEW CONCEPTION	**WMS correct**	**WMS simple**	**WMS problem**	**AB Everyday**	**AB personal**	**AB IKS**	**AB religious**

***** The three students listed under WMS correct and WMS problem gave two answers, one of which was an acceptable answer based on WMS, but under the 'personal explanation' gave an answer which while also based on WMS, was incorrect.

n = 191 (this includes blank/I don't know/unclassifiable: n = 1)

Students who showed evidence of one form of knowledge only:
Students who presented a WMS worldview only: (63+9+62+ 3) = 137 (72%)
Students whose worldview was not based on WMS: (4+7+1+5) = 17 (9%)

Students who showed evidence of more than one form of knowledge:
Combination alternative beliefs and science: (5+3+6+1+1+6+6+6+2) = 36 (19%)
Total students with at least some science in their explanation: (137+36) = 173 (91%)

Total number of students who referred to religion: (6+2+5) = 13 (7%)
Total number of students who referred to IKS: (3+1+6) = 10 (5%)

TABLE 5.6: “What causes day and night?” METHOD 2

Tier 3 Concept Category	Tier 2 Concept Category	No. of different Tier 1 code statements	Total number of occur-rences	Examples of the 3 most common code statements in each concept category (number of occurrences for that particular statement given in brackets)
Western Modern Science	Correct ideas:	14	168	Rotation (72); Rotation on axis (33); Rotation on axis in 24 hours (8)
	Simple ideas	6	76	Half the Earth is light, the other half dark (31); Position of the Earth relative to the Sun (13) Day is when the Earth is facing the Sun (11)
	Problem ideas Conceptual	9	106	Earth rotates around the Sun (52); Earth moves around the Sun (19); Equatorial circle of illumination (12)
	Problem ideas ‘Other’ e.g. language	10	89	Revolution (55); Angle of the Earth’s axis (9); Fixed axis revolution (5)
WMS TOTAL	**Ideas based on science**	**39**	**439**	
Alternative beliefs	Personal ideas:	20	29	Sun moves (7); Moon position causes day and night (2); Clouds open and close (2)
	Everyday ideas	11	90	Light = day, darkness = night (40); Light from the Sun causes day (16); Sun rises and falls/sets (9)
	Ideas based on IKS	7	8	Sun goes to sleep at night, wakes up in the day (2); Sun is swallowed by a crocodile at night (1); Sun is born in the morning and dies in the evening (1)
	Ideas based on Religion	6	31	Created by God (16); God’s creation (9) Secret of God (2)
AB TOTAL	**Ideas which are not based on science**	**44**	**158**	

The intention of this question was to establish what the situation was in this sample of students, for whom access to television programmes and libraries is unlikely to be the same as in First World countries, and where teachers’ pedagogic content knowledge (Shulman, 1986) may not necessarily be based on a mechanistic model. In addition perfectly satisfactory answers exist that don’t require you to distrust your senses:

> “When the sun goes to sleep it is night. When it wakes up in the morning it is day” (04.MS.16.PRE).

This again is a typical animistic view, common in traditional cultures, but there are also appealing folklore answers rooted in the environment:

> “The sun causes light from the morning to afternoon where it is swallowed by a crocodile and goes with it to east to throw it away” (04.COS.16.PRE).

Responses based on WMS were again in the majority for this question: 74% (439 occurrences out of a total of 439 + 158 - see Table 5.6) could be categorized as being linked to the WMS explanation, but the percentage of students who provided a 'WMS correct' answer was only 33% (see Table 5.5: 63 students out of n = 191).

Problems that arose in the categorization mainly involved trying to allocate responses as 'WMS simple' or 'AB everyday' where the criteria used for allocation were related to language (incorrect use of the scientific terms versus everyday language). However, when these two categories are added together, it can be seen that here, as in the 'ideas about stars', students relied on simple descriptive statements rather than attempting to give a causative explanation. Where students did try to use the scientific terms, revolution was often used to mean rotation, as in:

> "Day and night are caused by the revolving of the planet. Since the sun is in a fixed position the side of the planet that faces the sun will be exposed to light thus we call it a day. The side that did not face the sun is not getting any light from the sun so we call it night" (04.MS.24.PRE).

However, often not only the *term*, but also the *concept* was muddled, as in

> "The revolution of earth causes day and night" (04.COS.4.PRE)

The diagram drawn by this student (Figure 1 below) shows the Earth revolving around the Sun as the reason for day and night, rather than the Earth rotating on its axis.

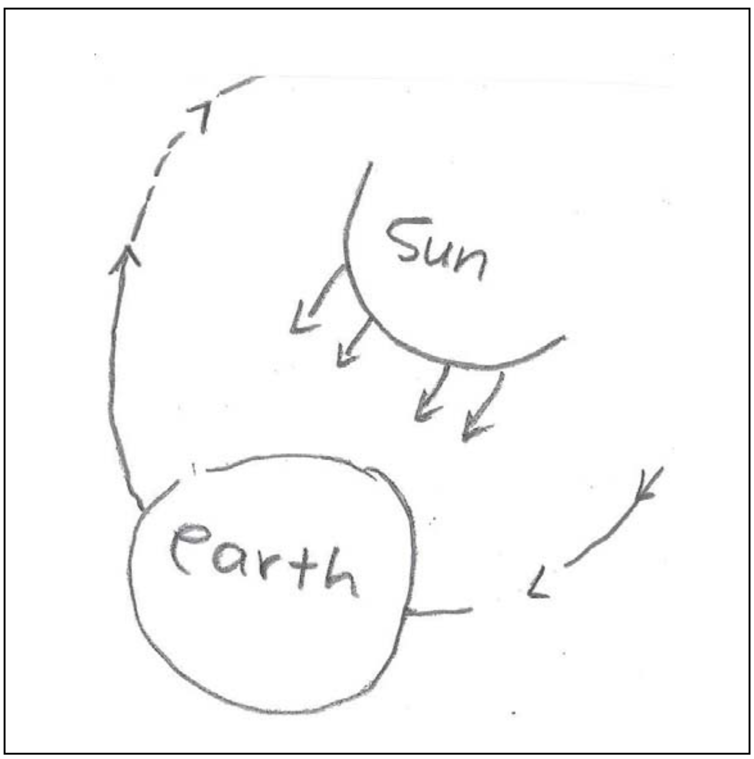

Fig. 1: Diagram to show cause of day and night (04.COS.4.PRE)

The scientific explanation for day and night is counter-intuitive and has to be taught. Albanese *et al*. (1997, 588) point out that the history of development of the Copernican model shows that the development of the scientific understanding "occurred by patient collection of data through the centuries" and that it is "impossible to construct a reasonable model of the day/night cycle by … considering only the information obtained by exclusively local observations (because from these observations), the geocentric model is perfect for explaining the heavenly phenomena".

However, the idea of a heliocentric solar system is one of the most fundamental principles of basic astronomy and is taught from early on in primary school. The following extract provides an example of the difficulty experienced in trying to construct the abstract model:

> **What causes day and night?**
> 2.1 The movement of the Earth around the sun, because at one point some places face the sun and receive day light while other remain in the dark (night)
> 2.2 Text books
> 2.3 At some point I thought the sun was moving and hide somewhere. But now I know that the movement of the Earth causes day and night.
> (04.MS.30.PRE)

For this student, their original understanding made more sense than the explanation received at school, but they know that it is 'wrong'. The greatest difficulty in helping people to construct the scientific models that are needed to understand the scientific explanations pertains to reconciling observational experience with the abstract model of the cosmic Earth. The understanding that 'the sun doesn't move' is common, but the difficulty is often resolved by moving the Earth from one side of the Sun to the other - which cleverly solves the fact that the Earth moves and the Sun doesn't move, but also indicates that the concept of rotation has not been understood. This is demonstrated in the following diagram (Fig. 2):

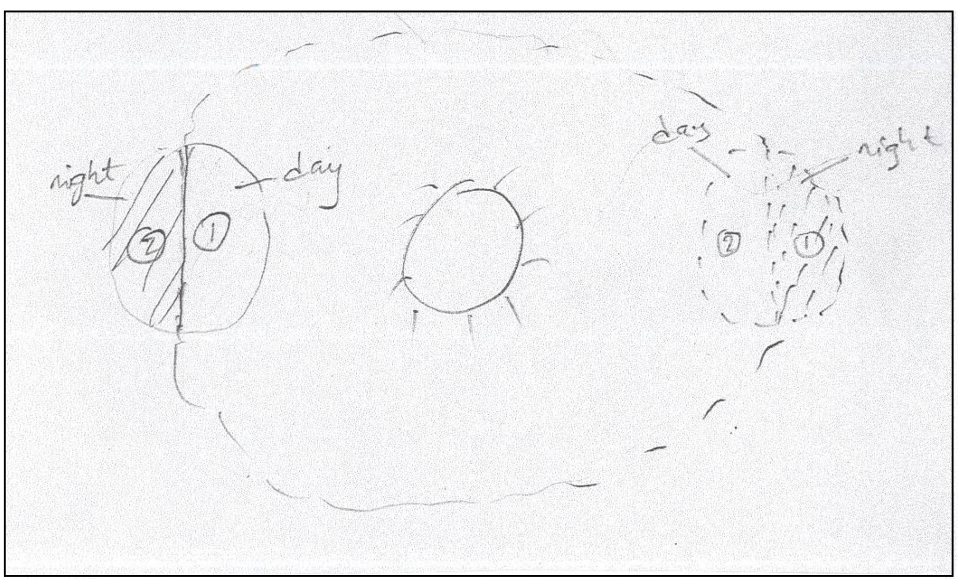

Fig. 2: Diagram to show cause of day and night (04.MS.42.PRE)

The confusion is exacerbated when students are confused about other concepts, such as the global location of the various hemispheres, as in the following example:

What causes day and night?
2.1 From our location perspective, i.e. southern hemisphere, if the sun is glow towards us, it is day and if the sun is glowing away or on the N-hemisphere is night.
2.2 Taught at school
2.3 I think that the Earth is tilting on its orbit. It is divided into 2 hemispheres In SH it is day if it faces the sun's rays (diagram shows a globe on a stand with a torch as the sun. SH and NH are shown as Western and Eastern hemispheres respectively)
2.4 - (04.MS.38.PRE)

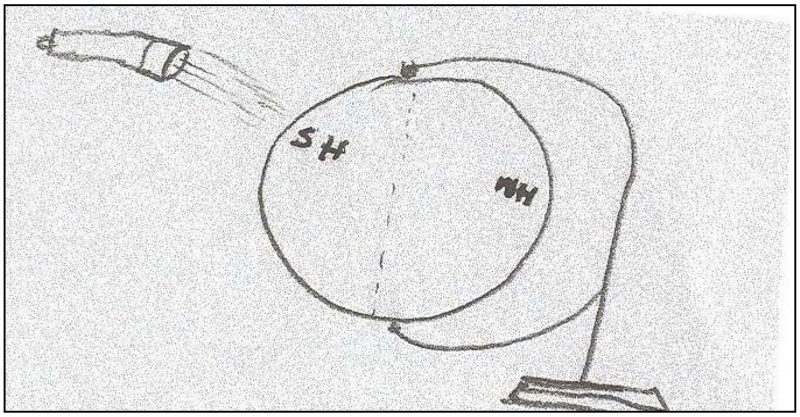

Fig. 3: Diagram to show cause of day and night (04.MS.38.PRE)

Confusion is also linked to an up/down 'Earth concept' (Nussbaum and Novak, 1976) which in Fig. 4 is shown to involve an equatorial circle of illumination:

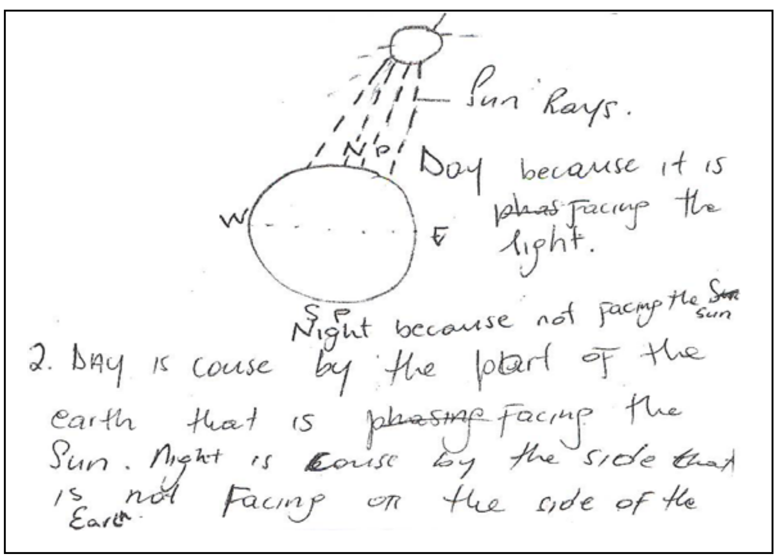

Fig. 4: Diagram to show cause of day and night (04.COS.28.PRE)

The retention of models that make sense can be seen in the following concise response, where the first answer, 2.1, the 'scientific explanation', which is claimed to have been learnt in 'climatology', is not echoed by the personal explanation (2.3), which is given by a trusted source, and which makes sense from an experiential perspective:

> **What causes day and night?**
> 2.1 the movement of the earth around the sun (scientific explanation)
> 2.2 climatology (source of this explanation)
> 2.3 the sun moves around the earth (personal explanation)
> 2.4 mother (source of this explanation)
> (02.G.1.PRE);

Other students indicated a static understanding of the Earth - with the Sun as the body that was moving - by making statements such as:

> "The sun moves to America when it is night in S.A." (02.G.7.PRE)

Those responses that contained elements of traditional culture again illustrate the anthropomorphism and teleology inherent in an organistic worldview:

> "The sun gets born in the morning and live for the whole day and die in the evening and another one gets born" (04.G.9.PRE);

and

> "The sun rises = day, sun sets = night. The sun wakes up and starts up the fire so that we have day. When the time comes it puts out the fire so that it is dark and this is night" (02.G.5.PRE)

The following story, which helps to clarify the students' responses, was provided by the Zulu technician in the Geography Department at Wits University:

> "The sun is an extremely hot fire, so hot in fact that when it rises from the water, it causes it to boil. The waves that wash the shoreline are the consequence of that boiling, and the fact that the water is not hot as it washes onto the coastline, is because it has travelled a long way from the horizon where the sun rose, to where the waves wash onto the shore" (Ntsimbi, 2002, pers comm.).

These folklore stories were rare in the students' responses, or else it was that they refrained from using them. However, there were also several references to religion, such as:

> "Because God created each and everything with a reason. He then decided that even people must rest by making day and night for living" (04.MS.41.PRE), and "…and the Lord said, let there be light, and there was light. Genesis Chpt 1" (04.MS.1.PRE)

5.1.2.3 IDEAS ABOUT THE SEASONS (REVOLUTION)

In the same way that stars and the cycle of day and night are familiar to us, seasons are part of the annual rhythm of life. In many parts of Africa, because the continent straddles the equator, the seasons are marked by the time of the rains, which set in motion activities such as ploughing and harvest, or the movement of nomadic herding communities. This rhythm is very much part of the daily life of rural communities, but many people are still connected to it even after several generations of urbanization. In traditional communities, the seasons are accepted as part of the God-ordained cycle of life.

The cause of seasons is a fundamental concept in basic astronomy and is included in the school Geography curriculum from primary school level. It requires a clear understanding of the Earth as a cosmic body, and the effect of the tilt of the Earth as it orbits the Sun. Whereas the question about the cause of day and night investigated the understanding of the Earth's rotation in relation to the Sun, in what could be perceived as 'contained space' i.e. the Sun moving across the sky, this question probed the students' understanding of time and space in a much bigger dimension. The mental model required here is a picture of the Earth journeying through space and around the Sun for 365 ¼ days, with its axis tilted constantly in the same direction. It requires an understanding of the Earth as a sphere, tiny in relation to the Sun, so that the sunlight can be pictured as streaming onto the Earth's surface in parallel rays, with the curvature of the Earth resulting in a concentration or distribution of this energy. It also requires an understanding that on two days of this revolution, the Earth reaches its solstice positions, signaling the longest day and shortest night, or shortest day and longest night, depending on the hemisphere. Seasons have little to do with relative distance to the Sun, which is the common understanding (even for Harvard graduates, as demonstrated in the video "A Private Universe" (Pyramid Film and Video, 1988). This understanding is based on human experience in terms of it being warmer 'closer to the fire' than 'further away' from it.

It is clear that the abstract model required for understanding seasons is a good deal more complex than the model required for understanding day and night. Ideas common to both models from the point of view of science are that the Earth is moving and the Sun is still – but both ideas are counter-intuitive. Further confusion stems from the fact that the terms used to describe these very different movements of the Earth i.e. rotation and revolution are unfortunately rather similar. For people whose everyday spatial experience may be largely limited to a rural village environment and for whom these terms are part of the jargon of a second language, the difficulties of creating abstract mental models of dimensions unsupported by any experience of large distances, as well as having to describe the concepts in a second language, amounts to seriously challenging border crossing. The difficulties of this border crossing are not necessarily only because of alternative traditional explanations, but may also rather be due to the counter-intuitive nature of the concepts, the complex abstract thinking required, the complications of language, and the likelihood, as suggested by Bishop (1996), of the concepts being presented before the learners are conceptually ready for them.

In asking “Why is it generally colder in winter than it is in summer?” the decision was taken not to ask directly about the seasons as in “what causes the seasons?”, but rather to try to draw out an explanation of seasons from the relationship between human experience of the seasons and knowledge of cosmic movements. The ambiguity that was also inherent in this question only became after the pilot study, when numbers of students gave a climatological explanation, i.e. geocentric reference point was used. The reason for this lay in the fact that for some of the groups, the Earth in Space course followed a course in Climatology. Consequently, a special sub-category was created under the WMS conceptions, i.e. WMS climate.

TABLE 5.7: “Why is it generally colder in winter than it is in summer?” METHOD 1

WMS correct	**16**							
WMS climate		**26**						
WMS simple		**5**	**27**					
WMS problem		**5**		**65**				
AB everyday					**6**			
AB personal		**1**	**2**	**2**		**12**		
AB IKS		**1**					**1**	
AB religious			**1**	**2**	**1**			**2**
WORLDVIEW CONCEPTION	**WMS correct**	**WMS climate**	**WMS simple**	**WMS problem**	**AB Everyday**	**AB personal**	**AB IKS**	**AB religious**

n = 191 (this includes blank/I don’t know/unclassifiable: n = 16)

Students who showed evidence of one form of knowledge only:
Students who presented a WMS worldview only: (16+26+5+5+27+65) = 144 (75%)
Students whose worldview was not based on WMS: (6+1+12+1+2) = 22 (12%)

Students who showed evidence of more than one form of knowledge:
Combination alternative beliefs and science: (1+1+2+1+2+2) = 9 (5%)
Total students with at least some science in their explanation: (144+9) = 153 (80%)

Total number of students who referred to religion: (1+2+1+2) = 6 (3%)
Total number of students who referred to IKS: (1+1) = 2 (1%)

TABLE 5.8: “Why is it generally colder in winter than it is in summer?” METHOD 2

Tier 3 Concept Category	**Tier 2 Concept Category**	**No. of different Tier 1 code statements**	**Total number of occur-rences**	**Examples of the 3 most common code statements in each concept category (number of occurrences for that particular statement given in brackets)**
Western Modern Science	Correct ideas: Astronomy perspective	15	120	Revolution (55) Earth moves around the Sun (19); Angle of axis (10)
	Correct ideas: Climatology perspective	18	48	Sun moves between the Tropics (12); Sun moves or migrates North (5); Seasons caused by meteorological conditions (5)
	Simple ideas	18	92	Position of the Earth relative to the Sun (13); Movement of the Earth (10); Earth moves (9)
	Problem ideas: Distance	5	52	Earth close to Sun= summer, far = winter (17); close and far positions relative to the Sun (11); distance away from the Sun (11)
	Problem ideas: Location on orbit	5	7	Seasons are located along the orbit (2); Earth moves into different climatic zones (2); Earth moves into different climatic areas (1)
	Problem ideas: terminology	6	62	Earth rotates around the Sun (52); Fixed axis rotation around the Sun (3) Rotation around the Sun (2)
WMS TOTAL	**Ideas based on science**	**67**	**381**	
Alternative beliefs	Personal ideas:	14	19	Time causes the seasons (5); Every 3 months the seasons change (2); Different activities cause different seasons (1)
	Everyday ideas	17	61	Seasons are weather related (10); Climate or climatic factors cause the seasons (9); Winter is cold, summer is hot (7)
	Ideas based on IKS	6	11	Seasons are for agricultural purposes (5); Seasons are to keep the balance and fairness in nature (2) Sun moves to hide somewhere
	Ideas based on Religion	2	6	God’s plan (5); God’s command (1)
AB TOTAL	**Ideas which are not based on science**	**39**	**97**	

The pattern in Table 5.8 of a low number of different code statements, but a high number of ‘hits’ (i.e. occurrences of these code statements), for example, 5 code statements for "problem ideas: distance" but 52 occurrences related to these code statements, indicates a degree of uniformity in the responses, while Table 5.7 indicates the reason for this: the majority of students (80%) indicated some knowledge of the scientific explanation. However, only 55 used the term ‘revolution’ correctly and only 24 made reference in some way or other[15] to the angle of the Earth’s axis. The responses frequently showed problems

[15] These figures have been extracted from data in Atlas.ti which do not necessarily appear in Table 5.8, as usually only the three most commonly occurring code statements are recorded in the tables.

linked to the incorrect use of terms, or difficulties in terms of language. For example, many students said that the Earth rotates (instead of revolves) around the Sun, and gave the common conceptual problem that distance determines seasons:

> “The rotating of the moon around the earth and the rotating of the earth around the sun” (04.MS.37.PRE) (- where the moon was thrown in for good measure!),

and

> “The earth revolves around the sun and at some point in time it gets more closer or farther. And the more farther the more it is cold and the more closer, the hotter” (01.G.7.PRE)

One of the interesting conceptual problems to arise was the idea of seasons being located along the orbit, almost like bus stops along a road. This idea is contained in the following statement, which starts with an indication of a lack of understanding of terminology, and then describes the Earth as 'moving into' different climatic zones, rather than revolution and the Earth's tilt causing different seasons:

> “Revolution during the movement of the earth. The earth moves into different climatic zones” (04.MS.45.PRE)

The 'bus stop' idea is illustrated in Fig. 5.

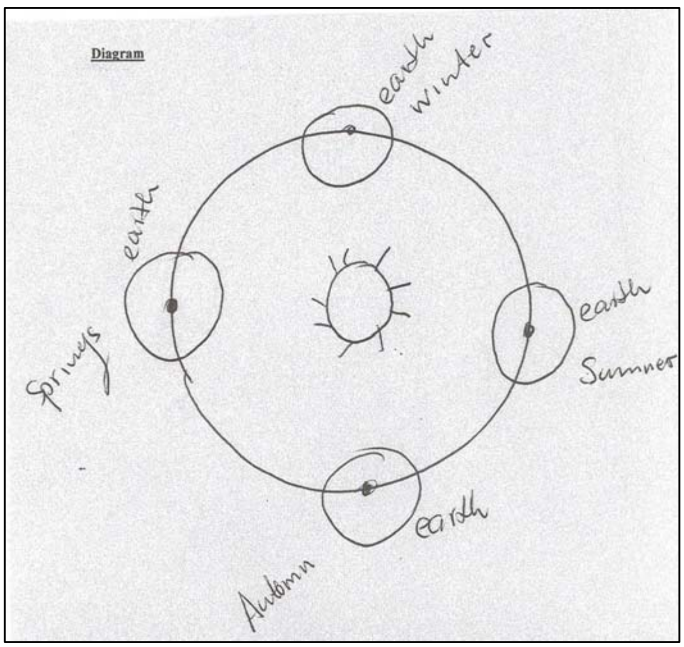

Fig. 5: Diagram to show the cause of seasons (04.COS.7.PRE)

Many of the students responded to the question using a geocentric and climatological perspective[16], which was probably due at least in part to the fact that some of the groups had completed a course in Climatology just prior to the Earth in Space course. Research questions aside, this indicates that in terms of didactics, particularly in a university context where different lecturers teach different topics, it is important to be aware that students will use the immediate past foundation on which to try to construct new knowledge.

Very few students provided answers based on IKS, and only a few gave a combination of worldview ideas. However, the animism and anthropocentricism associated with a traditional worldview was again clear in responses such as the following:

> “It is a way of nature to balance and refresh itself” (04.MS.11.PRE);

and

> “Mother Nature’s way of keeping everything on earth in balance” 04.COS.21.PRE).

These responses again are intimately tied up with a religious perspective:

> “This are the plans of God for time management to agricultural purpose” (04.MS.33.PRE);
>
> “Seasons change because of the human creator …. human beings to have food, thereby changing those seasons (04.MS.41.UN.PRE);
>
> “God assigned and made that there must be different seasons for different times of life, like harvesting” (04.MS.34.M.PRE)

5.1.2.4 IDEAS ABOUT MOON PHASES (THE EARTH /MOON SYSTEM)

The understanding of Moon phases requires the ability to picture the Earth and Moon operating as a system in relation to the Sun. A common misconception regarding the changing shape of the Moon is that it is caused by the Earth’s shadow falling on the Moon (Trundle *et al*., 2002; Kelfkens and Lelliott, 2006). This does, in fact, happen, but it results in a lunar eclipse.

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[16] During the Climatology course, the movement of the heat equator (linked to the seasons) is important in explaining the seasonal shift in weather patterns. The movement of the heat equator is explained in relation to the "sun moving north or south", thereby drawing on human experience related to a geocentric perspective. The Earth in Space course, which followed the Climatology course, provided the heliocentric or "astronomy perspective" which explained the 'apparent' movement of the sun.

Three phenomena are commonly taught together at school in relation to the Earth-Moon system: phases of the Moon, eclipses and tides. The phases of the Moon – the regular monthly pattern of waxing and waning between new Moon and full Moon – is the consequence of the view of the Moon from the Earth as the Moon orbits the Earth, while together they travel around the Sun. The question "why does the Moon appear to change its shape during the course of a month?" like the other questions, was asking for the explanation of a common phenomenon, but which again requires a clear mental model of the movement of the relevant bodies in space. This model, once meaningfully constructed, allows the explanation of such things as why it is possible to see the Moon during the day; how to predict from one sighting whether the Moon is waxing or waning and how to picture the relative position of the Sun in relation to the Earth at night. A more detailed understanding of the size of the Moon, the nature of the Moon's orbit, and its revolutionary speed, are needed to explain eclipses and the fleeting nature of solar eclipses compared to lunar eclipses, as well as why the tides are approximately 50 minutes later each day. All these concepts are part of the school curriculum, usually taught for the last time (in terms of the Geography curriculum) when learners are in Grade 8 or 9.

TABLE 5.9: "Why does the Moon appear to change its shape during the course of a month? METHOD 1

WMS Correct	16						
WMS simple		32					
WMS problem			61				
AB everyday				2			
AB personal	1		3		13		
AB IKS			2			11	
AB religious		1	3				3
WORLDVIEW CONCEPTION	**WMS correct**	**WMS simple**	**WMS problem**	**AB Everyday**	**AB personal**	**AB IKS**	**AB religious**

n = 191

(this includes blank: n = 39; and I don't know/unclassifiable: n = 4)

Students who showed evidence of one form of knowledge only:

Students who presented a WMS worldview only: (16+32+61) = 109 (57%)

Students whose worldview was not based on WMS: (2+13+11+3) = 29 (15%)

Students who showed evidence of more than one form of knowledge:

Combination alternative beliefs and science: (1+1+3+2+3) = 10 (5%)

Total students with at least some science in their explanation: (109+ 10) = 119 (62%)

Total number of students who referred to religion: (1+3+3) = 7 (4%)

Total number of students who referred to IKS: (2+11) = 13 (7%)

TABLE 5.10: "Why does the Moon appear to change its shape during the course of a month?" METHOD 2

Tier 3 Concept Category	Tier 2 Concept Category	No. of different Tier 1 code statements	Total number of occur-rences	Examples of the 3 most common code statements in each concept category (number of occurrences for that particular statement given in brackets)
Western Modern Science	Correct ideas:	7	24	Phases caused by position of the Moon relative to the Sun (10); Phases linked to position of Earth, Moon and Sun (8); From Earth we see part of the Moon reflecting the Sun's light (2)
	Correct ideas in relation to question	4	8	Moon does not change shape (4); Moon's shape never changes (2); Moon only appears to change shape (1)
	Simple ideas	28	77	Moon reflects light of the Sun (23); Moon moves around the Earth (8); Position of the Sun (7)
	Problem ideas	23	84	Phases are caused by the Earth's shadow (25); Rotation of the Earth causes phases (22); Rotation of the Moon causes phases (8)
WMS TOTAL	**Ideas based on science**	**62**	**193**	
Alternative beliefs	Personal ideas:	9	17	Sun and Moon are on opposite sides of the Earth: when Sun appears, Moon disappears (3) Clouds block the Moon (2) Someone took a bite out of it (1); A mouse eating it up (1)
	Everyday ideas	3	8	Phases are linked to the calendar (5); Changing quarters (2) Phases result of our perspective of different times of the month (1)
	Ideas based on IKS	9	12	New Moon symbolizes birth (2) Phases happen to show luck (1)Phases are the process of cleaning the Moon (1) Phase is affected by human emotion (1);
	Ideas based on Religion	4	7	Phases are a pattern of creation (3); Created by God (2);The Moon changes on Christmas eve (1); Phases are caused by gods and the zodiac (1)
AB TOTAL	**Ideas which are not based on science**	**24**	**44**	

The Moon is an important feature of folklore in many cultures, associated with werewolves, and witches riding broomsticks, by people with a Western cultural background, and other 'creatures of the night' - like a tokoloshe riding a hyaena, by people with an African cultural background.. While these particular stories may not be taken seriously (by some), it is interesting to note that even in Western culture, there is information that is relegated as superstition by some people that is valued by others, as in a popular magazine such as 'Country Living', which runs a regular monthly article featuring "planting by the Moon".

Research has shown that the most common understanding of the changing shape of the Moon is that it is caused by the Earth's shadow, while another common understanding is that phases are the result of the Earth's rotation (Trundle *et al*. 2002). It can be seen from Table 10 (WMS 'problem ideas') that this is also true in the sample in this case, with 25 and 22 occurrences respectively of these problems. The only other code statement to gain more than 20 'hits' fell into WMS 'simple ideas', where students noted that the Moon reflects the light of the Sun, but did not explain the spatial relationships required to produce the phases observed from the Earth.

Small studies by Kelfkens and Lelliott (2006) and Govender (2006) support the findings in the current study regarding beliefs about the Moon. These included a link to calendar time, the idea that the Moon is a source of light and that the Moon moves around the Sun. Other beliefs, which may be more specifically associated with African cultural beliefs, include the practice of not taking a baby outside until it has been shown the full Moon (Govender, 2006), and beliefs that the full Moon brings 'good luck'; that it affects people's moods or destiny; and that a crescent Moon implies imminent rain. The idea that Moon phases symbolize birth or a new beginning can be seen in the following:

> "During the first night of the crescent the moon is born then, it grows like a child and its size is getting bigger and bigger after each night with the moon being cleaned' (04.G.1.PRE)

The idea of the phases representing 'cleaning' was mentioned several times, for example:

> "I think is a geographic process of cleaning the moon" (04.MS.33.PRE),

with one student stating

> "The man in the moon covered the moon and didn't have a big enough cloth to cover the entire moon" (04.G.6.PRE).

The association of the phases with calendar time was linked by one Muslim student to the Islamic calendar:

> "The moon has different phases indicating the lunar calendar which aids in the changing of lunar months in the Islamic religion" (02.G.13.PRE),

but for the other students who made this association with the passage of the month, it was more of a general nature, rather than being associated explicitly with religion:

> "At first is full moon as the month process it get smaller in change or change the shape" (04.COS.4.PRE).

However, there were references to religion, with one student referring to the zodiac (the only time the zodiac was mentioned in this study by a student):

> "I've thought about it but never really got to the answer, so I just assumed that it had to do with the "gods" and zodiac" (04.MS.6.PRE);

Another student, who made no other mention of religion in their responses to the questionnaire, ascribed the origin of the following story to his/her mother:

> “On Christmas eve it changes as a sign to show the birth of Jesus Christ” (02.G.7.PRE)

The presence of an ‘organistic’ worldview (Lemmer *et al*., 2003) was again evident in the following explanation of phases:

> “It’s a process and it happens during the course of a month so the moon is aware of that and is used to it as it was created to be like that” (04.MS.43.PRE).

However, responses like this were in the minority. Eighty percent of those students who answered the question made some reference to the explanation offered by science, but there were 39 students who did not answer this question, which represents the highest number of ‘blanks’ for any of the questions. This possibly indicates that the students knew there was a scientific explanation and preferred to leave it blank rather than get the answer wrong.

The greatest difficulty experienced in categorizing responses in this question lay in the Tier 2 concepts, particularly in assigning responses as ‘personal’ or ‘everyday’ and sometimes even ‘IKS’. Was the idea of the Moon being covered with a cloth, for example, an idea that had its origin in traditional folklore stories or was it simply a family story, or the product of the creative imagination of the individual who wrote it? What also were the everyday or common understandings of the phases of the Moon: for example the common response that “phases are caused by the Earth’s shadow” and that they are due to the “Moon reflecting the light of the sun” were assigned to WMS problem and WMS simple respectively, because it can be argued that these responses contain elements of science, but it is also possible that these two ideas, because they are ‘commonly held’ according to the literature, should have been assigned as ‘everyday’ explanations.

Despite difficulties such as these, what was clear was that the scientific explanation was again poorly understood. The dynamic model required to really understand phases of the Moon involves the ability to think abstractly: to place oneself in a position in space away from the Earth and mentally observe the relative positions and movements of the Earth, Moon and Sun, and then transfer oneself back to the Earth’s surface to connect the shape that is observed from Earth with the positions of these bodies in space. Albanese *et al*. (1997, 588-589) point out that the scientific explanations:

> “…may induce a disbelief in what we observe in reality, which may lead to renounce the visible and “believe” in the “invisible” or, worse, to think that science has no value at all, except for answering the questions of teachers and the researchers.”

Albanese *et al.* (1997) were referring here to children in general, without specifically accounting for the additional challenges faced by children from traditional cultures, where the science was also being learned in a second language.

5.1.2.5 IDEAS ABOUT THE UNIVERSE

Although Immanuel Kant (1724 – 1804) had speculated that the Greater and Smaller Magellanic Clouds[17] were separate galaxies well beyond the Milky Way, it was only in the 1920's that it was firmly established that there are indeed galaxies outside of the Milky Way (Barrett, 2000). Since then, the Hubble telescope has changed the number of galaxies from millions to billions, with our home solar system becoming an insignificant speck in one of the arms of a rather graceful spiral galaxy.

It was apparent from test questions during Phase 1 that there was confusion regarding the concepts 'solar system' and 'Universe', and that while students were familiar with terms such as 'galaxy' and 'nebula', there was a lack of understanding regarding what they actually represented. Being able to meaningfully distinguish different dimensions in space, from the solar system and its position in the Milky Way to the vastness of the known Universe, is extremely difficult as the dimensions quickly become meaningless. In addition to these difficulties, the 'Universe' ideas that are associated with traditional or indigenous cultures, are usually confined to the familiar (Earth-based) environment, with the atmosphere (the 'sky' during the day and the 'heavens' at night) representing the boundary of that environment.

The pre-instruction questionnaire afforded the opportunity in 2004 to investigate students' prior knowledge of the concept 'Universe'. Responses that referred to the Earth and/or atmosphere were categorized 'AB *micro-view*' to distinguish them from responses that equated the Universe with the solar system, which were categorized as 'WMS *meso-view*'. Unlike the 'Earth-Universe' concept (an alternative belief which incorporates cultural ideas about the Earth), the 'solar system-Universe' would have been derived from science teaching at school. As a result, the 'solar-system Universe' responses were categorized under WMS.

The terms 'micro' and 'meso' were useful in separating these 'closer to home pictures' from the 'bigger picture' of the Universe – the 'macro-view' – which comprises the understanding of billions of galaxies, and features vast expanses of space with phenomena such as pulsars, supernovae and black holes, and mysterious 'dark matter' as part of this bigger picture.

'WMS problem' was used for responses where the idea was based on school science, but was problematic in some way. The most common 'WMS problem' was 'the Universe is a large vacuum' – an idea probably originating from the understanding that the atmosphere around the Earth becomes less dense with altitude, to a point where there is 'no air' - which is then conceived as 'space'.

[17] These galaxies are named "Kgoro" and "Tlala" in Sepedi, meaning 'the well fed' and 'the hungry' - descriptors which refer to the relative size of these two galaxies (Snedegar, 1995).

The distinction between 'personal' ideas and AB 'everyday micro-view' was somewhat impractical, but mainly served to separate comments such as 'the Universe is too confusing to explain' and that 'it cannot be understood' from ideas that contained at least a description of the Universe.

TABLE 5.11: "What is the Universe?" METHOD 1

WMS Correct	49						
WMS simple		44					
WMS problem			7				
AB everyday				19			
AB personal					4		
AB IKS						0	
AB religious	7	1		1	1		2
WORLDVIEW CONCEPTION	**WMS correct**	**WMS simple**	**WMS problem**	**AB Everyday**	**AB personal**	**AB IKS**	**AB religious**

n = 140 (not all sample groups were asked this question)
(this includes blank/I don't know/unclassifiable: n = 2)

Students who showed evidence of one form of knowledge only:
Students who presented a WMS worldview only: (49+44+7) = 100 (71%)
Students whose worldview was not based on WMS: (19+1+4+1+2) = 27 (19%)

Students who showed evidence of more than one form of knowledge:
Combination alternative beliefs and science: (3+7+1) = 11 (8%)
NOT SHOWN ON TABLE: Students who showed evidence of 3 different types of knowledge (WMS macro-view and AB religious and AB personal) = 2 (1%)

Total students with at least some science in their explanation: (49+44+7+3+7+1) = 111 (79%)
Total number of students who referred to religion: (7+1+1+1+2) = 12 (9%)

TABLE 5.12: “What is the Universe?” METHOD 2

Tier 3 Concept Category	Tier 2 Concept Category	No. of different Tier 1 code statements	Total number of occur-rences	Examples of the 3 most common code statements in each concept category (number of occurrences for that particular statement given in brackets)
Western Modern Science	Correct ideas: Macro-view (beyond the solar system)	18	123	The Universe is a big/boundless space (23); The Universe is everything that exists: planets, stars, space (21); The Universe is made of galaxies (19)
	Simple ideas: Meso-view (Solar system)	8	91	The Universe is the solar system (40); The Universe is the solar system and the stars (29); The Universe contains planets (8)
	Problem ideas	6	11	Universe is a large vacuum (6); The Universe is a nebula (1); The Universe is when many stars combine (1)
WMS TOTAL	**Ideas based on science**	**22**	**225**	
Alternative beliefs	Personal ideas	7	11	Don’t know enough about the Universe to explain it (4); The Universe is our global village (2); the Universe is full of interesting things (1)
	Everyday ideas Micro-view (limited to the Earth and atmosphere)	6	45	The Universe is our Earth/world/ environment (17); The Universe is made up of the Earth’s systems/spheres (hydrosphere/atmosphere/ biosphere) (12); The Universe contains all living and non-living things (9); The Universe is a place of living organisms (5)
	Ideas based on IKS	0	0	
	Ideas based on Religion	6	7	The Universe was created long ago (2) The Universe is like a miracle (1); The Universe is the total creation of God (1)
AB TOTAL	**Ideas which are not based on science**	**19**	**63**	

The Pocket Oxford Dictionary (1992) describes ‘Universe’ as “all existing things; Creation; all mankind”, while the Microsoft Thesaurus supplies ‘cosmos’ ‘world’ ‘creation’ ‘life’ ‘space’ and ‘Earth’ as synonyms. The term, as it applies to Earth Science, refers to all matter and energy that was created, and is, as a result of the Big Bang from a singularity, through Deep Time (which refers to the “immensity of geological time and the problem that man (sic) has in conceptualizing the several-billion-year time span over which geological processes on the Earth have been operating” (McCarthy and Rubidge, 2005, 61)). The twentieth century saw the expansion of the Universe from a single galaxy perspective to encompassing sufficient distance to warrant the calculation of the time of the Big Bang.

This is esoteric knowledge however, and the intention of the question “what is the Universe?” was simply to give an idea of what perspective the students held.

Of the sample of 140 students, 111 (79%) gave an answer that had at least some science in it, with 71% giving an answer that was *only* based on WMS. Table 5.12 shows that of the responses based on WMS, there were almost as many responses with a 'meso-view' i.e. solar system perspective as those with a 'macro-view' i.e. bigger than the solar system perspective. The relationship between the number of code statements and the number of occurrences of these code statements in Table 5.12 suggests only a few Tier 2 ideas, but with many people holding those ideas, even in terms of the alternative beliefs.

Lemmer *et al*. (2003) also identified three categories of understanding of the Universe in their study of South African students, which they described as organistic, mechanistic and contemporary. These equate, according to the diagrams provided in their paper (*Ibid*., 569) with the micro, meso and macro views identified here, although the categories in this study serve to distinguish the ideas on the grounds of spatial dimensions rather than the philosophical terms used by Lemmer *et al*. (*Ibid*.) Their study was a comparative one, with their calculation of *d*-values indicating that “European students responded more in accordance with a modern or mechanistic view of the Universe, while responses of an organistic nature were mainly found among African students” (*Ibid*., 578). It was not possible to ascertain whether the students who provided an egocentric (i.e. geocentric or micro-view) of the Universe in the present study were African or not, but while the proportion of students holding this view was very similar in the current study (14%) to that found by Lemmer *et al.* (15.1%), the racial mix was the opposite: in the Lemmer study, they referred to a "European/African" ratio of 60% to 40%, while in the current study, the proportion of African students to 'other' students was of the order of 65 to 70%. This possibly indicates, in the light of Lemmer *et al*.’s statement that “through continuous teaching, the child gradually reaches a mechanistic sense of causality based on inertia”, that it is the quality of teaching that has been received over the years that is actually more important in this particular context than culture. This does not negate the role of worldview in raising barriers to border crossing, but perhaps serves rather to highlight the role of education: the number of code statements extracted at both the meso and macro levels in Table 5.12 indicate a uniformity of conceptions – all of which must have been derived through the teaching and learning of science based explanations. It is suggested that the relatively small number of alternative beliefs that were indicated in the current study points more to a lack of direct competition or conflict in terms of prior beliefs and the explanations offered at school.

A more recent South African study, but one which investigated science *teachers'* understanding of the Universe, indicated that “more than three out of four of the respondents proffered IKS related explanations of beliefs compared to the scientific explanation for the origin of the Universe” (Webb, *et al*, 2006, 713). This very high percentage of IKS-related answers could be a reflection of the phrasing of the question that they used, which was: “Many scientists believe that the Universe occurred by chance, and since then has been undergoing continuous evolution. On the other hand, many people adhere to the religious or cultural view that a supernatural being created and controls the workings of the Universe. Express your candid opinion on both worldviews" (*Ibid*., 719). In my study, 71% of the students who were simply asked "What is the Universe?" gave a response that was linked to WMS, with only 19% giving an answer that was based on alternative beliefs. However, the conclusion drawn by Webb *et al*. (*Ibid*., 718) was that their study "reinforced the argument for the inclusion of learners' religious worldviews in the science curricula and classroom discourses that deal with various natural phenomena of which they hold specific beliefs" - a view that is supported by the current study.

5.1.2.6 OVERVIEW OF THE RESULTS REGARDING PRIOR KNOWLEDGE

The results from Tables 5.1 to 5.12 are summarized in Table 5.13, with Table 5.14 providing an overview of the numbers of students who mentioned IKS or religion in response to the six questions in the pre-instruction questionnaire.

TABLE 5.13: Overview of worldview profiles held by the students

Questions:	What is a star?	What happens to the stars?	What causes day and night?	What causes the seasons?	What causes Moon phases?	What is the Universe?
Sample size n =	191	191	191	191	191	140
Students with WMS worldview	68 (36%)	21 (11%)	137 (72%)	144 (75%)	109 (57%)	100 (71%)
Students with AB worldview	64 (34%)	117 (61%)	17 (9%)	22 (12%)	29 (15%)	27 (19%)
Students with combination of WMS and AB	49 (26%)	46 (24%)	36 (19%)	9 (5%)	10 (5%)	11 (8%)
Students who didn't respond to the question	10 (5%)	7 (4%)	1 (0.5%)	16 (8%)	43 (26%)	2 (1%)

Colour coding for Table 5.13:
Blue: Worldview based on Western Modern Science
Green: Worldview based on Alternative Beliefs
Yellow: Worldview is made up of a combination of ideas from Western Modern Science and traditional culture or religion

TABLE 5.14: Overview of the numbers of students to mention IKS and/or religion

Questions:	What is a star?	What happens to the stars?	What causes day and night?	What causes the seasons?	What causes Moon phases?	What is the Universe?
Students who mentioned religion	7	0	13	6	7	12
Students who mentioned IKS	10	9	10	2	13	0
Students with 3 conceptions	0	3	0	0	0	2*

* One of the three conceptions given by these two students was religious

FINDINGS FROM TABLES 5.13 AND 5.14: OVERVIEW OF PRIOR KNOWLEDGE

Prior knowledge based on Alternative Beliefs:

The highest numbers of answers linked to religion were found in response to the questions ‘what causes day and night?’ and ‘what is the Universe?’: these were the two questions that were most closely linked with prior knowledge based on Biblical ideas. The questions regarding seasons and Moon phases did not have the same emotive connection with religion, and here the answers rather revealed a teleological understanding which evinced an organistic rather than a mechanistic view. Very few students provided responses that gave a direct indication of knowledge based on IKS, but the traditional worldview perspective was implicit in the animism and anthropocentricism contained in many of the ideas categorized as Alternative Beliefs.

One question was anomalous in terms of coding between WMS and AB: whereas all the other questions showed a large difference between the number of students holding either a scientific view or alternative beliefs, the question ‘what happens to the stars during the day’ was heavily weighted towards alternative beliefs. The intuitive understanding that the reason stars fade from view in the morning and reappear at night is that their light is overwhelmed by the light of the Sun is so commonly held and makes such common sense that it is seldom questioned or even raised. However, as with so many of the other concepts in basic astronomy, the scientific explanation is not intuitive, nor is it based on observational experience. The rarity of correct responses indicates that the concept of light scattering in the atmosphere is not commonly taught at school, despite being part of both the Geography and Science curricula.

The most closely aligned number of responses between WMS and AB related to the question ‘what is a star?’. This may possibly be linked to the depth of folklore associated with the stars, the African Traditional Religion connection between stars and the ancestors, or simply that the question, through asking '*what*' is a star, did not demand more than a descriptive answer.

IKS and religion were referred to 91 times in the pre-instruction questionnaire. These references were made by 63 of the students, indicating that individual students may have referred to IKS and/or religion in response to more than one question. Only four of the 63 students referred to both religion and IKS in their questionnaire. The breakdown of these references is given in Appendix 12, where it can be seen that there were 44 references to IKS and 47 to religion. These 91 references (out of a possible 1095 answers: 191 students x 5 questions plus 140 students x 1 question), amounted to 8% of all the possible answers that could have been given. If all the responses listed under alternative beliefs (i.e. 'personal' and 'everyday' beliefs) were added together, with the exclusion of the two questions making up the 'ideas about stars' (where many of the responses were descriptive) the picture would be similar, with only a small percentage offering alternative explanations, indicating that students had been taught about these concepts at school.

Prior knowledge based on Western Modern Science

The question that scored the highest number of answers connected to science was 'what is the Universe?' The Earth Science understanding of the term is different to religious or traditional understandings, where 'Universe' is associated with creation and egocentricity, and is not just a descriptive term for a spatial dimension containing physical entities and forces. There were relatively few students who only gave an 'organistic' view, indicating that the term had been taught, possibly at church or at school.

An interesting finding was the almost even split between students whose scientific understanding was limited to a solar system conception (a 'meso-view) and those who indicated knowledge of space beyond the solar system (a macro-view). Both views are the result of science and science teaching, and possibly indicate an interpretation of the Geography curriculum, where the 8 planets (Pluto was demoted at the 26th General Assembly of the International Astronomical Union in Prague in August 2006) of the solar system and extra-planetary bodies such as natural satellites and comets are the focus of attention and the cosmos beyond the solar system may be seen as an optional extra.

Concepts such as day and night, the seasons, eclipses, phases of the Moon and tides are taught as part of the school Geography curriculum, usually for the last time in Grade 8 or 9. As noted under 'prior knowledge based on alternative beliefs' the majority of students gave answers based on WMS. However, there is evidence from the number of responses listed 'WMS simple' and 'WMS problem' that clear mental models of the science explanations have not been constructed.

Prior knowledge indicating a combination of knowledge systems

The two questions used for 'ideas about stars' indicated a similar number of students holding a combination of ideas (i.e. 49 and 46). However, these combinations tended to be descriptive (categorized as AB), but containing some reference to science, for example that stars 'emit energy' or they are 'in the galaxy'. The number of students to hold clearly different conceptions was few, and usually involved a combination of 'WMS correct' and 'AB religious' as in the following example, which comes from one of the 15 students to hold such a combination:

What is a star?

1.1 A star is sun which can also have planet around and his own system, for example, I can say that our sun is a star

1.2 - (no source of information given)

1.3 A star is a light which I can see during the night, and also were created by God in the Genesis of the world

1.4 Bible (04.MS.46.PRE)

There were only three examples of a combination of 'WMS correct' and 'AB IKS', of which the following, involving a repeat student, is the clearest (and indicative of what may, as a second time around, indicate a managed border crossing):

What causes day and night?

2.1 When the earth rotates one side faces the sun and another doesn't, thus one side is dark (night) and another light (day) (diagram shows sun Earth with 'axis around which the earth rotates' and day labeled on sun side and night on dark side)

2.2 First year Geol 104, 2003

2.3 Around the time to be dusk, somehow, it becomes dark - sun switches off and around dawn sun switches on.

2.4 Grandparents (04.MS.34.PRE)

The other question to have a fairly high number of combination views (i.e. involving 36 students) was the question about day and night, and here the combination again involved science and religion, which was linked to the Biblical "let there be light".

The questions about seasons, Moon phases and the Universe did not provide many examples of students holding a clear combination of views. Here the combinations usually simply involved general references to teleology, and 'simple descriptive' science.

5.1.3 SOURCES OF INFORMATION

The source of information of students' answers to the content questions in the Pre-instruction questionnaire

The content questions had been set up not only to elicit what the students thought the scientific answers were, and what their personal understandings were for each question. They were also asked to identify the source(s) of this information. It is acknowledged that it cannot be assumed that everything learnt at home or in the community would fit into the category of knowledge based on alternative conceptions, and anything learnt at school, or through the media sources listed, would fit into the category of Western science. However, despite the possibly ambiguous nature of this data, it was to provide some insight into the sources of the different kinds of prior knowledge of the students.

I was particularly interested in the role grandparents played in passing on traditional understandings of natural phenomena to their grandchildren, by comparison to the explanations given by the parents. In traditional extended family situations, as was typical in the farming area in which I grew up, it is often the grandparents, particularly the grandmother, who looks after the grandchildren. As urban migration has resulted in the growth of townships so there has been a breakdown in traditional family structures, accompanied by an increasing Westernization of Black society. This has resulted in the 'cultural distancing' referred to previously, where with the passing of generations, traditional explanations are not passed on, especially by parents who want a Western education for their children. As a result, these children may not have been exposed to traditional explanations, unless they were told them by their grandparents.

In African culture, there are also taboos and beliefs, even in families that are highly westernized, that may remain hidden or dormant until some crisis causes them to emerge. This can most commonly be seen in the practice of medicine, where people will revert to traditional healers if Western medicine is not seen to be effective[18]. While the inferences that can be made between the source of the knowledge and the knowledge itself may be weak, it was felt that interesting connections could possibly be made, firstly, in the light of the fact that cultural border crossing claims that the stronger the attachment to traditional values, the more difficult it will be to cross the borders into science, and secondly, that inferences could be made about how traditional cultural understandings are being lost as the younger generations 'succumb' to Western culture.

[18] Malcolm and Alant (2004) report that 80% of South African black people seek traditional healers as well as, or instead of, 'western style' medical doctors, when they are ill or troubled.

Table 5.15: Sources of information

Possible source of Western Science conceptions	***Number of references***
1. 1.1 School and teachers	401
1.2 Books (e.g. school text books/encyclopaedias)	275
2. Media	
2.1 television	92
2.2 newspapers/magazines	39
Total number of references	807
Possible source of alternative conceptions (traditional or religious)	
3. Family	
3.1 parents	194
3.2 grandparents	26
3.3 siblings or other family	29
4. Community (including religious input)/friends	33
5. Own thinking/reasoning/understanding/observation	238
Total number of references	520

The six content questions each provided the opportunity for the students to give two sources of information: one for the science explanation and one for their personal explanation. Of the possible 2292 opportunities to provide information about the source of knowledge (191 pre-instruction questionnaires x 6 questions x 2 sources of information), 1327 answers were actually given, representing 58% of all opportunities.

From the data that was provided, “school” was given the most number of times, confirming Reddy’s (2006) suggestion that for rural children especially, this kind of knowledge can only be obtained at school. “Family”, especially parents, was also very important as a source of knowledge for their children, and while in Table 4.3 they have been listed under “possible source of alternative conceptions” clearly this is an assumption, as parents may themselves hold, and teach, the WMS explanations for natural phenomena. Direct reference to community as a source of knowledge was minimal, with only three students referring to “Elders” – most of the responses listed under community were in reference to religious sources or friends. One of the interesting findings was the number of references ascribed to “my own thinking/reasoning/understanding/observation”, indicating how knowledge is often unconsciously absorbed, resulting in it then not consciously being associated with an external source.

Some of the more unusual sources of information were “Chappies wrappers” and “Astros” (bubblegum wrappers and candy boxes which have ‘snippets’ of information written on them), and a few Hollywood movies, such as “The Lion King” and “Star-Trek”.

5.1.4 SUMMARY OF THE FINDINGS OF PRIOR KNOWLEDGE FROM THE PRE-INSTRUCTION QUESTIONNAIRE

The aim of this study was to investigate whether a traditional African worldview was prevalent in first year Geography and Geology students doing a course in basic astronomy, and if so, if it was affecting their learning. The primary aim was thus not to establish their understanding of the geometry or physics of the Universe, but rather to try to establish whether culture was affecting their ‘border crossing’ into the world of science. Using constructivism as a theoretical framework, the purpose of the pre-instruction questionnaire was to record the prior knowledge of the students to establish the possible existence of such a worldview.

The assumption on which the questions were based was that all the students would have been exposed to the concept of a heliocentric solar system at school. All were matriculants, who had achieved sufficiently good results to be accepted into university. All would have done Geography at the Grade 9 level as it only becomes an optional subject from Grade 10. Consequently all should have completed a unit on basic astronomy which included concepts such as rotation and revolution, the phases of the Moon, eclipses and tides. These concepts are not covered again in the Geography syllabus, so even if the students had taken Geography as a matric subject, they would not again have received formal teaching in basic astronomy. The first year university course, the Earth in Space, thus assumes a basic background in Astronomy and the curriculum is structured to build on this basic knowledge. However, the question that was raised in this study was what actually *was* the prior knowledge of the students?

The results of the six questions asked in the pre-instruction questionnaire indicated that the level of scientific knowledge was very poor. The predominance of answers categorized as WMS simple, WMS problem, AB everyday and AB personal indicates that the effective and meaningful construction of the Western science model of the Earth as a cosmic body has not been successful at school level. Albanese *et al*. (1997, 588) point out that:

> “…for the effective … construction of a model of the Earth as a cosmic body, in the Copernican paradigm, it is necessary to work not only with the non-local astronomic phenomena, but, also, with the physical questions associated with these phenomena (gravity, inertia, composition of movements, etc.). Moreover … reference systems (are) the most important factor in the astronomy of position.”

The difficulties of relating personal observations to abstract theoretical models requires a change in reference systems that Bishop (1996), drawing on Piagetian developmental levels, suggests is not yet developed at the time that students are typically taught these concepts (which in the United States and South Africa is in the eighth or ninth grade).

Most of the studies documenting astronomical conceptions have been conducted on school-age children, but a few that have been conducted on university level students provide some basis for comparison with the results obtained in this study. Direct comparisons of research results are difficult to obtain, however, as most studies are nuanced by the particular interests of the researchers and the different methodologies that are used. Examples that provide some basis for comparison have included Parker and Heywood’s (1998) study of first year Bachelor of Education students in England. Their results indicated that only 10% of their sample was able to give a scientifically acceptable explanation for seasons and 10% for phases of the Moon - most provided alternative or ‘intermediate’ views. Trumper (2000), working with university students entering an ‘Introduction to Astronomy’ course in Israel, recorded 67% correct responses for seasons and 51% correct for Moon phases, but the methodology used in this study was multiple choice questions, which could be expected to produce different results to those obtained from open ended questions, where decisions need to be taken as to how much information constitutes a ‘scientifically correct or acceptable’ explanation. In comparing his results with those of another study on which his questions had been based (Zeilik *et al*, 1998, in Trumper, 2000) Trumper recorded that the Zeilik results were lower than his: for example, 31% had answered the question about Moon phases correctly. Trumper explained these differences by referring to factors such as the gender distribution of the samples (males were found to perform better than females), the courses the students were enrolled for (for example science majors by comparison non-science majors), and courses taken at school.

In the light of international studies such as those mentioned above, the weak scientific background knowledge encountered in my students was not unusual. In addition, in South Africa, there is the effect of syncretisms which are associated not only with personal views being inconsistent with the explanations and models of science, but those associated with cultural or worldview conceptions which are organistic (Lemmer *et al*., 2003) rather than mechanistic. When these factors are combined with the difficulties associated with language in education in South Africa (Rollnick, 1998(b); Rollnick, 2000) and the lack of resources in many classrooms (Bot, Wilson and Dove, 2000), the lack of basic knowledge becomes unsurprising, rather than incredible, as suggested by Lemmer *et al*. (2003, 578).

5.2 THE POST-INSTRUCTION QUESTIONNAIRE: REFLECTIONS ON LEARNING

5.2.1. INTRODUCTION

The purpose of the post -instruction questionnaire shifted, as the study progressed, from serving to establish conceptual change and the existence of collateral learning and border crossing, to an investigation of barriers to learning and the nature of border crossing experienced by students doing the ‘Earth in Space’ course. An early analysis of some of the data gathered in Phase 1 had indicated that on paper at least, conceptual change had taken place as a result of the course. But what had also been revealed, through the inclusion of a few additional questions where the students had been asked to reflect on the course in terms of what they found hard to understand and believe, was the intensity of feeling generated by some of the concepts that had been taught, particularly regarding theories about the formation of the Universe. As a result, the decision was taken to concentrate on the questions that explored border crossing and learning difficulties related to worldview. This decision was also a consequence of the first set of interviews in 2002, where the ‘pain’ of cognitive conflict and its effect on the students’ lives had become disturbingly apparent. For an African student – a “notoriously religious being” (Mbiti, 1969)

- with a religious family background, a comment such as “I used to go to Church with my family, but I no longer can do that after the course, because I don’t know what to believe any more” (02.122.25 interview) was a very strong and worrying statement.

Consequently, the results and analysis of the post-instruction questionnaire are presented in this chapter as follows:

1. **Phase 1**: Conceptual change: results of the content questions
   (Questions 1 to 6 in the first section of the post- instruction questionnaire in comparison to Questions 1 to 6 of the pre-instruction questionnaire)
2. **Phase 2**: Barriers to learning related to worldview: results of the ‘reflection’ questions
   (Questions 1 to 11 in the second section of the post- instruction questionnaire, including the biographical questions)

5.2.2 CONCEPTUAL CHANGE (PHASE 1)

(Post-instruction Questionnaire results from the content questions, Section 1 of the questionnaire)

The College of Science group was the only Phase 1 group where it had been possible to organize a sufficiently long ‘lag’ period between the administration of the two questionnaires to meet Jegede’s requirements that collateral learning only applied to long term or deep learning. Consequently only data from the 2002 College of Science group (from students who completed both the pre- and post-instruction questionnaires, n= 20) was used to establish the extent of conceptual change that had been effected by the course between the administration of the pre-instruction and post-instruction questionnaires. The analysis of the pre-instruction questionnaire data had indicated that accurate scientific understanding was limited, and that although only infrequently stated, there were ideas that were not always consonant with the WMS account. Establishing first the prior knowledge, and then the extent of conceptual change, was the first step in establishing whether the students had succeeded in crossing the borders from their worldview into the worldview of science, and what forms of collateral learning they were using to accomplish this.

The results for the twenty two students in the College of Science (2002) sample who completed the post-instruction questionnaire are provided in Table 5.16 on the following page. From this table it can be seen that only three students continued to hold what were categorized as ‘alternative conceptions’ (highlighted in red in the table). All three were in relation to the question ‘what is a star?’.

Table 5.16: Pre and post-instruction questionnaires: Results of the content questions

Student	Question 1		Question 2		Question 3		Question 4		Question 5	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	1.2	1.2	1.1	1.1	4	1.1	1.2	1.1	1.2	1.1
2	2	1.2	1.1	1.1	4	1.1	1.2	1.1	2	1.1
3	3	3	4	1.2	3	2	3	1.2	5	1.1
4	3	1.1	1.2	1.1	2	5	4	5	5	1.1
5	1.2	1.1	2	1.1	2	1.1	1.2	1.1	1.2	1.1
6	1.1	1.1	5	1.1	1.1	1.1	1.2	1.2	1.1	1.1
7	3	1.2	1.2	1.1	4	2	2	1.2	2	2
8	2	1.1	1.1	1.1	2	1.1	2	1.2	1.1	1.1
9	3	2	1.1	1.1	3	1.2	2	1.1	2	1.1
10	3	3	2	1.1	2	1.1	2	1.1	3	1.2
11	3	1.1	1.1	1.1	2	1.1	4	1.1	1.1	1.1
12	1.1	1.1	1.2	1.1	1.2	1.1	1.2	1.1	1.1	1.1
13	1.2	2	1.2	1.1	5	1.2	1.2	1.2	5	1.1
14	3	3	1.1	1.1	4	2	2	1.2	4	1.2
15	4	1.1	1.1	1.1	2	1.1	2	1.1	1.1	1.1
16	3	1.1	2	1.1	2	1.1	1.2	1.2	1.1	1.1
17	4	2	1.2	1.1	4	1.2	2	1.2	3	1.1
18	1.2	1.1	1.1	1.1	1.1	1.1	1.2	1.1	1.2	1.1
19	4	1.1	1.1	1.1	4	1.1	2	1.2	1.2	1.1
20	3	1.1	1.2	1.2	3	1.1	3	1.1	4	1.1

n = 20

Questions:

Q1: What is a star?

Q2: Where do the stars go in the daytime?

Q3: Why does the Moon appear to change its shape?

Q4: Why is it colder in winter than in summer?

Q5: What is an eclipse and why does it happen?

Note: The question 'what causes day and night?' was omitted from the post-instruction questionnaire, as it was clear from the pre-instruction questionnaire that students in this group all held WMS explanations for this question.

Coding:

Answers based on WMS: 1.1 Clear, correct and full explanation given
1.2 Partially correct
2 Science misconception
Answers not based on WMS: 3 Alternative beliefs
Blanks: 4 No answers given
5 Answer makes no sense

While there were a few post-instruction answers that made no sense (score of 5), *all* the other responses were scored as follows:

1.1 (clear, correct and full explanation given),
1.2 (partially correct answer, but one still based on WMS) or
and
2 (a misconception, but one which was also based on WMS),

This indicates that apart from three answers, all the others were now based on WMS. Most of the students had thus retained the explanations presented in the course for a period of about 5 months, which pointed to an acceptance of the WMS explanations. This finding supports Bishop’s (1996) contention that a critical factor in learning the concepts of basic astronomy relates to exposure when the students are developmentally ready to understand them, and, of course, the fact that astronomy must be explicitly taught.

While the findings shown in Table 5.16 demonstrate a swing to the explanations of WMS, the students’ responses to the questions in the second part (i.e. section 2) of the questionnaire, regarding what they had found difficult to understand and believe, presented a different picture to the simple findings shown here.

5.2.3. BARRIERS TO LEARING (PHASE 2)

As noted, after the second phase of data gathering, the focus of the study shifted to an interest in what the students had found difficult to understand and believe, and why. The fact that they were able to change their understanding had been established. What had emerged as a more fruitful area of investigation was related to the barriers to learning in this field.

Section 2 of the questionnaire was made up of 11 questions, some of which sought to reveal epistemological issues that could be affecting border crossing and collateral learning and some of which asked simple questions such as ‘who was your primary caregiver?’ and ‘where did you go to school?’, which were intended to capture personal information which could be helpful in the analysis of the other questions. These two different types of questions were coded slightly differently: Questions 7 to 10 simply provided numbers of students who, for example, attended urban schools compared to rural schools, while Questions 1 to 6 and Question 11 were more complex: as a result they were coded using the two methods that had been used in the analysis of the pre-instruction questionnaire. Method 1 was thus used to record the numbers of students who responded in particular ways to selected criteria, and Method 2 recorded the detail of the students' responses through the use of ‘code statements’. As with the pre-instruction coding, all the responses to these questions (i.e. from both phases of data collection), were coded using *Atlas.ti*.

The results and analysis of the post-instruction questions are presented as ‘reflections’ on issues of learning in the following way:

Reflections on understanding: Question 1
Reflections on believing: Question 2
Reflections on border crossing and collateral learning: Questions 3, 4, 5 and 6
Reflections on influences on learning: Questions 7, 8, 9 and 10
Reflection on values: Question 11

5.2.3.1 REFLECTIONS ON UNDERSTANDING:

Section 2 of the post-instruction questionnaire was introduced in the questionnaire as follows:

> Please answer the following questions as fully as you can. They are to help me understand how you have dealt with the information in the course to see if the way you think about certain natural phenomena has changed as a result of the course understand any difficulties or problems you may have had with the content of the course.
>
> 1. Was there anything in the Earth in Space course that you found **hard to understand**? Please explain your answer by telling me what and why.

The intention of Question 1 was to allow for the emergence of cognitive difficulties in relation to specific content areas. However, despite having read through the questionnaire with the students before they started answering it, and thereby making them aware that a question about what they found hard to *believe* followed the question on understanding, many of the students did not just list the issues they had had problems understanding. They also explained *why* they had a problem. Table 5.17 on the following page is thus divided into two sections: the first provides details regarding *what* was hard to understand (n = 163), and the second provides the additional details regarding *why* some of them found it hard to understand.

The 'double answer' (what and why) given by some students meant that some referred to the answer they had given in Question 1 as their answer to Question 2. However, overlap between the questions was inevitable, as they were all aimed at gaining insight into the students' ability to cross the barriers from their culture and worldview into the culture and worldview of science.

What was hard to understand?

As can be seen from the listing of examples of code statements in Table 5.17, in a number of cases individual students referred to several issues falling under the same general category. For example, under the category 'formation of the Universe' a number of students indicated that they did not understand the concept of a *singularity*, as well as having problems with the *Big Bang theory* and the concept of the *formation of stars*. Consequently the 'number of references' within each category is greater than the number of students who made reference to problems in that area. The inclusion of this information in the table, i.e. the frequency of occurrence or 'number of references' to the code statements for each category, serves to indicate the weight of the difficulties - the fact that students were 'vocal' in expressing their difficulties is visible through the number of code statements and the number of references to these code statements. The examples of code statements given in each category serve to illustrate the areas of difficulty in this specific category, as expressed by the students. The number in parentheses after each code statement refers to the number of times reference was made to that particular issue.

TABLE 5.17: "What did you find hard to understand?"

***What* was hard to understand?**	Number of students who expressed a problem	Number of references to problems in this area	Examples of the issues (as code statements) most frequently mentioned, followed by the number of times that particular issue was mentioned in parentheses **
Formation of the Universe (Issues related to Big Bang Theory)	49	71	Big Bang theory (38); problem with singularity (9); formation of the Universe (5); formation of the stars (3); size of the Universe (3); origin of the Universe (3)
Formation of the solar system (Issues related to Nebula Theory)	30	44	Nebula theory (20); formation of the Earth (3); composition of the planets (3); distance from Earth to the Sun (2); 3D concept of the solar system (2)
Big Bang AND Nebula Theory *	9		
Issues related to the Earth	22	25	Tectonism and plate tectonic theory (5); Tides and eclipses (5) Phases of the Moon (4); Stratigraphy (1); Mapwork (1)
***Why* was it hard to understand?**			
Epistemological issues related to the theories (Big Bang and Nebula theory)	26	32	Origin of Earth: theories conflicted with my religious beliefs (5); Where did the singularity come from? (4); Evolution (3) Where was the singularity before the Big Bang? (2)
Personal issues	15	16	Terminology/language too difficult (5); course was difficult: hearing work for the first time (3); missed work and struggled to catch up (2); difficulties linked to health (1); need to settle into university ways (1); did not go to lectures (1); difficult first course: lost interest (1)

* The 9 students who listed both Big Bang and Nebula theory are not included in the 49 who had difficulty with Big Bang only, or the 30 that had difficulty with Nebula theory only. However, the references they made to these theories are included in the frequencies of the code statements related to the Big Bang and Nebula Theories. This situation pertains to all other combinations in the tables in this chapter.

** Unlike the tables in Section 5 Chapter 1 (the pre-instruction questionnaire results) the examples of code statements here are not necessarily limited to 3 examples.

Sample: n = 163

(this includes blank: n = 4)

Students who "did not find anything hard to understand" : n = 42

Students who indicated that they *did* find something hard to understand:

n = (49+30+9+22+2) = 112

Students who gave a response regarding *why* they found difficulties in understanding but did not include information of *what* they found difficult to understand: n = 5

(n = 163 does not included students who listed issues related to the Earth AND Big Bang OR Nebula theory, where : n = 2, as they have already been included)

The 112 students who indicated that there was something that they did not understand in the course represent 69% of the sample. Of these, 90 students (49+30+9+2) or 80% of the 112, made reference to problems related to the Big Bang and Solar Nebula theories. The remaining 22 students referred to a variety of issues which were not linked to these theories, but rather to 'Earth-related' concepts such as tectonism, with some even referring to issues outside of the Earth in Space course, such as the tri-cellular model of air circulation and mapwork. It is clear, however, that the most frequently referred to problems related in some way or other to the scientific explanations for the existence and formation of the Universe. The following responses serve as examples of the students' problems:

> "I find it hard to understand the Big Bang Theory because I don't really get how energy can form from a little ball, and all of a sudden there is time, matter and everything. I really don't get it" (04.MS.4.POST);

> "It was hard to understand the principle of solar nebula theory. Where do the clouds and gas particles come from?" (04.MS.16.POST)

Some of the students were even reflective in how they responded:

> "The Big Bang theory (is hard to understand), because it is impossible for human minds to tell how the Universe began. All we have are theories, which we use as work to hide the fact that we don't really know anything" (04.COS.21.POST)

Why was it hard to understand?

Forty one students provided reasons as to *why* they had found things in the course hard to understand. The 15 students whose comments are listed under "personal issues" used the opportunity to express difficulties relating to settling in to university life, such as time management problems (missing lectures and having difficulty in catching up missed work); language issues; and even problems linked to their health. One student indicated that their difficulties may simply be related to the timing of the course at the beginning of the year:

> "Adapting to a university way of teaching and learning is not easy. Some of the concepts that I did not understand, maybe I would have understood them better if they were taught now" (04.COS.25.POST);

Matric Geography is not a pre-requisite for entry to this course, with the result that tension exists in the construction of the curriculum between simply redoing school geography and ensuring that all students have a sound foundation for subsequent courses. The Earth in Space course, designed to provide this foundation, but also extend it, has traditionally been taught as the first course of the year. However, the intention to bridge the gap and provide new materials appears to have caused problems rather than solve them. Almost all the comments categorized as "problems with the theories" were either ontological or epistemological, as shown by the following examples:

> "They say in the beginning there was nothing. I fail to understand how can something (universe) start from nothing?" (04.MS.23.POST);

> "The Big Bang theory states in the beginning that there was a ball with extreme energy then exploded. So I failed to figure or find out where exactly this ball was; was it nowhere?" (04.MS.7.POST);

> ""Where did this enormous ball of energy come from? How did it form?" (04.MS.9.POST),

> "I think Nebula, Big Bang, star formation, all those things I still do not understand or maybe its because I don't believe it" (04.G.16.POST);

> "I found it hard to understand formation of the universe, because first it has to change my belief and is hard to believe that something can be formed out of nothing" (02.COS.4.POST);

> "I found it extremely hard to understand how do scientists know the internal composition and structure of all the planets and the sun, because no-one has ever been to some of the planets before. How do they know what the inside of another planet looks like?" (02.COS.6.POST);

> "The most hard thing to understand was that Solar System was come out from a huge gas some millions of years ago. I mean nobody was there by that time. How could we learn about something that happened so long time ago?" (02.COS.20.POST);

These questions are common, and are not limited to people from a traditional culture. However, one of the responses that possibly points to difficulties related to traditional knowledge is the second of the two questions posed by the following student:

> "My question is what is outside the expanding universe? The other one is that if human beings are formed by stardust, then the question is why don't we glow like stars or are we dead stars?" (04.MS.6.POST)

The information that we are 'created out of stardust' – a popular and seemingly harmless comment often made in basic astronomy classes – may cause offence in terms of religious thinking, where the problem could be linked, firstly, to differences in conceptions of time and the age of the Universe (billions of years being by required by Big Bang theory to reach our present condition and existence, compared to only a few thousand years in the case of literalist Christian belief), and secondly, in terms of evolution and creation (especially of people: from star-dust according to Big Bang theory and just 'ordinary' dust and God's breath according to the Biblical account). However, African traditional belief links the stars with dead people (ancestors). In the context of the belief that the ancestors or dead people come out at night as glowing stars, the student's questions are very meaningful and raise, for him/her, some uncomfortable issues: how is it possible to be alive, and yet not glowing if we are, indeed, made of stardust - as are the ancestors? Or, as the student asked, since we are not glowing yet are made of stardust, are we then dead?

While there was only this one student's response that could be linked with cultural understandings, there were many who raised problems with regard to their Christian beliefs. These ranged from mild and disapproving to expressions of outrage:

> "Big Bang theory. It looks so bad and not simple to understand as its against Christianity" (04.MS.33.POST);

> "It's the Big Bang theory. To me it was hard to understand, because what I knew was God created the universe, I couldn't thought that there could be something like that." (04.COS.28.POST);

> "The Nebula theory. The theory I got was a theory that I had never expected to hear and I still don't believe that theory and on top of that I don't like that theory." (04.COS.10.POST);

> "…that thing of Big Bang theory. I think this is an issue we should not touch (the whole world). I believe it was an act of God." (01.G.1.POST),

and

> "The theory of the "Big Bang". From my understanding God created the universe and everything we see. The hypothesis that man evolve from animals is also a contradiction to my Christian believe that also God is the author of all human, specifical Adam" (04.COS.23.POST)

The main issues were thus centred around the creation account as opposed to the evolutionary Big Bang and Solar Nebula theories. For many students these are mutually exclusive. However, part of the problem was that for many of the students, the concepts were just new, and seemed to require 'mental acrobatics' that they were not prepared for.

The responses to Question 1 thus give an indication of the epistemological and ontological problems that the students faced, as well as pointing to the fact that for many students, a background on which to construct such 'foreign' ideas was absent. This adds the possibility of a much stronger cultural response than was immediately apparent. African Traditional Religion and philosophy is Aristotelian in its understanding of the world: the Earth is eternal, and constitutes, together with the sky and the oceans, the known Universe. Thus while there was only one student who seemed to make direct reference to cultural beliefs, it is possible that a student with a worldview that has not been shaped by notions of space beyond the sky (i.e. school science input), and where the unknown beyond the sky is a spiritual realm (i.e. religious or cultural input), would experience far greater difficulty with border crossing than someone who has been exposed to notions of, for example, space travel, by being given a space rocket as a toy when they were young.

Question 2, which asked the students what they found 'hard to believe', released a flood of comment related to trying to absorb the new information, as well as objections on religious grounds, but there was also the indication that many students were trying to work out some form of accommodation of the new ideas.

Analysis using 'code statements'

As noted, the use of code statements (Method 2) facilitated the emergence of the student "voice". Table 5.18 provides the categories that emerged from the mass of code statements created in response to the question "What did you find hard to understand?". Examples of some of the code statements have also been given.

TABLE 5.18 : Categories and code statements for Question 1: "What did you find hard to understand?"

Categories of issues	Examples of code statements from the data
Issues related to content	
Big Bang theory (25%)*	Big Bang theory was hard to understand; Formation of the Universe was hard to understand
Nebula theory (13%)	Origin/formation of the Earth; Solar Nebula theory was hard to understand
Cosmic body movements (11%)	Planets traveling in orbits; Phases of the Moon; Eclipses hard to understand
Space link (3%)	Formation of stars; Existence of other galaxies; Shape of the Milky Way
Earth link (5%)	Stratigraphy; surface processes; tectonism and plate tectonics hard to understand
Issues related to epistemology	
Singularity (8%)	How can something start from nothing? Where did the singularity come from?
Prior Knowledge (8%)	Human beings made from star-dust; origin of Earth conflicts with religion
Issues related to learning	
Personal miscellaneous (7%)	Difficulties linked to health; Need to settle into university ways
No problem understanding (20%)	Not really anything hard to understand; No problem understanding the course

* The percentages given here, and represented in the pie chart below, are drawn from the number of students who mentioned each of these issues: see Appendix 13

The code statements were grouped together according to issues related to specific content areas; issues related to epistemology; and issues related to learning. The frequency of reference to each of the code statements within these categories can be found in Appendix 13. However, here the frequencies have been converted to percentages and are displayed as a pie chart (Fig. 6) for an easy visual overview of the relative frequency of mention of each of the categories within each of the issues.

The intention of this question had been to highlight aspects of the course that could be hampering the effective construction of knowledge. The assumption was that those concepts identified as ‘difficult to understand’ could point to conflicting prior knowledge or a lack of foundational knowledge on which to build. While the pie chart highlights the problems raised by the theories, it also provides a view of the range of other areas of difficulty, such as problems related to cosmic body movements and Earth processes.

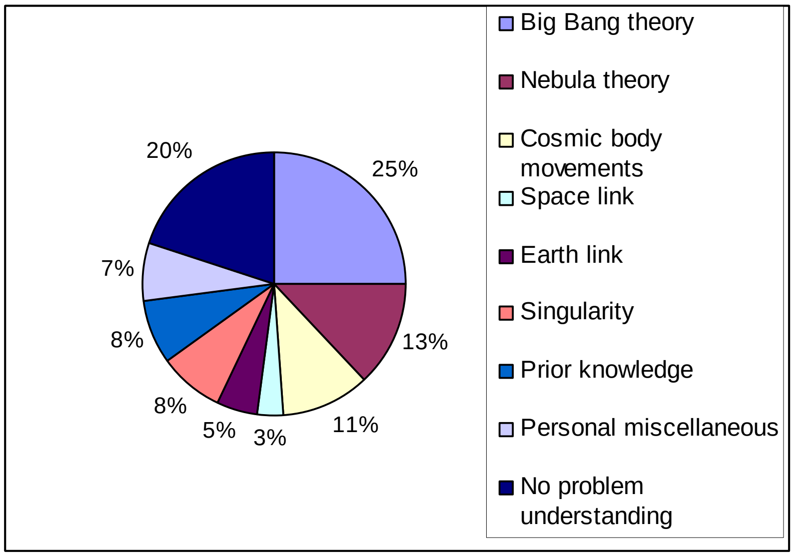

Figure 6: Pie chart showing relative frequency (as a percentage) of the categories created from code statements in response to the question “What did you find hard to understand?”

5.2.3.2 REFLECTIONS ON BELIEVING

The question regarding what students found hard to believe was stated in the questionnaire as follows:

> “2. Did any of the things you were taught **conflict** with ideas or beliefs you already had before you started the course? Was there anything that you learnt about in the Earth in Space course that you found **hard to believe**? Please explain why.”

Many of the students responded to this question by explaining *what* they had found difficult to believe, as well as *how* they were responding to the challenges to their beliefs. Consequently, Table 5.19 presents the results in two sections: the first shows the areas of difficulty in terms of content, while the second provides details of the students’ attitudes: whether they were receptive to the ideas of science, or opposed to them, or whether they were confused and facing the dilemma of having to choose between one way of understanding or another.

TABLE 5.19: "What did you find hard to believe?"

What did students find hard to believe?	Number of students who expressed problems	Number of references to problems in this area	Examples of the issues (as code statements) mentioned, with the number of times that particular issue was mentioned in parentheses
Formation of the Universe (Issues related to Big Bang Theory)	62	90	Big Bang is hard to believe (31); Singularity is hard to believe (10); Formation of the Universe is hard to believe (9); Size of the Universe is hard to believe (3); Age of the Universe hard to believe (2)
Formation of the solar system (Issues related to Nebula Theory)	26	37	Nebula theory is hard to believe (8); Its hard to believe that the Sun is the same as any other star (3) Nebula theory is implausible: just lies (1); Distance of the Sun to the Earth is hard to believe (2)
Big Bang AND Nebula Theories	11		
Issues related to the Earth	18	26	Plate tectonics is hard to believe (5); Hard to believe that the Sun does not move (2); Hard to believe in gravity (1)Hard to believe process of differentiation (2)
How did students respond to challenges to their beliefs?			
Open attitude to science: (a) Acceptance (b) Open minded	(a) 36 (b) 15	(a) 50 (b) 15	(a) No, there was nothing hard to believe (23); No, everything was feasible (9); Understood the ideas so was able to believe them (2); Scientific theories make a lot of sense (1); My original ideas were corrected (1) (b) I have an open-minded approach (7); Neither science not theology has all the answers (1); Confusion rather than conflict, but they can be reconciled (1)
Closed attitude: (a) Religion (b) IKS (c) Fatima's rules	(a) 57 (b) 2 (c) 2	(a) 69 (b) 2 (c) 2	(a) Conflict between creation and Big Bang (20); Conflict between creation and Nebula theory (14); Conflict between creation and evolution (9); Conflict geological dating and religious beliefs (2) (b) Volcanoes cause craters, not meteorites (1); Internal structure of Earth: where are the snakes (1) (c) Need to appreciate theories to pass exams (2)
Unresolved attitude: (a) conflict of belief (b) epistemological issues	(a) 4 (b) 9	(a) 4 (b) 10	(a) I now have a dilemma: which do I believe? (1); I am confused between the Biblical view and science (1) (b) How was the information for the Big Bang gathered? (3); There is no concrete evidence for Big Bang (2); Nobody was there to witness these events (2); How did they go back to the first minute? (1)

Sample : n = 163;

Blank: n = 1

Students who "did not find anything hard to believe" : n = 14

Students who did not respond with a specific area, but indicated that they had problems with issues of belief in the course: n = 29

Students who had issues related to the theories AND the Earth: n = 2

The 148 students (163 minus the 14 who did not find anything hard to believe) who indicated that there was something they did not believe regarding the course content represents 91% of the sample. This is in contrast with the 69% who indicated that they had some problem regarding *understanding* parts of the course (see Table 5.19: 49+30+9+22+2). The issues, however, remained basically the same, although the number of references to the Big Bang theory increased. This indicates that it could be there were students who did not have a problem understanding it, but they did have a problem believing it. The link between understanding and believing seems to be a personal one, as some students indicated that they were prepared to believe the information because they could understand it, while others said they were prepared to try to understand it because they believed it. This supports the study by Sinatra *et al*. (2003) which suggests that the relationship between learning and believing is a complex one, which while it is largely dependent on the student's disposition, may become even more complex when firmly held religious beliefs are seen to be in conflict with the scientific explanations.

As anticipated, this question facilitated an emotional response from the students. The reactions of those who gave an indication of their *attitude* to science have been grouped according to three categories: first, the 51 students who displayed an 'open' response to science, saying that the scientific explanations made good sense, or that they were prepared to be 'open-minded' about them; second, the 61 students who found the theories to be in conflict with their prior (religious) beliefs; and third, 13 students who were not sure what to believe - who either felt they had to make a choice, or who were questioning the reliability and origins of the scientific theories before doing so.

The Earth in Space course covers a variety of topics: the internal and external structure of the Earth, including Plate Tectonic theory, the Earth as a cosmic body, including the Earth/Moon system, the Solar System, and the unique nature of the Earth in the Solar System, (and in terms of the College of Science and Geology mainstream courses, meteorite impact structures and Palaeontology). Despite the broad range of information contained in the course, the focus here, in terms of issues of belief, fell on the Big Bang and Nebula theories. There is little doubt that if the students had been prompted or invited to specifically react to evolutionary theory, there would have been a far greater response in this area than there was. The third major theory presented in the course, Plate Tectonic theory, which is not in obvious conflict with creation theory and draws on more familiar phenomena such as earthquakes and volcanoes - and which does not require the levels of abstraction needed by the Big Bang and Nebula theories - drew limited objection. In this case the problems had more to do with students struggling to conceptualize the global processes involved in relation to their own experience:

> "Plate Tectonics is very fascinating because the continents are moving apart due to volcanoes under the sea and again the continents is huge and I think very heavy" (01.G.12.POST);

and

> "I find it hard to believe that continents were joined together so my confusion comes in between the continents there is water, the question is where does the water come from if the case is that continents were joined together" (02.G.4.POST).

The difficulties of cognitive construction, when resources such as exposure to a wide variety of learning experiences - especially in terms of learning in science - have been limited, can be seen in the following selection of responses to the question 'what did you find hard to believe?':

> " 'Sunrise' and 'sunset' – its so hard to understand because I grew up believing it, now I discovered the sun is not moving, but the Earth is moving and that we are rotating" (01.G.9.POST);

> "I want to know who measured the distance from the earth to the sun (that person is brave and it's a miracle that he still came back to earth alive)" (04.G.16.POST);

> "… the fact that gravity is at the centre of the earth it pulls everything towards it. I don't understand how we can be upside down yet standing up straight. It might be explainable scientifically, but it doesn't make sense to me" (02.COS.11.POST).

These answers are among those which were categorized as "Issues related to the Earth". As can be seen from Table 5.18, these were in the minority compared to problems with the theories of Universe and solar system formation. However, they provide insight into the levels of development of what Nussbaum and Novak (1976) termed the 'Earth concept' in these students. This could be helpful in terms of future curriculum planning that is designed to address gaps and problems in the students' prior knowledge.

In contrast to the numbers of students who indicated their problems were related to religious conflicts, there were two instances where issues of belief could be linked to more culturally traditional or IKS conceptions. The first may possibly be linked to the connection between stars – in this case shooting stars, or meteors - and beliefs regarding ancestors. This link is based on information given by one of the interviewees, who indicated that a shooting star represented someone who had "just passed" (died). This connection may be the source of the following student's reaction to the concept of meteorites and meteorite impact structures:

> "Meteorite – there is no such thing as meteorite. This whole thing claimed by scientists saying they (craters) have been structured by meteorites it just lies, this holes are caused by volcanoes by my understanding" (04.MS.23.POST).

The other student had a problem with the scientific understanding of the internal structure of the Earth:

> "Yes, internal structure of the earth. Crust, mantle and core, but in crust they didn't include snakes. At Dundee there is a place which is always producing smoke, there is coal underground, sometimes if you are underground trying to mine coal, we observe chicks and chickens walking around. Olders beliefs that there is a snake." (04.MS.44.POST)

Snakes are believed to be responsible for various unusual natural phenomena, such as earthquakes and tornados (Thamae, 2004). The chicks and chickens mentioned may be linked to the use of birds to detect the lethal odourless gases released in coal mines. The omission of these phenomena from a description of the crust appears, however, to make the scientific explanation fall short of this student's reality, and consequently the credibility of the scientific explanation is compromised.

The validity and credibility of scientific explanations was raised in the answers to Question 1, with students asking for acceptable and trustworthy forms of confirmation: who was there to see the Big Bang? How could they be so sure about what happened? What was there before? Where did the energy come from? Some of these are metaphysical questions, while others require an understanding of mathematics and physics well beyond the level of first year Geology or Earth Science. The students have learnt that 'evidence' and 'proof' are the trump cards of science. However, when the proof is inaccessible – for whatever reason - it is understandable that the reactions will be skepticism and rejection, particularly if the alternative way of knowing is one based on faith, linked to what is seen as eternal truth and which, therefore, is not seen to require proof:

> "I believe that Earth (from Bible) was made by God even though there has never been any approvals and proofs from this statement." (04.MS.31.POST)

The focus of this analysis has been on the religious response to the challenges posed by the Big Bang and Nebula theories taught in the course. However, 36 students indicated that they had no problems with the course content and that the scientific explanations made sense. Another 15 indicated a willingness to adopt the ideas of science, while those categorized as having an "unresolved attitude to science" (13 students) found the scientific explanations attractive but lacking in evidence, or attractive but costly: could they afford to give up their religious beliefs, which were seen to be in conflict with science when the price could be rejection or conflict with family or community, or even acceptance into heaven?

Analysis using 'code statements'

Table 5.20 shows the sorting of code statements (Method 2 coding) into categories which illustrate areas of difficulty in terms of what the students found hard to believe. The table of frequency of the code statements which was used to create the pie chart can be found in Appendix 14.

TABLE 5.20: Categories and code statements for Question 2: "What did you find hard to believe?"

Categories	Examples of code statements from the data
Issues related to content	
Big Bang (36%)	Big Bang is hard to believe; Formation and expansion of Universe hard to believe
Nebula Theory (12%)	Nebula Theory implausible: just lies; Nebula Theory is hard to believe
Evolution (5%)	Evolution taught as fact, not possibility; Conflict between creation and evolution
Earth link (4%)	Hard to believe process of differentiation; Conflict with geological dating
Issues related to epistemology	
Credibility of theories (5%)	Problem is there is no concrete evidence; Nobody was there to see Big Bang
Beginning of doubt (1%)	Belief in creation now being challenged; God did create, but how?
African Traditional Religion (3%)	Hard to believe in the smallness of the Earth; Hard to believe the Sun does not move
Conflict with religion (7%)	Earth was created by GOD; God created all things
Open minded approach (5%)	Neither science nor theology has all the answers; I have an open minded approach
Issues related to learning	
No problems (22%)	Gaps in my knowledge were filled; understood everything so no problems
Fatima's rules (0%)	Need to appreciate the theories to pass the exams (mentioned by one student only)

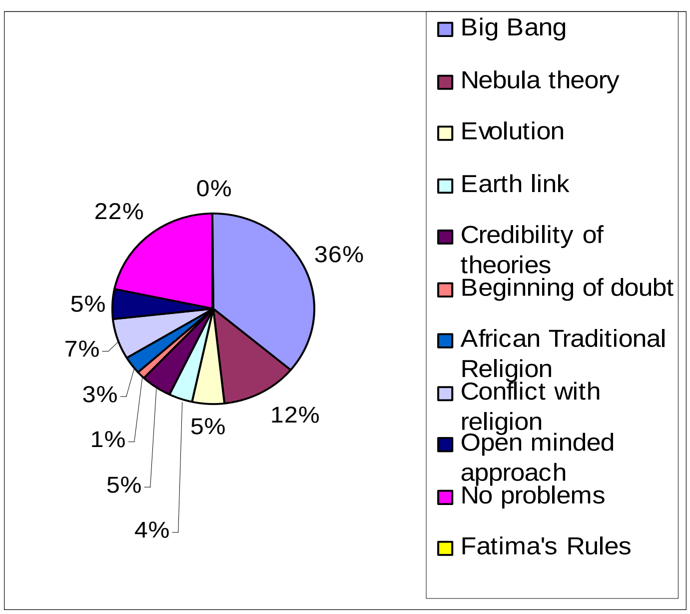

Figure 7: Pie chart showing relative frequency (as a percentage) of the categories created from code statements in response to the question "What did you find hard to believe?"

Coding in this way indicated that 22% of the code statements were related to expressions of appreciation about learning more about the Universe and how it was formed, and that there were no problems related to what the students were learning.

The question “What did you find hard to believe?” served, however, to highlight a strong emotional response to the scientific view of the origin of the Universe (and the human race), and indicated high levels of conflict and confusion at the apparently contradictory explanations given by science in terms of the students’ religious backgrounds. The most striking feature shown in the graph is that nearly half (48%) of the code statements focused on issues related to the Big Bang and Nebula theories. In fact, almost all the issues related to content had a bearing on epistemological issues: 7% specifically referred to the fact that the theories conflicted with the student’s religious views (i.e. the response was not just about *not* believing in the theories), 3% indicated that what was being taught could be problematic in terms of culture (categorized here as IKS/ATR), and 5% questioned the credibility of the theories. The nature of the question meant that even the areas mentioned in terms of content provided insight into the epistemological issues raised by the students.

5.2.3.3 REFLECTIONS ON BORDER CROSSING AND COLLATERAL LEARNING: QUESTIONS 3 TO 6

These four questions were given in the questionnaire as follows:

“3. Did any of your ideas change as a result of the course? Please explain what changed and why.

4. Do you think the science that is taught in the Earth in Space course (e.g. Big Bang theory, Nebula Theory, Plate Tectonic Theory) is the real truth about natural phenomena and how the world and the Universe works?

5. Do you think that the scientific explanations taught in the Earth in Space course are true for all situations and all people or do you think that there are other explanations that are also valid or useful or true? Please answer as fully as you can.

6. Did you find that any of the things you learnt about in the Earth in Space course suddenly made something that you had either

previously wondered about –
maybe not understood before –
maybe not thought about before –

become more clear to you or suddenly make sense to you? Please explain and if possible give an example.”

Questions 1 and 2 had served to highlight areas of content that had caused problems in terms of understanding and beliefs. Questions 3 to 6 had been formulated to try to draw out explanations that would indicate what kinds of collateral learning were taking place, and whether students were being successful or not in overcoming their barriers to learning.

Question 3 asked students whether anything they had learned in the course had resulted in any of their prior knowledge being changed. It was hoped that responses to this question could lead to insight regarding the different forms of collateral learning. The framework developed for the analysis of collateral learning and border crossing in this study had been developed during the course of the study to incorporate Barbour's Typology, which was 'borrowed' from theology because the data had indicated that conflict between science and religion formed more of a barrier for many more students than did issues that could be described as 'cultural'. Barbour's Typology has been useful not only in echoing the different forms of collateral learning, but in serving to clarify them.

However, both Barbour and Jegede's typologies suffer the 'slipperiness' of using labels as a *category* as well as a *process*: for example, in the same way that 'dependent' collateral learning describes a particular state of learning, and may also lead to 'parallel' or 'secured' collateral learning, 'conflict' can also be a process, not just an end point, leading to 'independence' or 'integration'. Consequently, the data analysis indicated the necessity of a sub-category for 'conflict': many of the students indicated that while the theories they were being exposed to were in conflict with their prior beliefs, they had not yet actually made the *choice* inherent in Barbour's 'conflict' category, i.e. to believe science *or* religion. The course had raised epistemological questions which sought confirmation or proof of theories, rather than engaging discussion ('dialogue') about different knowledge systems. '*Conflict (questions)*', which refers to situations where the students describe the science as being in conflict with their religious or cultural beliefs, but where the opportunity to discuss their questions and have them satisfactorily answered would possibly enable them to cross the epistemological barriers that prevent learning in this context, was thus inserted as a sub-category of 'conflict'.

Question 6 was formulated to investigate simultaneous collateral learning – the situation described by Jegede as occurring when there is a connection of ideas from two worldviews at the same time. The challenge in developing these questions was to frame the theory into a question, worded in such as way that it would clearly communicate what was being requested, without 'leading' and without the opportunity to explain the theory in order to make the questions clear. The wording of Question 6 was felt to be rather clumsy, despite many attempts at clarity and after a number of discussions with colleagues. This affected the responses to this question, and success in eliciting the kind of information that had actually been sought was fairly limited, as the students tended to answer the question by describing or explaining things of significance that they had learned. However, Jegede (1997, 11) had warned that collateral learning was "most difficult, if not impossible to explain or confirm", so while explanations that could be regarded as simultaneous collateral learning were few, this question did function to support Question 3, as did

Question 4 and 5, in the task of establishing patterns of collateral learning and border crossing in the sample.

As has been noted, the questionnaire was introduced to the students, at the time it was administered, by reading through the questions with them, firstly to make them aware of the different kinds of questions in an effort to avoid repetition in the responses, and secondly, because of the difficulty of phrasing of some of the questions. One of the 'solutions' was to make the phrasing of the questions as concise as possible in the questionnaire, but to provide brief verbal support at the time of the administration of the questionnaire (see Appendix 4). Despite this, some of the students responded to the questions by saying simply "yes" or "no", or by stating what was new to them in response to these questions, rather than by explaining what knowledge may have been changed and why. It is possible that these students felt they did not have related prior knowledge that had actually been replaced, or it could be that by the time they got to answering the questionnaire they only had the written questions to guide them, having by this time forgotten the supporting verbal explanations. However, as noted above, Jegede (Ibid.) has acknowledged that collateral learning is not easy to establish because of difficulties with relating the data to the theory. In this case, the students responded in such a way that, with the exception of a few cases where insufficient information was provided, it was possible to gain at least some insight into how students were responding to the challenges, and what their chances of success at border crossing would be, even if collateral learning could not be established.

Summary of the typologies used in the analysis of the data

It is probably helpful to restate here a summary of the typologies used in the analysis of data. First, the links between Jegede's levels of collateral learning and Barbour's categories of responses regarding science and religion, followed by the categories of border crossing and the nature of the students associated with them:

Collateral learning in terms of Barbour's Typology:

- **Conflict** represents both parallel collateral learning and secured collateral learning. Both forms of knowledge, i.e. science and religion, are acknowledged, but only one is regarded as true knowledge. Anyone holding this position is likely to be able to argue and justify their position, even if only very superficially (- which is the criterion that links 'secured' collateral learning to this category).
- **Independence** represents parallel collateral learning – the compartmentalization of different domains of knowledge. This serves to avoid conflict and can be a very useful (if dead end) point of view from the point of view of learning.
- **Dialogue** represents dependent collateral learning, where one worldview challenges another, where there is engagement in reflection, and where an attempt is being made to understand the views of both.
- **Integration** represents secured collateral learning in its original sense, i.e. the integration of knowledge through resolution. In the science /religion debate, true resolution, as suggested in the theoretical framework, is the domain of 'secured scholastics'. In the context of first year students, integration is at a very simple or unsophisticated level, and represents an attitude rather than an academic position.

Border crossing:

- **Smooth** refers to situations where the student's life world appears to be sufficiently congruent with the world of science that there are no obvious barriers to learning.
- **Managed** refers to situations where the worlds may be different, resulting in some problems, but these are not insurmountable and the student is likely to manage the transition into the world of science.
- **Hazardous** refers to situations where there is strong conflict between the student's life world and science. In the context of this study this category also points to a very poor grounding in school science. There is the possibility that the student may succeed – but this would probably necessitate strong academic support.
- **Impossible** refers to situations where the student is not likely to succeed in learning in science: the worlds are highly discordant and in this context the student's background so poor that even with support, the student is unlikely to be able to succeed in the time available.

Types of students:

These different types of students were first formulated by Costa (1995) in the context of a study in the United States. They were linked by Aikenhead to the forms of border crossing in his typology and serve as a further categorization related to the attitude of the students.

- **Potential scientists**: these are academically able students who enjoy science and are able to cope with its demands. Their life world in this context may be different to science, but they have the willingness to learn and the potential to succeed.
- **Other smart kids**: these students also present as academically able, but there may be aspects that are not personally meaningful to them and where they may refuse to engage in learning. In this context, this usually refers to students who experience conflict between religion and science, but this may not prevent them from succeeding in science. They may use "Fatima's rules" to deal with those aspects that conflict with their beliefs or are offensive to them.
- **I don't know students**: these are students whose lifeworld may be inconsistent with science and who are struggling to come to terms with the content and demands of the course. This category has been subdivided to include '**I don't know: disadvantaged'** in response to the data which indicated that for many of the students, the lack of chance of success is related to a very poor foundation in basic astronomy, including a lack of understanding of the Earth as a cosmic body, including a Copernican view of the solar system and even in some cases a flat Earth concept.
- **Outsiders**: these are students whose lifeworld is also inconsistent with science, but where the chance of success is extremely limited: they are either not interested, or so in opposition to the content, that it appears they have chosen the wrong course at university.
- **Fighters**: this is a new category, added in the context of this study, in response to those students who despite discordant lifeworlds and a disadvantaged background, were making an enormous effort to succeed. The 'fight for success' in which they were engaged encompassed severe strain related to finances, language skills, poor academic background, and a lack of family support as they were far from home.

The results for Question 3 to 6 are handled as follows: first, six 'overview' tables are given (Tables 5.21 to 5.26), which show the *numbers of students* involved with each of the typologies making up the theoretical framework. These tables are then followed by the students' responses to each of questions 3 to 6 in the form of code statements, given first as tables which show the relevant issues as well as examples of the code statements for each issue, and second, as pie charts, which visually present the relative importance of each of the issues for each question.

It needs to be noted before the presentation of any of the tables for this section on border crossing and collateral learning, that students experienced three different kinds of conflict which affected their border crossing: these were religious conflict, cultural conflict (in terms of IKS), and cognitive conflict. The last type of conflict was not associated with religion or culture, but occurred where the difficulty was simply that the ideas were new and overwhelming – to the point of being described as “hogwash” (04.COS.29.POST); “junk” (04.MS.20.POST) and “nonsense” (02.G.14.POST), as well as frequently being described as ‘unbelievable’.

The first three ‘overview’ tables show numbers of students in relation to the typologies of the theoretical framework:

Table 5.21: the numbers of students showing evidence of collateral learning in relation to religion and IKS, as contained in Barbour’s Typology;

Table 5.22: the numbers of students showing evidence of the different kinds of border crossing in relation to religion and IKS, and also in relation to cognitive conflict.

Table 5.23: the numbers of students, using Costa's categories, who had issues with border crossing linked to religion, IKS and cognitive conflict.

The second three overview tables present connections between the three typologies, i.e. between Barbour’s Typology of the responses to conflicting knowledge systems; Aikenhead’s typology of border crossings and Costa's typology of types of students:

Table 5.24: Barbour's Typology (in terms of religion and IKS) in relation to border crossing;

Table 5.25: Barbour’s Typology (in terms of religion and IKS) in relation to Costa's types of students

T**able 5.26**: The different types of border crossing associated with different types of students in relation to religion, IKS, cognitive conflict and ‘no problems’ students.

Each table is followed by a brief analysis of the findings shown by the table.

OVERVIEW OF TABLES: QUESTIONS 3 TO 6

Table 5.21: Collateral Learning using Barbour’s Typology

Barbour’s categories	Religion	IKS
Conflict	28	6
Conflict (questions)	23	1
Independence	15	2
Dialogue	10	0
Integration	6	0

n = 163

Students indicating no problem with religion or IKS: n = 37

Students indicating no problem with religion or IKS, but where problems of belief are based on the novelty or foreignness of the ideas (categorized as ‘cognitive conflict’: n = 35

The data in Table 5.21 support the findings from Questions 1 and 2: the greatest area of difficulty for the students was in the perceived conflict between science and religion, rather than science and IKS. This conflict was expressed as follows:

> "I believe in God and everything in the Bible and therefore anything that goes against that I do not consider" (04.MS.15.POST);

> "I still don't believe the hypotheses that the universe formed from matter that accreted together because I think God is the creator of the World and everything that is" (04.MS.4.POST);

and

> "To me, a lot of the things in the course sounds very unreal. As a result I have had conflicts with previous and new ideas. Most of the times, I personally favour my previous ideas. Since I found things such as the "Big Bang and Nebula theory" to be just a theory of fiction facts based on assumptions" (04.COS.27.POST);

and even

> "Big Bang is just a lie or an assumption (some)one made to make money. Its irrelevant" (04.MS.7.UN.POST);

Those students who were open to discussion and searching for a way to resolve the conflict, i.e. those whose ideas had been challenged and who were engaged in 'dialogue' made statements such as the following, which are illustrative of dependent collateral learning:

> "I have not believed these theories and not discarded them either. I think more explanations are still to come. I think more research work can help clarify some of the unbelievable explanations" (04.COS.30.POST).

Of the 51 students categorized under 'conflict' in terms of religion, 23 also asked questions, indicating that this conflict was the result of a lack of understanding of scientific method and philosophy, as well as a reliance on their own observations to confirm the 'truth' of the theories. Many of the students asked questions along the lines of 'who was there to see the Big Bang?' (as discussed under Question 2), but a response related to Plate Tectonic Theory makes an interesting change here and also illustrates the difficulty students have with understanding geologic time:

> "…they said like Cape Town and Brazil were one before plate tectonics. I believed then when they say like they have found similar fossils, but why are people there in Brazil and those in Cape Town speaking different languages?" (04.MS.14.POST)

Consequently an introduction to the history and philosophy of science would probably go a long way to assisting students to deal with questions such as these, as would an emphasis on helping students to come to grips with geologic conceptions of space and time.

For those students who had reached some form of resolution, i.e. independence, dialogue or integration, the decision to compartmentalize the different forms of knowledge was the most popular. Examples of this way of dealing with the conflict include:

> "Science cannot answer everything, so some of the things we can just conclude as: God made it this way and that's it" (04.G.12.POST),

to the optimistic:

> "I believe everyone and everything has their/its own truth and people would be happier if they followed and believed in those truths, also world peace would be achieved if everyone respected everyone else's truth" (04.MS.1.POST).

For those students who claimed to have resolved the conflict, it can be seen that the resolution was superficial and consequently probably fragile if subjected to intense challenge from either side. However, these students had found a way to move on without having to sacrifice one belief system in favour of the other, but also without resorting to compartmentalization (independence). Examples include the following:

> "I believed that the universe was created by GOD and now that I heard about the Big Bang it has slightly changed. I think that the Big Bang is just a theory for human to understand the way GOD made the universe. That little particle that expanded causing the universe could have been supplied by GOD and that gravity could also be supplied by him. So I'm willing to accept the Big Bang as GOD's way of creating the universe" (02.G.11.POST)

Literalist interpretations such as the six days of creation were dealt with as follows:

> "I just convinced myself that God's time is no way equivalent to our time" (04.COS.26.POST).

Conflicts relating to cultural understandings were far fewer in number, and besides difficulties with meteorites and snakes, which have already been mentioned, these include more general responses such as

> "Most explanations are just there to oppose our traditional beliefs or they are explanations of certain cultures and so they should be told in those cultures only and not in others" (02.G.7.POST),

and

> "Maybe it did in some way change my whole way of thinking, but I'll stick to my beliefs. I believe what you learn each day should not be an eraser of the past but should add more knowledge of what you know" (04.G.11.POST).

From the table and the discussion above, it can be seen that parallel and dependent collateral learning, identified through Barbour's categories of conflict, independence and dialogue, were common. 'Conflict' does not represent a potential learning situation as it is a closed position, with the decision having been taken to believe in one or the other. 'Independence' takes the middle road, a safe 'live and let live' attitude which is also largely closed to learning, but here a satisfactory way of dealing with the problem for approximately 20% of the 82 students who indicated difficulties with relating the two ways of knowing. However, 'conflict (questions)' and 'dialogue' present opportunities for a lecturer who is prepared to acknowledge other ways of knowing to act as a culture broker. This will be further discussed in Chapter 6.

Table 5.22: Cultural border crossing in relation to religion, IKS and cognitive conflict

Aikenhead's categories of border crossing:	**Religion**	**IKS**	**Cognitive Conflict**
Smooth	4	0	0
Managed	44	1	13
Hazardous	27	5	18
Impossible	6	3	4

n = 163

Students indicating no problem with religion or IKS: n = 37 (One student who indicated a problem with religion gave insufficient other information to allow me to make a decision about what kind of border crossing they would be able to achieve)

It can be seen from Table 5.22 that many of the students, despite problems, appeared to be coping with the transition from their life world into the world of science. This table includes those students (listed under 'Cognitive Conflict') who did not specify religious or cultural problems, but for whom issues of disbelief and incredulity, particularly with regard to the Big Bang and Nebula theories, were hampering their learning. While 13 of these students provided indications that they would manage to overcome their difficulties, 18 appeared to be seriously affected by their lack of background knowledge. Fundamental concepts such as the cause of day and night, the Earth as a sphere, the concept of gravity, and an understanding of space were inadequate or absent. This can be seen in the following selection of responses:

> "I thought that stars were just small light bulbs upon the skies" (02.G.9.POST);
>
> "I had always thought that the earth was a round plate and it had no interior. After the Earth in Space course, I know a lot more about the earth than I ever did before" (04.COS.15.POST);
>
> "I didn't know how the stars are formed, and I didn't know the causes of eclipses into deeper details. The only thing that I know about eclipses was that they occur when the moon covers the sun, how I didn't know. Secondly I didn't know that there is no sunset and sunrise because of the earth's rotation. Lastly I didn't know what causes the sea water to rise during the day" (01.G.10.POST).

The fact that many of the concepts of basic astronomy are counter-intuitive and very difficult to get one's head around can be seen in the following comment which shows a common way of combining knowledge that the Earth is a sphere with a lack of understanding of gravity, where only the 'upper half' can be lived on:

> "… (after the Earth in Space course)… what I have learned at school gives more sense than what I thought. But I still believe that the earth is round and cut into half where we live, and atmosphere" (01.G.4.POST)

The responses given by these students indicate that they had not moved out of Nussbaum and Novak's Notion II stage of development of astronomical concepts before attending the course. This indicates a significant mismatch between university expectations and the actual prior knowledge of the students.

One of the seemingly small changes that was made between the two phases of data collection in terms of the post- instruction questionnaire was the inclusion in the last question of 'religion' alongside 'traditional' and 'scientific' as options regarding what type of knowledge the students would teach their own children. It seemed, however, to have a profound effect on the way that students answered the questionnaire. It needs to be recalled that at the time of administration of the questionnaire, I had read through all the questions with the students before they started answering it. This meant that for the respondents in 2004, the word 'religion' had appeared once, right at the end of the questionnaire. However, this word was not present on the questionnaires administered in 2001/2. The effect can partially be seen in the fact that 22 of the 35 students who were categorized under 'cognitive conflict' came from the 2001/2 group. It is very possible that had these students had any hint that they could have mentioned religious issues in their questionnaires, their responses would have been different and more students would have associated their difficulties with religious beliefs rather than just indicating that there were cognitive problems.

Forty four of the students who referred to religion as a problem were categorized as being able to manage the border crossing. The following response is illustrative:

> "Coming from a religious background I find it very hard to believe, but if there is valid explanations to back up these theories I might be able to see things from both ways (religious and scientific) because my religious beliefs is something that I won't give up." (04.G.13.POST)

However, there were 33 students for whom the border crossing on religious grounds was hazardous or impossible. The selection of responses already provided (and there are many more) illustrate problems with a fundamentalist epistemology. An often repeated problem was related to the issue of "seeing is believing", particularly as far as the theories of Universe and solar system formation were concerned. While these theories require levels of understanding of physics and mathematics that are probably not (yet) accessible to these students, the response of several of the students to the field visit to Tswaing, a meteorite impact crater a few kilometres north of Pretoria, indicated a willingness to 'believe if I see it with my own eyes':

> "I couldn't believe that there are stone from space that could fall as meteorites. The trip to Tswaing and from what I heard before, I came to believe it" (04.MS.12.POST).

This willingness 'to believe' extended to eclipses ("when it happened I did not know what's going on but now that we have done the solar eclipse I understand what I saw" (04.G.10.POST) and Moon phases, and even to Plate Tectonic theory because the associated volcanoes and earthquakes were at least familiar terms. However, there were a few students who were not able to 'cross the borders' even with physical evidence: one of the students refused to acknowledge Tswaing as anything but volcanic, saying that there was "no such thing as meteorites" and that the suggestion that the crater could be the result of a meteorite impact was "just lies" (04.MS.23.POST).

The Big Bang theory and Nebula theories do not present opportunities for 'seeing with my own eyes' and thus require a teaching approach that addresses the students' questions and problems. This could enhance border crossing and possibly avoid the following type of situation:

> "I couldn't manage to understand so I got in the stage where I reject the whole I hear" (04.COS.28.POST)

Table 5.23 : Types of students (Costa's categories) in relation to cultural border crossing

Costa's categories	Religion	IKS	Cognitive Conflict
Potential Scientist	22	0	8
Other Smart Kids	26	1	0
I Don't Know Students	10	2	4
Disadvantaged Students	18	5	17
Outsiders	6	1	2
Fighters	0	0	4

n = 163
Students indicating no problem with religion or IKS: n = 37
Student who indicated a problem with religion but where insufficient information was given to categorize the response in terms of Costa's categories: n = 1

The students making up the sample were predominantly Black students, but it is clear from the responses, in terms of language use and levels of knowledge, that a spectrum was represented in terms of 'cultural distancing' and different schooling backgrounds. Potential scientists were those students who appeared to have a life-world that was not in disharmony with science, and who were likely, as a result of good grounding and an interest in the subject, to succeed. The 'other smart kids' were those who were also likely to succeed in learning science, but did experience problems, usually linked to religion.

These problems were usually dealt with through compartmentalization or integration, or there was evidence that the students were currently dealing with them (dialogue) in such a way that they were able to progress in their learning.

The students who were at risk in terms of border crossing comprised those in the ‘I don’t know’ and ‘disadvantaged’ categories. It is clear that a lack of prior knowledge and conceptual development in the field of basic astronomy puts these students at a tremendous disadvantage. They seemed to be struggling to come to terms with the course content, either because of cognitive conflict, and/or because of difficulties with religious or traditional beliefs. One of the critical problems as far as these students are concerned is time: on the part of the student, novel and abstract concepts take time to build, and on the part of the teaching staff, prior knowledge takes time to be accessed and assessed, and university time tables are unforgiving. The difficulty is that poor structures are built on poor foundations, as can be seen in the following comment - which represents the kind of information that is unlikely to be accessed by a lecturer in the normal course of events, but which is indicative of problems in terms of conceptual development, possibly linked to traditional conceptions:

> “I was wondering what do they mean when they say someone is going to the space, while is like we are inside a grave and why the sky is not limit” (04.MS.8.POST)

The student is clearly aware of space travel. The difficulty is, where or what is space? Is it not the sky? If someone is being sent to the sky, is that not where the dead people go, and therefore why would they send an alive person to where dead people go? The problem about how to understand the ‘heavens’ is linked not only to cultural beliefs, but also to religious beliefs:

> “Earth Science also give me lots of questions about life itself, like if there are other living creatures, somewhere where we don’t know, how is their life, technology, do they also think about us, are they also doing some research. From Christianity it made me have lot of questions, like where is heaven?” (02.COS.4.POST)

The South African Revised National Curriculum Statement states that other forms of knowledge are to be recognized and valued in the context of education. Religious and traditional knowledge, which is deeply ingrained in many students, is challenged by the scientific explanations of basic astronomy, but neither of these ways of knowing are acknowledged or valued in university courses designed to provide a basic foundation for degrees in science. According to the data, 42 out of 91 students who subscribed to other ways of knowing may be effectively prevented from crossing the borders into science as a result of these other ways of knowing. The remaining 49 have been able to work out a way to deal with the problems, but clearly the provision of appropriate scaffolding would be in the interests of both staff and students. The issue of how to tackle these other ways of knowing from the point of view of teaching, is, however, highly complex, and will be part of the discussion in Section 6.

However, a point to be noted here is the role played by the disposition of students and emotional factors associated with this disposition (Zembylas, 2005). These have been shown to be critical in learning success or failure. In addition to the 'other smart kids' who had managed to deal with problems of conflict, there were a few students who were categorized as 'fighters': these were students who did not have much going for them in terms of prior knowledge and a congruence with science, but who were determined to succeed. The extract selected from the following student illustrates this determination:

> "My ideas did not explain the theories clearly. Firstly all what I thought I know was not enough about all the theories that I learned. All the theories were interesting even if some are hard to believe. I didn't know about the formation of the stars ... and the big bang theory and plate tectonics are hard to believe. How can there be an explosion when the stars were born. Again the universe is very huge, it is not easy for an astronomer to guess that had happened. Lastly does the stars of zodiac fit into the solar system. If you do not believe these theories you need evidence to explain where you think you disagree. All I can say is that the past is the key to the future. Earth in space is still be studied by the international astronomers about the formation of the earth and other theories that we do not understand" (01.12.G.POST).

Tables 5.21 to 5.23 have provided an indication of the numbers of students involved at the different levels of border crossing and collateral learning. Tables 5.24 to 5.26 present the connections between the various typologies of the theoretical framework to highlight the relationships between them. All the data presented in these tables has been drawn from Atlas.ti.

In terms of the 81 students who indicated difficulties in relation to the science/religion debate raised by the Earth in Space course, **smooth** border crossing, where there are no obvious barriers to learning (Aikenhead, 1996), only seemed to be experienced by four students, who all compartmentalized the different knowledge systems. A typical response is that given by the following student:

> "I'm one of the most open-minded people I know, I take info I get and see where I can fit it into my personal mental library, slowly building up an impressive archive with all info I do regard as 'acceptable'. I make sure I can argue for those points. I can now explain better to theologists how science does not stand to conflict with all their beliefs… this stuff (taught in the E in S course) does make sense and I like the way it compliments theology" (04.MS.1.POST)

Most of the students designated likely to **manage** the learning had to deal with problems of conflict, but succeeded in finding a way to do so. Managed border crossing refers to situations where although the student's life world is different to science, the problems are not insurmountable, and the student is likely to manage the transition into the world of science (*Ibid*.). Most of the students who fell into this category, i.e. 28 students, resorted to parallel collateral learning, having been categorized as Barbour's 'conflict' (13 students), 'conflict (questions)' (8 students) and 'independence' (7 students). An example of a student who appeared to manage the border crossing into science responded is the following:

> "Yes, how earth and space came to existence conflicts with my religious beliefs, because we were brought up and taught about having faith in God who's the creator of everything. So its hard to believe in the Solar Nebula Theory/the Big Bang theory… but because I love the course I understood these theories and accepted them" (04.MS.2.POST).

Table 5.24: Barbour's Typology and Border Crossing

Barbour's categories: **Religion** (1 student not categorized)	Border Crossing Smooth	Border Crossing Managed	Border crossing Hazardous	Border Crossing Impossible	Totals
Conflict	0	13	14	6	33
Conflict (questions)	0	8	8	0	16
Independence	4	7	5	0	16
Dialogue	0	9	1	0	10
Integration	0	6	0	0	6
Totals	4	43	28	6	81
Barbour's categories: **IKS**					
Conflict	0	1	2	3	6
Conflict (questions)	0	0	1	0	1
Independence	0	0	2	0	2
Dialogue	0	0	0	0	0
Integration	0	0	0	0	0
Totals	0	1	5	3	9

n = 163 (One student who indicated a problem with religion gave insufficient other information to allow me to make a decision about what kind of border crossing they would be able to achieve).

Students indicating no problem with religion or IKS: n = 37

Students who indicated a problem with cognitive conflict (not included in the table)
n = 35

The 9 students listed under 'managed border crossing' who were categorized as 'dialogue' indicated an engagement with the different forms of knowledge (i.e. dependent collateral learning). While they felt challenged, they were open to the ideas of both. For example:

> “Some of the theories make sense because there have been proven, but there some question marks that are not answered (eg Big Bang). (Science) is true to some extent because of proofs, but is not true for all situations and all people, because some people believe that everything was created by God, and from their explanations, some are valid because you can even understand, but last but not least, the other true because of the solid proofs” (04.MS.22.POST).

An example of managed integration (which corresponds to secured collateral learning) is illustrated by the following:

> “Now I believe that God created everything in this way. By this I mean that he did not maybe make this things so simple by words but through these processes” (04.COS.25.POST).

Most of the students for whom border crossing appeared **hazardous** also compartmentalized the two forms of knowledge, but here religion was often privileged over science. Hazardous border crossing refers to situations where there is strong conflict between the student’s life world and science, and where the student is only likely to succeed if there is strong academic support (*Ibid*.). A typical example of hazardous border crossing includes the following response:

> “The formation of the solar system has caused some conflicts with my religion and understanding. I found it hard to believe this concepts of how planets formed because it tends to crush our religious beliefs. In some circumstances I do believe but some theory I found it being unreal” (02.G.15.POST)

For those students for whom border crossing was **impossible**, the conflict was irreconcilable:

> “I still don’t believe the hypotheses that the universe formed from matter that accreted together because I think God is the creator of the World and everything that is. Everything we learnt except the climate part was controversial and I don’t believe it” (04.MS.4.POST).

Impossible border crossing, according to Aikenhead (*Ibid*.) describes the situation where the student is unlikely to succeed in the time available: the worlds are highly discordant and the student’s background so limited, that even with support, he/she is unlikely to succeed.

As far as cultural beliefs were concerned, six of the nine records for IKS indicated that cultural beliefs and science were seen to be in conflict. Five were recorded as likely to involve hazardous border crossings, and in three cases, the border crossings were seen as impossible. The following extracts are illustrative of the problems between culture and science:

"I think that not all people would agree with these scientific explanations because many people belief in cultural explanations" (04.G.8.POST);

"I will believe what the elders of my culture have taught because it makes it clear before research" (02.G.7.POST)

Table 5.25 : Barbour's Typology related to Costa's categories of student

	Barbour's Typology in relation to religion				
Costa's categories	Conflict	Conflict (questions)	Independence	Dialogue	Integration
Potential scientist	1	2	8	5	6
Other smart kid	6	13	2	4	0
Fighter	0	0	0	0	0
I don't know student	7	2	1	0	0
I don't know (disadv)	8	4	5	1	0
Outsider	6	0	0	0	0
Total	28	21	16	10	6
	Barbour's Typology in relation to IKS				
Costa's categories	Conflict	Conflict (questions)	Independence	Dialogue	Integration
Potential scientist	0	0	0	0	0
Other smart kid	1	0	0	0	0
Fighter	0	0	0	0	0
I don't know student	2	0	0	0	0
I don't know (disadv)	2	1	2	0	0
Outsider	1	0	0	0	0
Total	6	1	2	0	0

n = 163

Students who indicated no problem with religion or IKS: n = 37

Student who could not be categorized: n = 1

Students who experienced cognitive conflict, **not** related to IKS and religion : n = 35

Table 5.25 primarily links Barbour's typology with Costa's categories of students, but is also useful in indicating the numbers of students involved in the different types of collateral learning. The connection to collateral learning is provided by using colour as a key:
The categories 'conflict', 'conflict (questions)' and 'independence' (shown in purple in the table) are connected to Jegede's concept of parallel collateral learning, where different knowledge systems are compartmentalized.
Barbour's dialogue (orange) equates with Jegede's dependent collateral learning and
Barbour's integration (green) equates with Jegede's secured collateral learning,

The most striking observation that can be made from Table 5.25 is that there was greater conflict in terms of religion versus science than IKS versus science. The only students to achieve a level of 'integration' with religion were the 'potential scientists', who also displayed the highest levels of 'independence' and 'dialogue'. While these students appear to have already achieved levels of thinking that resulted in them being placed in these categories, the 'other smart kids' appear to be in the process of asking questions: the highest number in the 'conflict questions' category were the 'other smart kids'. In contrast, there appeared to be far less conflict between IKS and science , with only one student asking questions about the apparent conflict between science and IKS.

In terms of the relationship between the categories listed in the table and collateral learning, it is clear that overall, the students most likely to succeed (the Potential Scientists and the Other Smart Kids) predominantly used parallel collateral learning, linked with Barbour's categories 'conflict', 'conflict (questions)' and 'independence' (highlighted in purple in the table), where the two domains of knowledge are placed in separate compartments. There were only 15 students (11 Potential Scientists (5+6), and 4 Other Smart Kids) who appeared to be searching for (or who had achieved) some coherence between the knowledge systems and were unlikely to be held back in terms of their learning. The single student classified under 'Religion' as 'I don't know disadvantaged'/'Dialogue' was unlikely to succeed despite openness to exploring the conflicts, as their background in science was extremely limited. The remaining 'I don't know disadvantaged' and 'I don't know' students also mainly used compartmentalization to deal with the conflicts.

As far as IKS is concerned, compartmentalization (shown in purple on Table 5.5) was also the common way of trying to deal with the conflict with science. There were not any students who entered into any form of dialogue or integration in terms of cultural understandings and scientific explanations.

Table 5.26 confirms what could be expected in terms of border crossing and the types of students for each of the response groups, i.e. students who managed to find a way to deal with their problems were likely to succeed, while those whose background was just too weak or who were fundamentalist in their beliefs were less likely to succeed.

The Potential Scientists were those already familiar with the course content and who had no conflicting beliefs, as well as a few religious students who avoided conflict by compartmentalized their different beliefs. This compartmentalization or parallel collateral learning, which is the least taxing of the ways of dealing with conflict between knowledge systems, was the common response of those who were able to manage the border crossing into science. The most common reason for 'hazardous' border crossing, which affected 58 of the students (in comparison to the 71 who were categorized under 'managed' border crossing) was poor background knowledge. The foundations that had been built were just too weak or incomplete to enable the development and extension of 'old' knowledge (for example the concept of day and night in relation to rotation, and the understanding of the Earth as a spherical cosmic body) and the construction of 'new' knowledge (particularly regarding the theories). The students in the sample had all chosen to do Earth Science at university, and had been offered a place, which should reasonably allow the assumption that some of the basic knowledge would be in place. However, the following extracts indicate that this is not so, and, as previously noted, some of the learning was taking place at disturbingly basic levels:

"Previously I was wondering why the earth is not flat and I also thought it was static" (04.MS.5.POST);

"I thought the sun was moving, but I learnt that the sun is not moving. It change my mind because the whole idea makes a lot of sense to me now" (02.COS.3.POST);

"I have always wondered about stars: how do they manage to stay up in the sky" (04.MS.6.POST);

"Is where the earth or planets spin/rotate in air or on the surface, it on the surface is it becoming flat now?" (04.MS.44.POST)

Table 5.26: Border Crossing and Types of students

	Type of border crossing			
	Smooth	Managed	Hazardous	Impossible
Type of student				
Religion	0	0	0	0
Potential Scientist	4	17	1	0
Other Smart Kid	0	20	4	0
Fighter	0	0	0	0
I don't know student	0	4	6	1
I don't know student (disadv)	0	2	15	1
Outsider	0	0	2	4
IKS				
Potential Scientist	0	0	0	0
Other Smart Kid	0	1	0	0
Fighter	0	0	0	0
I don't know student	0	0	1	1
I don't know student (disadv)	0	0	4	1
Outsider	0	0	0	1
Cognitive Conflict				
Potential Scientist	0	8	0	0
Other Smart Kid	0	0	0	0
Fighter	0	1	3	0
I don't know student	0	2	2	0
I don't know student (disadv)	0	2	12	3
Outsider	0	0	1	1
No problems students				
Potential Scientist	13	12	1	0
Other Smart Kid	0	2	0	0
Fighter	0	0	0	0
I don't know student	0	0	0	0
I don't know student (disadv)	0	0	6	0
Outsider	0	0	0	0

n = 163

There was insufficient information to classify 4 students for Table 5.26 (2 'no problems students'; 1 'religious student' and 1 student whose border crossing was 'impossible', s linked to both religious and cultural conflict)

The development of mental models of the earth as a cosmic body and member of the solar system takes time and repetition. To be confronted with concepts of space that involve distances that need to be measured in light years and star life cycles that involve millions of years when the sky is the limit and the place where heaven is, and where the stars (which are actually dead people) live, requires enormous ‘mental gymnastics’, as pointed out by the following student:

> “Some people discard any scientific explanations for anything what so-ever, especially those who are culturally/traditionally oriented. It is hard for them to switch from one thinking dimension to another” (04.COS.31.POST).

Many of the students had problems with the theories, some in terms of their novelty:

> “Like me I don’t know about Big Bang till I do geology at university this year. For people who are not doing geology when I try to tell them about the theory they think am joking or is a fairytale. People believe in different thing, but this one is difficult to understand” (02.COS.17.POST),

and some because of conflict with religion:

> “Everything of the Big Bang goes against my beliefs and the geological dating made it worst (04.MS.16.POST).

The consequence was:

> “…these things I learnt began to somehow interfere with my religion because they might be true. Everything just seems to be confusing” (02.COS.14.POST);

> “The big bang theory conflicted with what I have believe all along and now I’m kind of in a dilemma. I don’t know weather to stick to my religious belief or adapt to scientific theory” (02.COS.14.POST);

> “I am confused with the whole thing” (04.MS.21.POST);

and

> “I used to believe the explanation given in the Bible, but now Earth in space left me with a big task to do” (02.COS.16.POST).

For some the task was not so big:

> “…my parents have their beliefs and like the earth was created in 7 days, but for myself, I don’t think everything is true as different fokes, different strokes” (04.COS.34.POST);

and some gave a more considered response:

> “I think that for the people that study geography the theories are true, but ordinary people have their own explanations” (02.G.9.POST).

However, for some the results were more serious. As they went through the course, a number of students were convinced that the theories represented the ‘truth’ and consequently questioned or discarded their religious faith:

> “I always thought that God created everything but now I find it hard to believe, because the big bang theory is understandable” (04.G.14.POST);

> (The theories) “…conflict with what I was taught to believe, but it just confirmed my doubts about religion and how they were formed” (04.COS.21.POST);

> “…my original ideas were crazy compared to the scientist’s ideas… my ideas changed, because at first I thought stars were there before the beginning of time and they were placed where they are by God because he wanted to keep an eye on us during the night time by sending those angels with bright eyes” (01.G.2.POST).

The university environment, the authority of the lecturers and the evidence and proofs that are seen as the hallmarks of science, seems to have resulted in a growing scientism:

> “When it comes to the formation of the universe it is not easy to believe (but) as time was going by I came to understand how it works and now I think it is true” (04.MS.36.POST);

> “They have been proven by great scientists. Why do we have to believe Isaac Newton for the law of gravity and not believe physicists or astronomy” (04.G.14.POST)

> “All are current theories with a lot of proof backing them. More so than the ideas of religions and traditionalists” (04.COS.19.POST).

The challenges, and for many, the conflicts that arose were probably unexpected by many of the students who had opted to take Geography or Geology as a subject at university. Equally, the extent of challenge and conflict is probably unexpected on the part of the lecturing staff, who are unlikely to be aware of the extent of the impact on the students. However, in the interests of promoting learning it would be helpful for them to be aware that …

> “…there are many who reject the theories that have come forward and may take offense” (02.G.12.POST).

One of the issues not yet dealt with is the response of some of the Geology mainstream students to evolution. For these students, a course in Palaeontology followed the ‘Earth in Space’ course and because the post-instruction questionnaire was administered near the end of the year, the result was that students incorporated some of the content of courses other than the Earth in Space into their answers. While only nine students mentioned evolution, it is clear that there was a strong reaction:

> "…this truth should not be manipulated by a theory of evolution (utter crap!)" (04.MS.27.POST),

> "The whole science of evolution - I think is no longer taught as one of the science of possible origin of life, but rather forced to us to believe we have evolved" (04.MS.24.POST)

It is clear that for any university courses where theories are presented that are perceived to be in conflict with religious beliefs, the same barriers to learning could also unwittingly be being raised.

The data were also coded using the concept of code statements. The results of this coding method for Questions 3 to 6 are now presented in the form of tables and pie charts, with the findings pertinent to this method of coding being presented for each question.

ANALYSIS OF CODE STATEMENTS (Questions 3 to 6)

(Please note that the questions were abbreviated for the headings and the tables. The full question as it was asked in the questionnaire is given before the first table for each question).

QUESTION 3: "WAS ANY KNOWLEDGE CHANGED OR REPLACED?"

3. Did any of your ideas change as a result of the course? Please explain what changed and why.

Most of the students answered this question by explaining why their ideas had changed, with relatively few referring to specific areas of content where their ideas had changed. The most striking result that emerged from the code statements was the indication of "growing scientism" – the conviction that science, with all its supportive evidence and proofs for its theories, is more powerful and reliable in terms of explanation and knowledge than other forms of knowing. In terms of collateral learning, the evidence of growing scientism would seem to indicate a prevalence of dependent collateral learning, with the scientific worldview apparently successfully challenging previously held beliefs and understandings. This is in contrast to the results obtained from the deductive coding system, Method 1, which used preconceived worldview categories for analysis. Here it had appeared that most of the students had compartmentalized their knowledge. The extent of dependent collateral learning, as a process, had not been able to emerge. The 'richness' of using the two systems of analysis is thus apparent, as it is shown here that while many of the students may have appeared to have compartmentalized their knowledge, science is providing a serious challenge to both religious and cultural ways of knowing. The question that must then be asked is: is this desirable? Is it inevitable that cultural ways of knowing will be ousted by science? Do these knowledge systems actually need to be replaced for learning to be considered successful? This question will be raised and discussed in the following section.

Table 5.27: “Was any knowledge changed or replaced?” Analysis of code statements: n=163

Categories	Examples from code statements
Issues related to content	
Earth link (6%)	I used to think the earth had a top and bottom; have learnt about plate tectonics
Solar system link (3%)	Understand now how eclipses work; Learnt about orbital motion of the planets
Space link (14%)	Am now understanding space in a different way; Gained broader insight about Universe
Issues related to epistemology	
Growing scientism (61%)	Now hard to believe God created the earth; Everything can be explained by Science
Clash with IKS (0%)	Scientific ideas clash with traditional understandings (only one student)
Confusion (1%)	I am now confused by the whole thing; Ideas now confused – need more explanation
Issues related to learning	
Attempt to integrate science and religion (6%)	The course changed my approach to two ways of knowing: personal and scientific; God used natural processes for creation; the course was presented by qualified people but its important to have faith in your beliefs
Religious views not replaced (6%)	My religious ideas did not change; I will stick with my religious beliefs; I don't believe anything I have learnt
Fatima's rules (1%)	Had to replace knowledge to pass exams; Was only doing the course to pass
Cannot be classified (2%)	Answer did not make sense

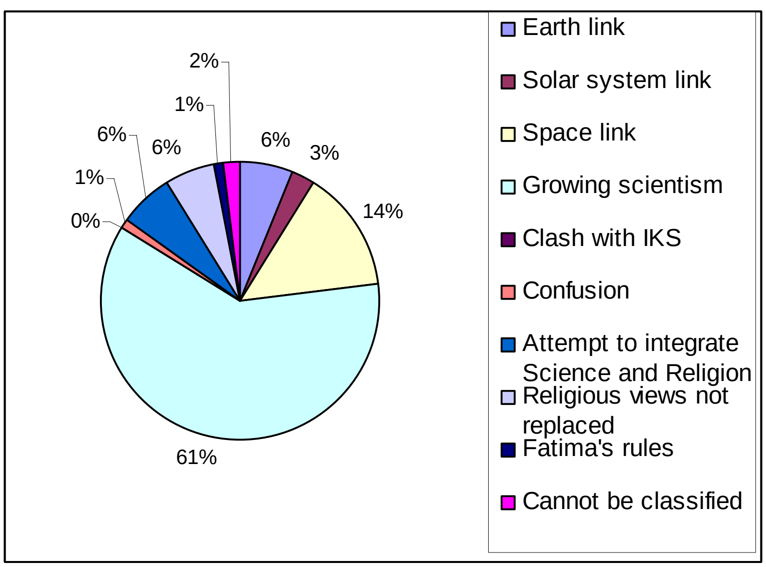

Figure 8: Relative frequency (%) of categories created from code statements in response to the question “Did any of your knowledge change as a result of the course?”

A further finding highlighted by the second method of coding is that in contrast to all the issues surrounding the Big Bang and Nebula Theories, Plate Tectonic theory, which does not have a specific Biblical equivalent, was embraced as being powerfully explanatory by most of the students. Responses that specifically mentioned changes in understanding regarding Earth processes, for example in terms of Plate Tectonic theory, and those that indicated changes in understanding with regard to meteorites or eclipses, or other issues to do with cosmic bodies in the solar system, together accounted for 23% of responses indicating replacement of knowledge. The inference is that when the knowledge is intelligible, plausible and fruitful, as suggested by conceptual change theory (Posner, *et al*. 1982), the new knowledge is embraced. However, conceptual change theory has been criticized for being too cognitive: Jackson *et al*. (1995) for example, point out that religious commitments can elicit emotionally charged reactions, with people refusing to change their beliefs even when they may at one level seem intelligible, plausible and fruitful. The responses to Questions 2 and 3 appear to bear this out: when the students were faced with the practical issue of learning science in a course they had chosen to take, the picture painted was different to when they were asked about their beliefs. Only one student indicated a clash with traditional explanations, while 6% stated categorically that their religious views would not be replaced by science. The lack of conflict with traditional ideas may be explained by one student's observation - that 'our forefathers only had their eyes' to help their observations, but now that technology was available, it made sense to accept the claims of science.

QUESTION 4: "DOES WMS GIVE THE TRUE EXPLANATION FOR NATURAL PHENOMENA?"

> 4. Do **you** think the science that is taught in the Earth in Space course (e.g. Big Bang theory, Nebula Theory, Plate Tectonic Theory) is the real truth about natural phenomena and how the world and the Universe works?

Questions 4 and 5 were specific in seeking to highlight the students' responses to the ideas and explanations given by science. The results for Question 4 were very similar to those for Question 3, which had asked if any of their knowledge had changed as a result of the course. In Question 4, again more than half of the code statements fitted into the category 'scientism', with the students referring to the convincing evidence and proof that was given by, and which supported, the theories of science.

Table 5.28 : “Does WMS give the true explanation for natural phenomena?” Analysis of code statements: n = 163

Categories	**Examples of the code statements**
Integration (2%)	Science fills in some gaps from the Bible; Science complements religion
Negative to science (6%)	Science is too full of assumptions; Science is just made up explanations
Positive to science (15%)	There is 95% chance of science being true; Plate Tectonic theory is true
Religionism (8%)	Truth is based in God; Biblical explanation came first and I trust in that
Skeptical but open (7%)	Will hold judgement – more explanation is needed; Science not real truth yet
Scientism (55%)	Science is supported by deep reasoning/proofs/evidence
Specific areas of doubt (6%)	Idea of singularity is weird; Big Bang theory is awkward – hard to believe
Unable to classify (1%)	Answer does not make sense

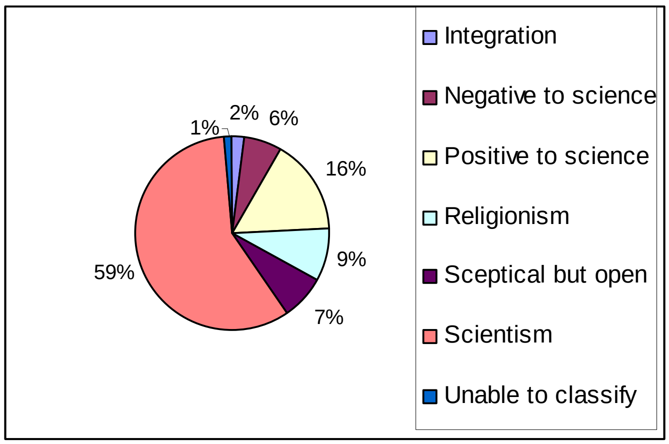

Figure 9 : Pie chart showing relative frequency (as a percentage) of the categories created from code statements in response to the question “Does WMS give the true explanation for natural phenomena?”

The category ‘positive to science’ captured specific responses that provided the opposite view to the ‘negative to science’ category: for example ‘science is 95% true’ in comparison to ‘science is too full of assumptions’. However, the ‘positive to science’ category, when added to ‘scientism’, accounted for 70% of the responses, again indicating a very positive acceptance of the explanatory power of science.

In contrast, 20% of the responses to question 4 (does Science give the true explanation for how the world works?) i.e. those that fell into the categories ‘negative to science’, ‘religionism’ (a term coined as an antonym to ‘scientism’) and ‘specific areas of doubt’, reflected the results of Question 2 (what did you find hard to believe?): those students with very strong religious beliefs continued to associate science with conflict with religion. One tenth of the responses (‘integration’ and ‘skeptical but open’ – see Table 5.28) reflected either critical thinking, for example the students who indicated they would withhold judgment until they were able to think through the issues more carefully, or superficial thinking, as in the case of students who claimed that science and religion were entirely complementary and they simply could not see any problems. However, they did not explain how they justified this claim of secured collateral learning, or in Barbour's terms, integration.

QUESTION 5: "ARE THERE OTHER VALID EXPLANATIONS FOR NATURAL PHENOMENA?"

5. Do you think that the scientific explanations taught in the Earth in Space course are true for **all situations** and **all people** or do you think that there are other explanations that are also valid or useful or true? Please answer as fully as you can.

Table 5.29 : "Are there other valid explanations for natural phenomena?" Analysis of code statements: n = 163

Categories	Examples of code statements from the data
Personal responses	
Cultural explanations (6%)	People tend to believe their parents; All communities have own theories
Fatima's rules (0%)	Just learnt the stuff to pass (stated by only 1 student for this question)
Integration (3%)	Education can change people's views; believing science is a choice you make
Reflection on debate: Science and religion	
Negative towards science (33%)	Calculations of science are suspect; Science is only theories
Positive towards science (14%)	Science is dynamic; Science offers the most valid explanations
Religion is true (9%)	Science is only true for unbelievers; The Bible is the best reference point
Scientism (35%)	Science is based on fact and truth; Explanations of science are all true

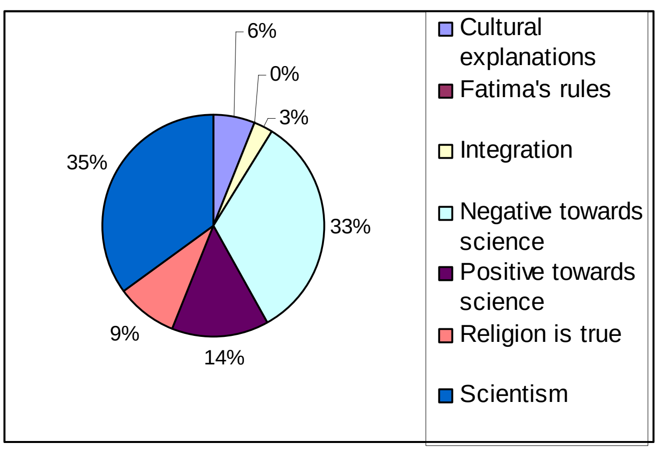

Figure 10: Pie chart showing relative frequency (as a percentage) of the categories created from code statements in response to the question "Are there other valid explanations for natural phenomena?"

The phrasing of this question, which seemed to suggest that there might be situations where science may be an inappropriate way of thinking, or that there might be groups of people for whom science may not necessarily (or always) be the preferred or valid way of knowing, served as a probe in terms of Questions 2 and 4. Question 2 had asked what the students had found difficult to believe and Question 4 had asked whether they thought that the explanations given by science were the true explanations for natural phenomena. The implication in Question 5, that science was not necessarily useful or true for all situations and all people, seemed to allow students the freedom to express their doubts about Western science in relation to cultural and religious ways of knowing. In contrast to the support for science shown in the previous questions, here there was a balance between responses indicating that science was true for all situations and all people (the categories 'positive towards science' (14%), and 'scientism' (35%), with a total of 49%) and those that indicated that science was not always an appropriate way of knowing ('negative towards science' (33%), 'cultural explanations' (6%), and 'religion is true' (9%), giving a total of 48%).

This question, and Question 11, ("What will you teach your children?"), were the questions that succeeded in drawing out a response in relation to culture. Question 5 provided the space for students to acknowledge other ways of knowing, while question 11 focused on how important those other ways of knowing were for them personally.

Issues of positionality (including power relations, with the research being conducted by a member of the teaching staff, who in terms of this question seems to provide 'permission' for other ways of knowing), as well as issues of context (these were after all science students who had chosen to take a science course) can be seen within the responses to this question. Whereas in Question 4 science was given strong support as "true" knowledge, here the 'other ways of knowing' were recognized by half the sample as also representing true knowledge. This shifting perspective indicates the human ability to slip across the borders of different ways of knowing, with truth remaining elusive, representing something that cannot easily be pinned down.

QUESTION 6: "WHAT DID YOU LEARN?"

6. Did you find that any of the things you learnt about in the Earth in Space course suddenly made something that you had either

previously wondered about;

maybe not understood before;

;maybe not thought about before –

become more clear to you or suddenly make sense to you? Please explain and if possible give an example.

Simultaneous collateral learning is one of the categories of collateral learning proposed by Jegede (1995). It refers to situations where the student connects ideas from two worlds at the same time. Question 6 was devised to try to capture situations of simultaneous collateral learning, but as already noted, the question had been rather clumsily phrased. This was reflective of the difficulty of trying to conceptualize a question that would elicit situations where students connected ideas from two worlds, but where it was not suggesting to them that this was possible.

Table 5.30 : “What did you learn?” Analysis of code statements: n = 163

Categories	**Examples of code statements extracted from the students’ responses**
Related to physical content:	
Earth concepts (24%)	I learnt about rock cycles/how mountains form/plate tectonics/volcanoes
Solar system concepts (18%)	I learnt about meteorites and comets/solar eclipses/Moon phases
Universe concepts (27%)	I learnt about the Universe and stars; I learnt about star life cycles
Related to reflections on learning:	
Problems with religion (5%)	I always thought God created stars; I was told God created everything
Problems with IKS (6%)	I used to think the earth was a plate; used to believe volcanoes caused by snakes
Still don't understand (6%)	I still don’t understand the formation of planets/gravitational forces
Convinced by science (14%)	I changed thanks to the course; My understanding has broadened

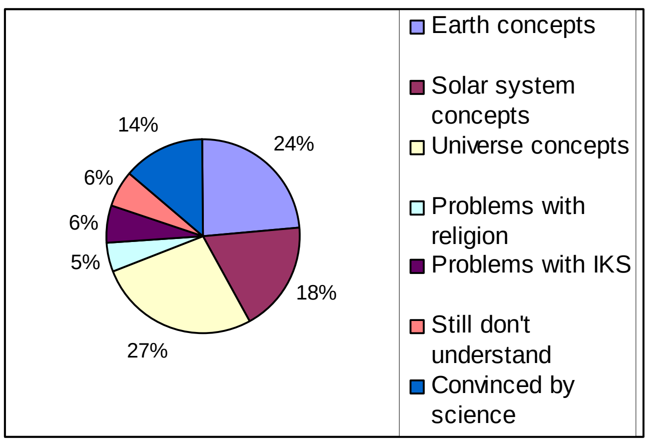

Figure 11 : Pie chart showing relative frequency (as a percentage) of the categories created from code statements in response to the question “What did you learn?”

While a few interesting examples were given which could be described as simultaneous collateral learning, for example, the student who connected community descriptions of the heat ‘down in the mines’ with the internal structure of the Earth, in contrast to his own experience of digging holes where the soil under the surface was ‘cold’, this question was more successful in indicating those areas where the students felt that learning had taken place. This was more or less equally distributed between ‘Earth concepts’ (24% of all responses), ‘solar system concepts’ (18%), and ‘universe concepts’ (27%), indicating that learning had taken place, not just in terms of the 'new' work presented at university level, but in terms of basic concepts that are part of the school curriculum.

4.2.3.4 REFLECTIONS ON INFLUENCES ON LEARNING:

QUESTIONS 7 T0 10

In the post-instruction questionnaire, these questions were given as follows:

"**Last bit of info needed to help me link your present ideas with your background:**

7. While you were growing up, who was your primary caregiver?

Parents	Grandparents	Other (state)

8. How would you describe the type of schools you attended while growing up?

Urban	Township	Country	Other (state)

9. Who are the people who most influence the way you think?

Parents	Other family	Friends	Teachers	Other (state)

10. Does your family think it is important to follow traditional customs (e.g. marriage, coming of age ceremonies etc) Tick your choice:"

Yes	No

These questions were included to investigate the possibility of establishing links between the students' ability to manage border crossing and a number of other criteria: firstly, who had taken care of them when they were growing up, with the idea that grandparents would be a richer source of traditional explanations for natural phenomena; secondly, the type of school they had attended, with the idea that students who attended rural schools would be closer to their cultural roots than would be students who had attended city schools; thirdly, what was the possible effect of community in terms of influencing the way that students thought or were prepared to change their thinking; fourthly, did their families think it was important to follow traditional customs, with the idea again that community is more important than individual thinking in traditional communities; and finally, what would the students' teach their own children? The last question was perhaps the most important of this group of questions, as it was hoped that it would provide insight into what the students valued in the long term, i.e. values related to the different ways of knowing.

QUESTION 7: "WHILE YOU WERE GROWING UP, WHO WAS YOUR PRIMARY CARE-GIVER?

"7. While you were growing up, who was your primary caregiver?"

Parents	Grandparents	Other (state)

The role of grandparents in taking care of their grandchildren can be profound in terms of the stories, traditions and customs that are passed on when the children are young and impressionable. In South Africa, grandparents are frequently relied upon to look after their grandchildren because the parents of the children are working in cities or in employment situations where the children are not welcomed, or because HIV/AIDS has taken its toll of the parents. However, relatively few students indicated that they had been looked after by their grandparents, and three of the total of 20 students who listed Grandparents as their primary care-giver(s), also listed 'parents' as having taken care of them. A possible explanation is to be gained from the responses to Question 8, which gives an indication that most of the students in the sample came from urban situations. This meant they were likely to be living with their parents, rather than having been left in the rural areas with their grandparents while their parents sought work in the cities.

Table 5.31 : "Who was your primary care-giver?"

Who was your primary care-giver?	Totals
Parents	94
Parents and Grandparents	3
Grandparents	17
Other (other family members or guardian)	2

n = 118 (data obtained from the College of Science and Geology mainstream groups only)

Blank : n = 2

In analyzing the data, it was found that of the 17 students who were raised primarily by their grandparents, there were none who were classified as having 'smooth' border crossings. Seven were categorized as having 'managed' border crossings, six were 'hazardous' and two 'impossible'. While the numbers involved are too small to draw any conclusions, this finding may be seen to support the anecdotal expectation that children brought up by their grandparents would have a more strongly developed traditional worldview. However, as far as IKS was concerned, only two students made reference to traditional cultural ideas, indicating that within this sample, grandparents could *not* be seen to have played a major role in instilling traditional ways of knowing into their grandchildren.

As far as religious views were concerned, eight of the students looked after by their grandparents indicated a position of 'conflict' between science and religion, two a position of 'independence', and four a position of 'dialogue', thus indicating a broad range of responses in this area.

It is possible that if the sample had contained more students from rural areas, the role of grandparents would have been seen to be more significant. But perhaps it was the wisdom of a grandparent that was manifested in the following comment:

> "I think if everyone from birth was left to think for themselves, believe what they want to believe, have their own ideas, then life will be much simpler than walking on someone's idea of life" (04.COS.21.POST)

QUESTION 8: "WHAT TYPE OF SCHOOLS DID YOU ATTEND WHILE GROWING UP?"

"8. How would you describe the type of schools you attended while growing up?"

Urban	Township	Country	Other (state)

The purpose of this question was to try to establish a relationship between the type of school attended and the nature of border crossing achieved by the student. Not all the students provided this information on their questionnaires, and for a few of those who did, it was not possible to establish the type of border crossing achieved. The table below provides the information that was available.

Table 5.32 : Relationship between the type of school attended and types of border crossing

Type of school	Smooth Border crossing	Managed Border crossing	Hazardous Border crossing	Impossible Border crossing
Urban	14	22	4	3
Township	0	26	17	1
Rural	2	9	11	2

n = 111

Urban schools : n = 43

Township schools : n = 44

Rural schools : n = 24

It had been anticipated that it would be possible to make a connection between the prevalence of IKS and the degree of cultural distancing that was likely to have occurred, with the type of school that had been attended. It was anticipated for example, that students from rural schools would be more likely to have closer ties with traditional explanations for natural phenomena. However, only one student from a rural school referred to traditional knowledge, indicating that the assumption that had been made was unsupported in terms of the current sample.

The most important findings to emerge from examining the relationship between the type of school attended and the type of border crossing achieved were in relation to township schools. There were *no* smooth border crossings recorded for students who attended township schools. However, at the other end of the border crossing spectrum for township schools, there was only one recording of an 'impossible border crossing' situation. This involved a student who was extremely religious and claimed to “believe nothing” that was presented in the course. Township schools also produced 17 students who were listed ‘hazardous’, a categorization that was usually reflective of poor grounding in the discipline. However, 26 township students were categorized as having achieved ‘managed’ border crossing. These students did not appear to have a problem with their content knowledge, but many of them had problems associated with their religious beliefs. Their success at border crossing was mainly achieved through compartmentalization.

Urban schools produced the students who were categorized as having ‘smooth’ border crossings - possibly an indication of these students having attended schools with better resources than the township and rural schools. Urban schools represent a range of different types of schools, from independent to ex Model C schools, with one student indicating that they had attended a “Christian school’. While there were a similar number of managed border crossings, the other major difference between the urban and township schools lay in the number of hazardous border crossings, again perhaps an indication of the advantage of attending urban schools over township schools. Urban schools also produced three ‘impossible’ border crossing situations, which were not associated with a poor grounding: two of the students were very religious, and indicated that the conflict with their beliefs precluded them from learning anything that conflicted with these beliefs, while the other simply indicated that they had “lost interest”.

It is interesting and encouraging to note that two students from rural schools were classified under ‘smooth border crossing’. The fact that there were more ‘hazardous’ than ‘managed’ border crossings for students from rural schools is suggestive of the well known poor resourcing of rural state schools, where the provision of running water and electricity is frequently a problem (Bot, *et al*., 2000).

QUESTION 9 : “WHO ARE THE PEOPLE WHO MOST INFLUENCE THE WAY THAT YOU THINK?”

“9. Who are the people who most influence the way you think?”

Parents	Other family	Friends	Teachers	Other (state)

Knowledge is accumulated over time, with parents, friends, teachers and members of the community playing a significant role in influencing knowledge that is taken as true. The intention of this particular question in the post-instruction questionnaire was to try to establish the relative importance of each of these groups of people to the young adults in the sample. Many of the students indicated more than one of the alternatives given, and this table was compiled using both the pre-instruction and post instruction questionnaire data, depending on where the questions had been asked. Consequently the totals do not match the post-instruction questionnaire sample size. The pie chart is more useful in indicating the relative importance of each of the different groups.

Table 5.33 : Influential people: n = 163

Categories of influential people	Totals	%
Parents	134	60
Other family	15	15
Friends	22	10
Teachers	43	19
Church	0	0
Myself	10	4

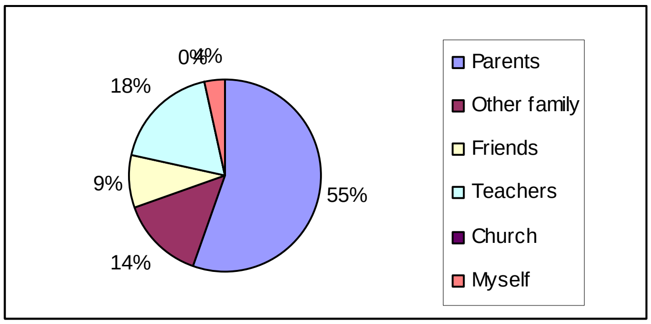

Figure 12 : Pie chart showing relative frequency (as a percentage) of the categories from the question "Who most influences the way you think?"

The data indicate that parents play the most significant role, while teachers are also very important as figures of authority and power in establishing the truth value of knowledge.

It is interesting in the light of student responses to the theories that none indicated the role of the Church in influencing how they think, although it is recognized that religious input is likely to come from the family. However, difficulties with the big Bang and Nebula theories are not only associated with creation accounts, but also with African philosophy, which maintains, like Aristotle, that the world is eternal, with no beginning or end:

> "Science may be true but not for all situations and for all people. I don't believe in ancestors but there are people who believes in such things and some think the universe had no beginning. There are a lot of stories going around - you wouldn't know what to believe' (02.COS.3.POST).

There was no mention of the role of Elders in answer to this question, although a few students had mentioned their importance in relation to other questions, for example:

> "…as children there are stories we were told by elders to make the understanding easier" (04.G.11.POST).

The role of community was more apparent in the interviews and will be discussed in the analysis of the interviews in Section 5.3.

QUESTION 10 : "DOES YOUR FAMILY THINK IT IS IMPORTANT TO FOLLOW TRADITIONAL CUSTOMS?"

☐ "10. Does your family think it is important to follow traditional customs (e.g. marriage, coming of age ceremonies etc) Tick your choice:"

Yes	No

Like Question 10, this was a "background" question, the aim of which was to try to establish the prevalence and importance of traditional customs and culture in the families of the students in the sample. Several of the students referred to issues such as respect, knowing how to behave and knowing where you have come from, as part of what was valued in traditional thinking. Those who referred to customs such as the pouring of libations usually ascribed these practices to older members of the family, but linked them to issues of respect. Those responses categorized as 'other' indicated neutrality or a 'lack of strictness' in terms of the family's response to traditional customs. Together, Questions 10 and 11 provide some insight into responses given in the previous questions: parents (and teachers), who hold strong traditional worldviews together with strong religious beliefs are important in shaping the way their children (many of whom are the first in their family to attend a tertiary institution) think and respond to what may be perceived as a threat to fundamental values.

Table 5.34 : Importance of traditional customs

Is tradition important to your family?	Totals
Yes	104
No	42
Other	2

n = 150 (the 2001 sample was not included here as they were not asked this question)

Blank : n = 2

69% of the students indicated that traditional customs were important to their family. As has been noted, data on race was not collected, so while it is probably reasonable to assume that 'traditional customs' was interpreted to mean Black African traditional customs, the possibility of some of the other (e.g. White or Indian) students also indicating that traditional customs were important cannot be excluded. However, what was indicated was the importance of this aspect of the home worldview.

5.2.3.5 REFLECTION ON VALUES

QUESTION 11 : "WHAT WILL YOU TEACH YOUR CHILDREN?"

"11. When you have children, will you teach them traditional/religious/scientific explanations for natural phenomena? (Tick those appropriate for you)

Traditional	Religious	Scientific	Not sure

Please explain your choice:
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………..………………………………………………………………………"

Table 5.35: "What will you teach your children?"

What knowledge system will you teach your children?	Totals
All 3: Science, tradition and religion	36
Science and tradition only	10
Science and religion only	32
Science only	19
Tradition only	5
Religion only	9

n = 113 (only the 2004 samples were used for the analysis of this question: in 2001 and 2002 the students were not given the option of religion as one of the suggestions as to what they would teach their children)
Blank : n = 1
Number that could not be classified : n = 1

The purpose of this question was to probe what values were important to the students through asking what they wanted to pass on to their own children in the light of their on-going education. There was a strong recognition of the values inherent in religion and tradition, but this was often balanced by a pragmatic understanding that the modern world was driven by science. The students who indicated that they wanted their children to have access to all three knowledge systems wanted them to have the choice so that they should be able to make up their own minds:

> "I believe that a child should know everything from all aspects of it, life, and make up their own mind. I was told about phenomena from all aspects, tradition, religion and science and I feel good knowing that I made up my own mind" (04.MS.33.POST)

At the same time, they wanted to prevent confusion and difficulty:

> "I want them to know everything that I know now, not to be blind as I was" (02.COS.8.POST).

What was especially noteworthy was the evidence of holism that was displayed by many students:

> "They are all important and they play their own unique role in every persons life, so its important that we should know all of them" (04.COS.14.POST).

Many students spelled out what these unique roles were, for example:

> "Traditional - as to how people should conduct themselves
> Religious - who is the Creator and what He wants from us
> Scientific - to keep abreast with new technology and innovation"
> (04.MS.20.POST)

There was a clear recognition of "living in a changed world" (04.MS.18.POST) with the following statements reflecting the sentiment of many of the students:

> "I believe that everybody has to grow up knowing God 'cause he is the only one who give us wisdom, courage and knowledge of everything that revolves around us. Science - these day everything is all about science and technology. So I believe that children should grow up knowing about science so that they can be able to improve certain discoveries". (04.MS.31.POST);

The students who referred to the importance of tradition explained that they wanted their children to know where they have come from:

> "Look tradition is the foundation of where we came from, you need a bit to grow" (04.MS.11.POST);

> "I was taught that there is no future without a past, so you have to know where you come from to know where you are going" (04.G.11.POST);

and even :

> "I believe that tradition is very important and should never be lost. Traditions are what differentiates different races. They make a race unique and special" (04.COS.10.POST).

However, adherence to religion was again stated in the strongest terms, with students reiterating that if there was a clash, religion was the most important , because "it helps you live your life in a right way" (04.MS.36.POST); "…its what builds a person" (04.MS.19.POST); that the "Bible is the best reference point" (04.MS.4.POST) and that it is "… the source to a human beings happiness" (04.MS.21.POST). Statements such as 'I am a religious person' and that 'belief in God is vital' and 'religion keeps you on track' were repeated over and over again.

The findings of the post-instruction questionnaire can be summed up by the following response to the question 'what will you teach your children?'

> "Religious is the first priority of all because it give reasons for life. Tradition, to know where you come from, is important. Scientific, this is the technology century everyone need to know as much as possible" (04.COS.23.POST).

After the administration of the post-instruction questionnaire, students were invited to participate in an interview. These offered the opportunity to probe further the comments made by the students. The results of the interviews form the subject of the next chapter.

Table 5.36: "What will you teach your children?" Analysis using code statements: n = 163

Categories	**Examples of code statements from the data**
All 3: Science, religion and tradition (20%)	They must know all so they can choose; All important, each has a unique role
Philosophical approach (2%)	They must think for themselves; All 3 conflict at some point
Science and tradition (14%)	To broaden children's knowledge; So they can adapt to any situation
Science and religion (20%)	Science and religion go hand in hand; Hope to find a way to balance them
Religion only (12%)	Religion gives values/provides meaning/helps you make the right choices
Science only (23%)	Science can be proven/makes sense/gives knowledge and power
Tradition only (9%)	Tradition must never be lost; You must know where you come from

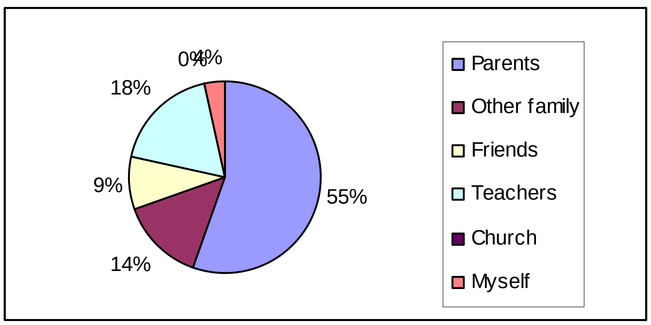

Figure 13 : Pie chart showing relative frequency (as a percentage) of the categories in response to the question "What will you teach your children?"

The composite results of the responses to this question were interesting in the fairly even distribution of alternatives, clearly shown in the pie chart. However, only 23%[19] of the responses indicated 'science' as the only choice in terms of what they would teach their children. Many stated that they wanted their children to have the privilege of grounding in all three areas, so that all were familiar in order to provide the opportunity for freedom to make their own choice of belief system.

[19] According to the first method of coding, 16.8% of the students indicated that they would only teach their children science. This difference of 6% was the consequence of the second method of coding being able to capture nuances in the answers given by the students, thus giving a more refined result)

The data provide an important comparison in terms of the expressed allegiance to religious versus traditional beliefs. While the 'religion only' category is only a few percentage points more than the 'tradition only' category, when the ‘religion and science’ category is added to that of ‘religion only’, the result is 41%, while 'tradition' and 'science and tradition' adds up to 23%. This may again be linked to the idea of cultural distancing, where children brought up in an urban environment are less exposed to traditional ideas and beliefs.

An interesting observation as far as the Geology mainstream group was concerned was they recorded an 18% response in the ‘religion only’ category - 6% higher than the average. The hard line science stance or even scientism associated with Geology as a result of the long history of conflict between Biblical and scientific accounts of the creation and physical development of the Earth, means that other ways of knowing are unlikely to receive support or recognition by lecturers in this discipline. However, it would be of benefit for the students if the lecturers were aware of the extent of religious adherence in students who have chosen Geology as their major. The many comments by Geology mainstream students which have already been recorded in this chapter provided an indication of the importance of religion to them. Sensitive assistance in dealing with potential conflict could go a long way to facilitating smooth border crossings into science, without the loss of other belief systems.

5.2.4 SUMMARY OF THE FINDINGS FROM THE POST-INSTRUCTION QUESTIONNAIRE

The purpose of the post-instruction questionnaire had been, firstly, to establish the extent of conceptual change, and secondly, to investigate the barriers to learning, especially those related to worldview issues which affected student’s border crossing into the world of science.

The findings from the comparison of the 2002 College of Science pre-and post- instruction ‘content’ questions (“What is a star?”, “What causes day and night?” etc) clearly indicated that the students had been able to master the content of the course: the WMS explanations had ‘survived’ for more than five months, indicating that a far as a ‘paper test’ was concerned, conceptual change had been achieved.

The most important findings to emerge from the analysis centered around the students’ reaction to the scientific theories regarding the formation of the universe and the Earth. These reactions support Mbiti’s statement that “Africans are notoriously religious” (1969, 1). For many students, these theories were identified as what they had found hard to understand and hard to believe. The concepts were foreign in relation to traditional beliefs, and they presented a threat to their (Christian and Muslim) religious beliefs. For some students this threat led to a ripple of reaction which undermined the credibility of science. The cognitive discomfort experienced, manifested in disbelief, scorn, uncertainty and even pain, is underpinned in cultures where community is more important than the individual, by an awareness of the social and cultural costs of adopting a new worldview.

The two methods of coding yielded slightly different views regarding how the students were responding to these threats in terms of collateral learning and border crossing: the first method indicated that the students were compartmentalizing their knowledge and trying to cope in that way. This compartmentalization either took the form of '*conflict*', Barbour's term describing the acceptance of only one form of knowledge as truth and rejection of the other, or '*independence*', Barbour's term describing the position of acceptance of both science and religion as legitimate, but mutually exclusive, forms of truth and knowledge.

This surface view was enriched by the second method of coding, which yielded evidence of the 'worldview battle' that was going on. The growing scientism that was manifest in the students' responses probably stems from the fact that many of them were under-prepared academically; that they are dazzled by the university's academic power and the hard evidence associated with science; and that since they are there to learn, there is pressure to conform and take on what they are being taught. However, in an environment where other ways of knowing are not acknowledged, and the hegemony of Western science is the driver, 'learning' may be problematic because of invisible social and psychological costs.

5.3: VIGNETTES OF BORDER CROSSING

5.3.1. INTRODUCTION

The interviews were conducted towards the end of the academic year, after the post-instruction questionnaires had been completed. At the time of administration of this questionnaire, I invited the students to participate in an interview to discuss their questionnaires and any issues that may have arisen which were relevant to their experience of the Earth and Space course. I was amazed at the response: so many students volunteered that it would have been impossible to interview them all, particularly before the onset of the exam period. The result was that the interviewees were selected on a 'first come first served' basis in relation to being able to find a mutually acceptable time for the hour or so that the interview would last, up to the time that the students left to go on study break. As a result, only 25 formal interviews were able to take place. There was a strong sense that in the impersonal academic environment they had encountered at university, they were relieved to have the invitation to share their difficulties and that they were appreciative of having interest shown in what their experiences of learning had been.

The demographic composition of the interview sample was very similar to that of the sample as a whole: most of the students who were interviewed were male, and most were Black. However, included among the interviewees were three female students, and one White male. A breakdown of the composition of the interviewees is given in Table 5.37:

Table 5.37: Composition of the interview sample

Race	Male	Female
Black	20	2
White	1	0
Indian	1	1

The interviews were tape recorded and transcribed as described in Chapter 4. Some of the students needed very little prompting to talk, some were articulate and communicated their ideas very clearly, others less so. Although several of the students indicated their willingness for me to use their names, for ethical reasons the names that have been used in these vignettes are not the real names of the students. In the vignettes, the questions as asked in the interviews, and the students' responses as recorded in the transcriptions, have been italicized to make them easily distinguishable in the text.

As the students started to understand more clearly through the interviews what I was trying to investigate in terms of barriers to learning in the Earth in Space course, several students wanted to make sure that it was clear to me that the difficulties they experienced were not because they were ‘stupid’ or ‘foolish’. Sibusiso, one of the students who was interviewed, added the following to the transcription of his interview before giving it back to me:

> “*As one of the student I know that we don’t fail because we are foolish but because we get confused with the kind of information we have in our minds. I thought it is good because you are trying to find a way of solving this problem of being unable to intergrate the information we have collected. Even though the solution you might come up with might not work for everyone I am positive that it will work for the majority of student who are doing or will do Geology* (Earth Science).”

His comment highlighted the legacy of pain of traditional knowledge systems being considered inferior to Western ways of knowing, and the impatience of an education system that has yet to recognize the need, in our multicultural country, for effective, empathetic and respectful ‘culture brokering’. This problem is not unique to South Africa, but is a common problem in African countries that were colonized. Burkhardt (1999, 2) points out that in Nigeria, even after independence in 1961, the education system there has continued to transmit Western culture, ‘owing to a myth, perpetuated by Nigerians themselves, of European superiority’. However, the recognition of the need to incorporate Indigenous Knowledge into the science curriculum creates its own set of intractable issues, such as how this knowledge should be incorporated; who decides which knowledge should be incorporated; and what knowledge should be incorporated? The second part of Sibusiso’s comment gave me a sense of sadness, in that he indicated his hopes for some sort of solution to the problem of ‘intergration’ as a result of his encounter with my research. While South Africa’s Revised Curriculum Statement, introduced in 2004, states that ‘other ways of knowing need to be recognized and valued’, the *which, what* and *how* have not been addressed. In addition, science teachers or university lecturers who are steeped in Western modern science are likely to have difficulty with the recognition and inclusion of other ways of knowing, in terms of their own epistemology, and in terms of time constraints for researching appropriate IKS for inclusion in their courses - if indeed, they are prepared to recognize other ways of knowing. The work of finding appropriate ways to include IKS is thus likely to be as difficult as changing the institutional culture of an organization where the dominance of science has been well established.

However, sections 5.1 and 5.2, in presenting the results and analysis of the pre- and post-instruction questionnaires, have given a clear indication of the presence of a traditional worldview in many of the students in the sample. Examples were given of anthropomorphism (the representation of nonhuman entities having human characteristics), anthropocentricism (the perception that mankind is the centre of existence), animism (the belief that inanimate and natural phenomena have souls) and teleology (the explanation of phenomena by the purpose they serve), all of which are characteristic of a traditional or organistic (Lemmer *et al.* 2003) worldview. As a result, in this section, the focus moves away from explaining natural phenomena in terms of these characteristics, to presenting vignettes (see Chapter 4.5) which highlight the human experience, with particular reference to the understanding that “Africans are notoriously religious” (Mbiti, 1969, 1).

The first vignette deals with difficulties experienced by the students in relation to African Traditional Religion (ATR) and Indigenous Knowledge Systems (IKS). The second deals with difficulties related to Christianity, which in Africa has been indigenized and tends to be fundamentalist. Despite my awareness of the effects of positionality and the comment by Vuyo, one of the College of Science students, who rather hesitantly told me about some of the cultural practices, such as traditional praying to the ancestors, which involved:

> *“…using snuif (snuff)…and our own traditional beer…I should call their names and say I’m giving them food… pour the snuif and beer on the floor, so they should be sending me something for good luck…” but then added that “we never talk much about what to …all the traditions…”,*

the students were surprisingly open in talking about how what they were learning affected them in terms of their culture and their religious beliefs. It is possible that because these interviews took place at the end of the academic year, after I had spent a considerable time with the students on field trips, in afternoon practicals, tutorials and lectures, a degree of trust had developed that enabled them to talk as they did in response to the questions, and to be willing for me to quote from what they had told me. The interview situation produced a richness of information that was not forthcoming from the questionnaires, possibly because of the trust that had been built up over the course of the year, and because of practical constraints such as space and time availability in the questionnaires.

The third vignette is different to the first two: rather than focusing on barriers to learning, it presents the concept of 'fighters' - students who are determined to succeed at university, despite very poor backgrounds in science, and despite the epistemological and ontological barriers inherent in their worldview.

The vignettes thus represent 'character sketches' as a means to demonstrate how the worldviews held by students in this study affected their learning in the field of basic astronomy. However, while each vignette serves to highlight one specific issue, these issues are not necessarily separable in terms of individual students. The students presented a spectrum of beliefs and experience: many experienced a 'disadvantaged' schooling background, as well as reflecting a worldview which was a complex synthesis of Christianity and ATR. Some positioned themselves as "born-again Christians", claiming not to believe in "that stuff" – referring to ATR and IKS, while others indicated only an affiliation with the African worldview. The vignettes thus offer a flavour of the interviews, where students responded to questions which sought to probe their responses to the course.

5.3.2 VIGNETTE 1: CROSSING THE BORDERS: ATR AND IKS

Nombuso is a vivacious 19 year-old Black College of Science student who was interviewed in 2004. She is outgoing and confident, hard-working, academically able and unafraid to speak her mind. She grew up in a caring home, looked after by parents and grandparents who "influenced me to be an independent person at heart and mind. I have to do what is best for my being". She attended urban schools, and indicated that her family did not think it was important to follow traditional customs, because "they understand that we're living in a modern world, where tradition doesn't play much of a role as it used to. So they tell me to respect the tradition, and not be afraid to make my own footsteps in life". However, her intention is to teach her own children from a traditional, religious and scientific perspective, so that it "would be up to them in the end to decide which explanation is best".

Even though the role of tradition seemed to be down-played in Nombuso's responses in the biographical section of the post-instruction questionnaire (the source of the information given above) her interview revealed a passionate belief in the values associated with a traditional worldview. This is clearly shown in the following extract:

Q *What are the things that are important?*

A *With tradition? With my culture as Xhosa?*

Q *Ja…*

A *The … well starting with virginity … I still think it is my pride … ok … they are not actually saying it … don't do it and what you call. You… as my parents would put it … it's your choice … and it's my choice and I'm taking it as my duty to keep my virginity. It's my priority, it makes me a girl. Ja. And then I think that is important … that um … respect …*

respect for yourself and respect for other people. I mean if you don't respect yourself, obviously you are not going to give a damn about the next person … and then um how you address other people … how you address your elders … how you address someone who is your age … how you address the youngsters. You don't speak … with a person who is older than you.

This belief in the values associated with African culture was shared by other students, but there is also a recognition of the cultural distancing that happens with urbanization and the absorption of Western culture: Bheki, for example, one of Nombuso's class mates, grew up in rural Kwa-Zulu Natal, but attended township schools. In his interview, he said:

"I think my culture and my tradition is good…I think its very good, those things… I don't want my family to lose those values, I want them to know everything about tradition, like the respect we are taught at home, what to do. Maybe you are on the train… then you are sitting on the chair and the adult is standing, then you are supposed to stand up and give the chair to the adult, that is what we are taught, to respect…in fact even if maybe others are having a conversation, we know, ok, now you are supposed to go out. Those things we are taught, and even now I do those things…thanks to my parents…… maar (but) in other instances I have noticed that, the new generation from now, the people who are coming after me… they don't have what I have. The people from rural areas they still have that respect, but in the townships, you don't find that. In the rural areas… I grew up in KwaZulu-Natal, so I got my education there…so in the rural areas, we know each other …we know that that house is Mr So and So's house, we also know the children there… so maybe if you are standing around with your girlfriend, and maybe a parent…an adult comes, you have to run, you have to hide, because that person knows you, and that person is your parent who can just catch you and just…(laughs)… slam you. But here in the townships, nobody cares… you can even kiss your girlfriend in front of the adults and it doesn't matter… so I think moving to the suburbs, moving to the townships has changed some things… because now, even if an adult can tell you what you are doing is not right, some people they will respond "you are not my parent…what can you tell me?"… so I think its affecting us…"

However, Bheki was careful to distinguish between social behaviour and traditional beliefs:

"…but those theories and superstitions, those ones are the ones that I'm going to keep away from them…but … most of my tradition, my culture is very good."

The "…but…" at the end of Bheki's statement about keeping away from superstition, hinted at the powerful hold that it has. During the interview, he rather sheepishly related two stories that are illustrative of the tension that exists between different ways of knowing:

A *…there was this belief of tornadoes, … they are snakes that are going from one lake to another… so most of the time when this happens, they will take big bells and strike them, because they had a belief that if you make that noise that tornado will not pass straight on top of you… go the other way… (laughs)… so that knowing that, and now, knowing that the tornado is something else which is not affected by noise and so… I see, that was in vain. But we believed it, and we could see it working… obviously maybe it was working… just maybe… because interconnecting that… (laughs)…*

Q *Bheki… if you look at the new curriculum, you will see that what are called "other ways of knowing" are now seen to be important… in the classrooms, the teachers are told they need to understand and value these other ways of knowing things…if you go back to your* *grandmother or even your great grandmother, they had ways of understanding things that was their belief… that worked for them, that were their ways of understanding things…*

A *Yes, they are stuck with… that… things… if the thing is supposed to pass here, it will pass here…no matter how much noise you make… and there is also this funny thing about lightning… they say you are not supposed to show shiny stuff like this… like mirrors… we used to cover those things if there was a lightning storm… things like that… you don't wear a hat in the house… a man…every one, was supposed… (laughs)… to take off their hat, and most… there was this story when I was growing: one guy was wearing a hat - there was lightning and thunder, so the lightning striked him, then, that's when I started believing. I also believed that thing… this happens when you are not behaving the right way, lightning will strike you…but from what I've heard now, lightning is not affected … like wearing a hat in the house, its not the thing that attracts lightning… from what I've heard its only the poles of the …polarities, whether its negative… the clouds negative… and most of the time it strikes the highest point, that's why you will see on the buildings, they put this earth thing, just to attract the lightning and let it go underground, to the earth…*

Fatalism is deeply ingrained in the African worldview, as is belief in mystical power: Mbiti states that "this mystical power is not fiction: whatever it is, it is a reality and one with which African peoples have to reckon. Everyone is directly or indirectly affected, for better or for worse, by beliefs and activities connected with this power" (1969, 193). Mbiti goes on to say: "this power is ultimately from God, but in practice is inherent in, or comes from or through physical objects and spiritual beings. That means that the universe is not static or 'dead': it is a dynamic, 'living' and powerful universe" (*Ibid*., 197).

A worldview recognizing this power, and which has been passed down through the centuries, will not be snuffed out by a few generations of Western education. For Nombuso, whose "mom is quite scientific also, so I grew up in a scientific way of thinking", who has been encouraged to be herself and who is training as a geologist, the compelling power of the African worldview lies not too far under her stylish, Western, urban exterior:

"…I have a teeny, tiny belief on this ancestral things. Like my granny passed on three years ago …. when I go outside sometimes, or just when I think about … I just think ok she is watching over me somehow, and while when I am feeling hurt or stuff like that…I can't look at the stars in all scientific way … otherwise I wouldn't write poetry. I wouldn't look at it in the same way…"

While this need to have connection with loved ones who have 'passed on' is a common human experience, the relationship with the stars is one that links the African worldview with the ancient Greek understanding of the heavens. Mbiti is again helpful in this regard, by pointing out that

> "…the living-dead, and to a less extent the spirits also, act as intermediaries between God and men… they are the guardians or police of tribal ethics, morals and customs…any breach of these customs is an offence not only to the human society, but also to the spirits and the living-dead" (*Ibid*., 202).

Nombuso puts this into the current context, evident from the following extract from her interview:

Q *In question 5, you made a comment that I wanted to pick up on. You were talking about … is science true for all situations and all people … and your response here is "no". "Some people discard any scientific explanations for anything whatsoever"… ok… "especially those who are culturally, or traditionally oriented" … ok …"it's hard for them to switch from one thinking dimension to another". Now I want to pick up on that … this "it's hard for them to switch"…talk to me about that? Why do you think it is hard for them to switch?*

A *Because they have this belief … coming through to cultural things … right … like tradition, African tradition specifically, the slaughtering and the what, what, and the what, what. When they look at the sky, they don't see a scientific thing … they just know that… ok … it is just the sky … the stars … the stars are so called the ancestors looking down on them. So for them … and palaeontology… that's the worst part … 'cause palaeontology is like digging up what you call bones and stuff like that … and for them it's like an insult to their ancestors. They believe … how can you dig up someone who is laid to rest, and who is watching all on you. So when you tell them about fossils and stuff like that … they really … they don't want to go there. They think no, no, no the ancestors are going to be angry at us and what have you. So they … it's quite difficult for them to see the world in a different way … so…they believe this is the way it is, that's how it's going to go … and that's that. So that's why I say it's quite difficult for them, and it's … like in class when you wanted to … I saw it with some of the people ok … I was also studying some people there .. you could see … the White guys … the White people and some of us there … the Blacks … we… we do believe this. We know, ok, things follow scientifically … within the modern world on top of that … so right, and then the other people ... they really … they try hard, they even go to the library and go pick up heavy books for a simple explanation for how a star is born. You just have to get it, digest it and understand it… that's it. There is nothing hard about that. And then… they tend to think, no… its an insult to the ancestors … what have you, what have you … . Culture just closes them completely, but then again the person has a right to do whatever they want with their mind … I guess that's how it is going to stay. But in times when they are not going to… logical … they are not going to… what you call it, they are not going to digest that. They… they believe in their culture not to do that, then they are not going to do it … and that's how actually they fail to what you call … to answer the questions properly and then you bring their grades down … so it's not entirely that they are lazy or stuff like that … they do try … it is just that they don't understand … they just can't catch that idea.*

Q *…It is that difficulty with understanding that I'm really wanting to focus on. Is it … do you think that if they, if they um … can't… if they can't … is it that they can't shift their belief?*

A *Exactly. They, they just… ok …and another thing is that they are ignorant. They don't want to shift their belief. You show them this is how it is … then they like: No, fine… we understand Einstein and the singularity …but how did he know that there was a singularity …. And… now ok it is a scientific question … he discovered … and since the theory, it makes sense the way he explained it. It's not like he just come up one day and he was like… ok, there is a singularity… and this, that and the other … no … he actually sat down and thought about it, and then he worked his way back, and then that's the part that beats them. Why did he sit down and work his way back? I think it's out of his curiosity, and then since everything … and he wasn't the only one … maybe there were other people who were around him who were* *trying to get the same idea … were trying to figure out what is it that makes the planet… and then they sat down … and then he was .. and then he had the best explanation … and that's why the world follows his explanation … and then it's hard for them to actually sit down and look at the world critically … ja … and actually criticise scientific stuff, and understand them. They refuse to understand.*

Q *So do you think they are refusing to understand, what do you think …*

A *Why is that? Because they think it's quite a chore … just the heavy burden to understand a different thing … and another thing it will have clashes with their belief. So maybe they might think … ok fine …ok maybe I believe it … and when they go home and talk about it then … then… some people at home are going to lash out at them and go … no, it's not supposed to be that way… no … . Maybe … I think part of it is a fear to go home and tell them … "oh, you know what, I think um, Mrs Ples was… this one, and that one … and I think that… another thing" - that causes major, major conflict … the palaeontology again … the thing that we come from evolution … it just does not click with them … not at all. When you look at it nicely … ok… when you correlate the Bible with geology … I think it makes a little bit of sense … and then with them, they think it is a big insult .. and I'm like thinking, you know,… really … shift your eyes a bit, ja…. 'cause when you look at it nicely, you can actually see when you just put the timeline of the Bible and the timeline of geology, it correlates somewhere, somehow … but for them, they don't see that, they think, ok fine … they say according to palaeontology that the earth formed … whatever million years ago … and then life started to form at about 65 million years … they don't believe that. They think… ok … why is it that in the Bible humans were there before that? The way I see it, after 65 million years, when people were there, then the Bible era came in. That's how I see it. And then afterwards civilisation grew, and then it became um …it was even before Christ, it was anno domini now and everything went on and on and on … the Industrial Revolution and all the other - what you call? - major events. They just can't get that. They think ok, God came … Adam and Eve … that's it, made the earth… and we move on… and that's how we ended up here. And then… when I look at it in another way, that's what I believe …*

This extract illustrates the merging of traditional beliefs with religious beliefs; the conflict between these beliefs and science; and Nombuso's attempts to integrate these different ways of knowing – while she recognizes that for other people, this integration is impossible. She also specifically points out that people with a traditional worldview do not have a simple freedom to choose what they wish to believe. There is much at stake: the danger of insulting the ancestors is very real, and any actions, or thoughts, or intentions that could be construed as incurring their displeasure, is to be avoided. If what is being taught is seen to be in conflict with these beliefs, they can constitute a powerful barrier to learning, which may be further complicated in terms of community relationships. Jabulani explained how these problems affected him:

Q *Looking at the question in the questionnaire where it asks was there any understanding you had that was replaced , you say "No, I learned about all of these and tried to understand the point of view of other people without being judgmental and also to question the teaching of others. Its not that I accepted both, but that I learned both to know more"*

A *Yes, that's when I switch: turn it off, turn it on…..*

Q *What is the "both" you are referring to here?*

A *Oh, the both? The both would be these Western or Einstein theories and the traditional teachings of how the world is….you know they have stories, of things like the Moon and how the seasons change and stuff like that…you know…. and here you get that seasons change by…. the earth is further… and the Sun is …..you know all of that, you see, and sometimes the both is that….. traditional and this Western science field…..so I try, and what goes into here I keep it here (indicates closing one hand) and what goes into here I keep it here (closing the other hand)……*

Q *… is there any way that you can put them together?*

A *I mean there is ….there is a chance to put them together, but…..right now….. (laughs a little) I am doing my exams and I might think that actually if I put them together, I might have an opinion of mine about them being put together and someone might find that it is not appealing or is not the right one, so I will keep it until I can myself put them together without….. like hurting other people, or being rude…..or something…..*

Q *Would you accept one as truth, or both, because you are talking about the both?*

A *Both of them. Actually…well, I would say, its because of my surroundings: if I am here, then the truth is that Einstein developed the theory of thermodynamic. But then, if I am home, in the rural areas of Qwa-Qwa, and all that, I believe actually here that all these traditional things work, because I do not want to be ostracized. Because now…. they say…I believe I am White, because that comes into the point….always that… and… its very difficult when I go…. home, I don't, I mustn't speak English, and that's very difficult because I've been speaking English so much, I must try and speak my own language. Sometimes it's difficult….and I have to put up with them saying…"mmmm ...snob!"…so, that…. basically taught me how to separate them, …switch….*

These extracts indicate how real these worldview barriers to learning are, and how real the personal costs are to taking on the explanations of WMS. Unless a way of negotiating the two world views can be found, the conflict may result in the abandonment of one.

The nature of the Earth in Space course, with its emphasis on cosmology, resulted in the interview discussions usually focusing on issues that emerged from conflicting creation accounts. One of the students, however, gave an example from the field of Biology, which helps to illustrate some of the epistemological and ontological differences between African and Western thinking. Khaya, in explaining why there were different explanations for natural phenomena given by Western science and traditional cultures, said:

"…those people did not have what we have today to make explanations. So their explanations are OK and our explanations in terms of science, its also OK, depending on how we look at things and what do we have to make out what is happening there…like…let's say we are looking at something under the microscope, and I say…in my tradition, that thing is not an animal because it doesn't have blood. Someone else will tell me no…it doesn't have to have blood to live: it's a virus, but its very small. But in tradition, we'll say something that lives has to have blood. Some people don't believe that there are small organisms that are "flying" on air, or when the milk get sour there is some bacteria present in the milk. This is because they cannot see it with their eyes, but with a microscope they can. So it is in those cases whereby if I knew nothing about microscope I wouldn't believe science even if there have

been publications made on that topic. Conclusion: seeing is sometimes the best way to believe."

Abimbola's (1977) comment about 'science being regarded as a pack of lies by African children' can be seen to tie in with this reliance on personal observation - as one of the students said: 'I believe my eyes won't lie to me'.

5.3.3 VIGNETTE 2: CROSSING THE BORDERS: RELIGION

While the research sample contained Muslim, Hindu and Christian students, the majority of the students were Christian, with the importance of their religion being clearly stated. Two of the students who volunteered to be interviewed were Muslim: one male, a quiet young Somali man whose regal dignity testified to the fact that his father "is the leader of his tribe and his nation"; and one female, an attractive, intelligent, and thoroughly modern young Indian woman. Their responses to the conflicting ways of knowing raised by the course were similar: "we may not question what the Holy Book says. The Holy Book says that the Earth is stationary and the sun moves across the sky". However, the stakes were higher for Mohamed as he is heir to his father's position as traditional and religious leader of his tribe. For both Nirvashnee and Mohamed, the only recourse they had to dealing with the conflicting information given in the course was to compartmentalize it, using Barbour's position of 'conflict'. Mohamed explained his position as follows:

Q *How will you deal with this conflict when it comes to the exams?*

A *I will write the way you taught us. To get marks. But it's hard to believe. Because of how I was taught from a year old. Since my childhood, up to now, I was hearing all this, and if the Quran says…its perfect…you cannot do something else…so it will be even difficult to tell my community that this…I will be seen like someone who is trying to come against the traditional beliefs and the Quran and the religion…all those stuff. So I don't think I'm allowed to believe this. My father is a religious man and (our) people are not like the people who live in developed countries…I cannot come contrary to him. I believe what he believes. I …stay together with him…I'm…stick together with him. In that morning we did the questionnaire, I asked the ladies (referring to two Indian girls – also Muslim – in his class) "how do you answer this?"…then they told me…we say: we don't believe this, but we are doing it for the exam, because they say…we…it is directly contrary to what we believe…*

Nirvashnee position in terms of her own beliefs and her sense of belonging within her community was not as clear cut as Mohamed's, but the pressures were clearly still very real:

"…in Lenasia where I stay, you find like a lot of the very…you know, people who have gone up and studied and got tertiary education…a lot of them have become atheists, because they don't know where to find their balance, because …like…you know, they want to believe Big Bang…then they have their religious side. I know quite a few people, like my doctor for instance, he is atheist, but he was brought up a Muslim, and you know, its just…you don't know where…you know, if you question one thing, you are going to question a lot of other things after that, so I don't know where to …like, you know, if I am going to question…people

start to look at you in a very different way, its like you've changed, but you know you haven't. But you have changed to them…"

For the African students, border crossing into science may be even more complex, as illustrated by Samson's story:

Samson grew up in a village "*in a religious kind of family*". He attended Sunday School, but became aware of traditional customs as he was growing up: "*I found out that there were things that were done by my family and other people in the villages…like…slaughter a cow for the ancestors…"* These practices caused him some confusion, because the ancestors were seen as 'gods' and this "… *contradicts, because they are no longer believing in one God, but in many gods…that is very contradicting…".* However, while he was able to accept what he saw, recognizing "…*this has been going on for many, many centuries… what they normally do, when they go to Church, they practice Christianity, their religion, and then, when they are at home, they forget about that, and do something else, which is of course traditional custom…*" he became cynical because "…*you are not allowed to ask questions as to why you are doing **this** here, yet you do **this** at Church…even an Elder who preaches about God, Christianity…and then next week, he does some traditional culture which contradicts what he has told me last week at Church…ja…you don't have to ask those kinds of questions*…".

This cynicism shifted from simply contradictory practice to being seen as something that had been forced on Africa: "…where I grew up, in Africa…its like White people were exploiting us…were like programming our parents, because that's how they made us grow up, we never had to question anything, we had to believe what they taught us, because that's what they had been taught by the Western people, so it becomes more of a political thing…these western countries are like making money out of us, making us believe what they want us to believe…". Despite this cynicism, Samson is deeply religious. As a result, some of the course content was seen to be in conflict with his religious beliefs, producing unsettling results and a short term solution:

"It's not that I believe, but I do understand what some of the things Earth in Space explains. What I mean is that understanding doesn't mean believing. Something that gave me a problem though, is that these things I learnt began to interfere with my religion because they might be true. I decided to make a decision and stick to my religion until these theories are proven and I'm convinced. Everything just seems to be confusing. "

Nkosi, like Samson, faced the same dilemma:

Q *So how do you deal with this stuff? You hear all this stuff, you know that there are exams coming up, so what do you do?*
A *What I'm doing is…let me say I thank God that we did Palaeontology in the last semester so that what I must do is just to cram the stuff and pass this thing and just leave it… that's what actually I did…I could not manage to carry on with it… 'cos when I carry on with it, I think I'll believe it…that's why in the course - I just run away from the course, I just avoid it as… much as I can, just avoid it, you see…*

Some of the students managed to overcome the apparent conflict between the scientific theories (particularly Big Bang) and the creation account, by coming to the conclusion that "God's time is not our time – the Bible says that for God a day is like unto a thousand years", or by ascribing the Big Bang to God. But many of the students did not get to a place where, as Thato described it "they are peaceful together". Many of the students struggled to deal with the conflict caused by the science/religion debate. The following extract from David's interview was typical of the difficulty that these students were experiencing:

"…you know, when I was growing up, I believed in Christ, and then I tend to get whatever they were saying and try to understand it so as to pass it…I tried not to confuse myself, I tried not to forget whatever I was taught back there…you see, and then…I've been struggling, you know, to find a way to interact this…two things, like…ja…but…you know I got confused, and I tend not to believe everything I was taught, but because I am studying science, there is proofs and everything and I believe whatever they are doing is right, but…I cannot try to replace what is in my heart by this knowledge that I have just got…and I try to ignore it…

5.3.4 VIGNETTE 3: CROSSING THE BORDERS: THE FIGHTERS

Costa's (1995) typology of student attitudes to learning in science consisted of 'Potential Scientists', 'Other Smart Kids', 'Drop Outs' and 'Outsiders'. This typology was developed for American school children to indicate their potential for success in science. It was used by Aikenhead in conjunction with his theory of border crossing and has been useful in this study as well, in analyzing the border crossing ability and potential of students in this sample. However, the juxtaposition of the First and Third World in South Africa, the lack of social security, and the value that is placed on education as a ticket out of poverty, particularly by Black people, appears to have created a unique brand of student, described here as 'fighters'. These are students from rural areas who have to overcome enormous barriers to even get to university. These include financial barriers which impact on the most basic needs: accommodation, transport, food. Once all these practical hurdles have been managed, the cognitive and epistemological ones begin. One of the students who was interviewed represents these "fighters".

Xolani is a young man who was brought up by his grandparents in the country. He attended rural schools in the Transkei, where traditional Xhosa ways of life have not been impacted in the same way that they have in the cities. His grandparents instilled the old values of respect in him, as evidenced by the following recollection of his childhood:

"Without my grandmother, I was not even going to know what is a star…I was just going to lose interest. I grew up in the Eastern Cape, and while we were young we used to stand outside there at night and they used to tell you don't point up…you see…when you point up, you must just bend your finger…you must not point, because there was a belief that ok…for us Xhosas…they believe that that is heaven, the sky is heaven, so you don't have to point God, like… you have to bend your finger…"

This upbringing was firmly rooted in traditional African religious beliefs, where the stars his grandmother was showing him were not balls of burning gas, but the ancestors:

> *"…in Xhosa beliefs, when someone die, after a couple of years have passed, they then say that person is an ancestor and they slaughter a goat for them, to thank the person - like my grandmother or grandfather - what they did to me, like they call that " izinyanya"… ancestors, so there is that belief, you see, that the ancestors are there, in the stars, looking after them…"*

Xolani's schooling introduced him to some appealing ideas, which gave him different explanations to those given by his grandparents:

> *"…when we were going to the bush to get some woods to make some fires, we have to ask them, "what causes this?"…you see, and they say, "no, some other animal came and dig and go down and go down and open such a hole", and we will accept that, you see, because that is what we are told by them, but then we meet now, and we find out that there is a hole, you see, then you can understand from geology what happened…that there is limestone and the water sinks down, so that carbonate dissolves in that water, open that hole….but they would tell us that an animal came and dig and dig and other came and dig and dig…but it is interesting…"*

While Xolani's grandparents followed the old traditional ways, he went to church "since I was young, you see, even now I am still going to Church" and unlike the explanations associated with limestone weathering described above, some of the ideas introduced at university caused big problems:

> *"I still remember, when I heard about Big Bang, to me it was like a nightmare… it was really hard, you see, because I am saved, I am born again, so what is happening… I was saying geology is really contradicting God because, my idea that I had before I was attending the lectures was that God created the universe and everything that is in it, and that was the only thing that I knew…and I was not even going to …I was not listening to anyone who was going to come and say this…like when I was doing Palaeontology course, the way they explain the human evolution you see, that's where I also … having problems, because when they say we are originated from chimps…I was really, really, really…I really didn't believe…it was…I did believe, but it was hard for me to believe, 'cos… like I believe that God created the Universe and as in the Bible it is stated that God has created a person, there was no processes that has been stated there ...you see… so then, to me it was really… really, you see it was a hard time for me…"*

These strong beliefs, and the difficulty that was experienced by Xolani as a result, could have led to a situation of impossible border crossing, but there was another driving force in his life:

> *"…what I really follow in my life is what I got in my childhood, because there are things that I got in my childhood that are determining me, the way that I am going now… like… there were days when I used to sleep without eating … when I'm grown, when I grow up this won't happen again … when my grandmother was going to wash washing…she would say: "you see my child if you don't study, if you don't read ..you will be like this also"… which is what is determining me, that when I read… 'cos I was told when I was still a child, I will never experience some of the difficulties that they went through…that is what is motivating me. My step father was a mine worker, he was just working on the mines, but in Grade 10 that stimulated interest for me, now I want to go to the mines and be something on the mines…the way he was. Working, getting up and leaving the room at 2.00 am… it stimulated me. Even me, I'll go to the mines. But I wouldn't go to the mines as a worker, ordinary, but I will go to*

the mines having a particular degree, because he really helped me to go to mining industry - he told me it is interesting to work there, but if I want to go and work in the mines, I must obtain a degree, because then you work very nice and you get paid much better… he told me "I have just got Std 5 and it's the only thing I can do. I've got no qualifications" - but if I am a geologist I will be telling them, "no - you must drill from here to here"… take some measures… They just drill, they don't know why they are drilling… That stimulated my interest in the mining side…"

While the odds are stacked against him, and his answers to the content questions (which he managed to complete) in the post-instruction questionnaire were full of hybrid notions (Baxter, 1991) i.e. a mix between the student's alternative framework and the taught ideas, his determination to succeed, which was more evident in his response to his work in the classroom than in the interview situation, may enable him to overcome the barriers presented by his worldview and disadvantaged background. While Sinatra *et al*. (2003) indicate that a student's disposition is the most critical factor in enabling conceptual change, they also point out that the key to instructional approaches that would be successful in assisting students like Xolani to cross the borders - for him to realize his dream of becoming a geologist - involve

> "…the portrayal of science as a powerful but bounded enterprise (and that) the goal of such instruction is not to change students' religious beliefs or persuade them to accept (scientific) theory. Instead, the goal of such instruction is to help students understand how science does not provide the only answers important in their lives. This conception, that science is not the only source of answers, may decrease potential aversion to concepts related to (science)" (*Ibid*., 524).

In terms of the attitude of students in the sample, disposition is certainly critical, but it is enmeshed in a worldview shaped by African epistemology and Africa's history of colonization. The dilemma of science as an imported way of knowing, desirable as a ticket out of poverty, yet threatening not only to religion as in the case of Samson, but to identity and culture, can be seen in the following extracts from the interview with another 'fighter', Meshack.

Q *Do you think what you are learning now makes a problem in terms of the traditional understanding?*

A *Yes, it is a problem, because according to me, its like…..Science is…. belongs maybe, science is something that comes from overseas countries like America or Europe…. so… I think a long time ago here in Africa…we didn't have information about what is science, so its like, because, when I read the scientific book, maybe let's say, they talk about Galileo in 16-something who did this stuff… so I think those years, here in Africa, we didn't have science. Africa used to be mainly agriculture, so its like science in Africa, its now...starting… maybe to grow. Because we didn't have enough information about science…. so… I think if maybe I can talk to my grandfather he will not believe in me because he doesn't know that maybe the Sun is bigger than the earth, because most of them they believe that the earth is bigger than the Sun. So those theories, they come from America or Europe, so I think… in Africa we didn't do research about the Universe unlike in America where they studied the stars …..that* *is where they got that information. If you didn't study then, how can you know that the Sun is bigger than the earth? You have to study so that you can believe, because you can't believe on something that maybe you didn't learn…. that's what I believe.*

Q *Do you think Western science is going to replace the traditional understanding? Or do you think people will always look after the stories of their culture and teach them together?*

A *I don't think…its… like we have to stay African, I mean if you can change our tradition because of science so its like, we gonna lost our culture. So its something its not good, its not right, so I would prefer if we maybe we can use science and traditional….*
I will use both…if I can stay with science, its like I will lost my culture, so its like …I believe in my culture, I am proud of my culture, so…to lost it and follow the science, I'm gonna, …ja…I'm gonna lost my culture.…….

Q *You are doing a science degree, so what are you going to do with the science?*

A *Well…you can't find a job…you must go to school….education does broaden your mind…. nowadays, the world is influenced by technology ….in order for you to be part of the world, you must go to school first….but I will make sure that my children don't lose my culture, because this is Africa, we must follow this tradition. But we must go to school and learn other things because the more we read and the more we learn, its like… the more we will be compete-able with the other countries….long time ago….. Africa it was maybe…oppressed by other countries, so the more we learn, its maybe, the more we can have enough information…*

The difficulties expressed by Meshack were highlighted by the then President of Tanzania, Kenneth Kaunda, in 1966, when he asked:

> "how can we 'preserve what is good in our traditions and at the same time allow ourselves to benefit from the science and technology of our friends?" (in Jegede, 1995, 127).

Aikenhead, in his work with Canadian Aboriginal students, raised the same problem, but on a different continent, highlighting it as problem that affects people from traditional cultures from around the world, when he asked:

> How can Aboriginal students gain access to a Western scientific way of knowing without losing something valuable from their own cultural ways of knowing?" (Aikenhead, 1998, 4)

The 'loss of something valuable' can be very costly, as pointed out by Schroeder (2001, xiii) who said: "new technologies simply displace old cultural ties, and in doing so jettison traditions that formerly stabilized society".

5.4 CONCLUSION TO CHAPTER 5

Chapter 5 has presented the results and analysis of the pre- and post-instruction questionnaires and the interviews. The most important findings to emerge from the pre-instruction questionnaire were:

1. the students in the sample had poor levels of scientific understanding and
2. the explanations given for their understanding were based not only on culture or tradition, but also on religion.

Research in Astronomy Education has indicated that poor understanding of concepts in this field is common, although usually unexpected, given that explanations for phenomena such as day and night and the seasons are considered as basic to an education in Geography as the difference between plants and animals in Biology. What was less expected was the response to scientific ideas that challenged religious beliefs. While the importance of culture has been prominently brought to the fore in the science education discourse, there has been far less specific reference to the effect of religious beliefs on learning in science. In the First World science classroom situation, this may be due to the historic split between science and religion, while in the multicultural context of Third World situations, science education research has tended to view religion as an inherent part of culture.

The most important findings from the post-instruction questionnaire were
1. the students were able to learn and retain the cognitively challenging explanations of science - whether on not they believed them.
2. there was the barrage of objection to what was seen as science challenging dearly held religious beliefs.

As far as being able to learn and retain information is concerned, Piagetian adherents, like Bishop (1996), would maintain that the reason the students were able to do this was because they had reached a stage of being developmentally to build the abstract mental models required for an understanding of the processes and phenomena taught in basic astronomy. As far as the religious objections are concerned, the point was made that for the African students, culture and Christianity (and in a few cases, Islam) are separate issues in relation to science. Both presented challenges, but in the context of basic astronomy, the gauntlet was clearly thrown at religion rather than IKS.

The next and final chapter of this thesis is a discussion of the findings of this study in relation to the body of research presented in the literature survey. It also suggests how the ‘potential aversion’ (Sinatra *et al*. 2003, 524) to basic astronomy may be decreased by the respectful acknowledgment of other worldviews and other ways of knowing.

CHAPTER 6

DISCUSSION AND CONCLUSION

CHAPTER 6

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> "I find science so…flat…it has nothing. It's information: warrah, warrah, warrah. Learn it quick… aaahhh…exams…
>
> But with tradition! You learn… you feel - you feel it, you live it… you sing about it, you… it has emotion! It makes you feel….happy, safe….you know… sad… things like that."
>
> (Mbongwa, interview 2002)

This final chapter is presented in four sections. The first section discusses the prior knowledge of the students in my sample in relation to other studies that have been done in the field of basic astronomy, and in so doing answers the first of the two research questions framing this study. This question was "What is the nature and effect of the prior knowledge about selected astronomical phenomena held by students enrolled in a basic astronomy course?" The indication from the results is that when this study is compared to other studies on conceptions in astronomy, there was nothing unusual about the high incidence of misconceptions held by the students in this study. These misconceptions are related to the fact that many of the fundamental concepts in basic astronomy require a clear understanding of mental models that are counter-intuitive. The development of these mental models, and a clear understanding of how they work, requires high order thinking skills as well as access to information that cannot be arrived at intuitively - it must be taught. In addition, the quality and timing of the teaching of these concepts is important. In the light of the findings of this study and in the light of recommendations that have been made in relation to other studies in the field of basic astronomy, two of the main causative explanations in South Africa for problems associated with understanding phenomena such as the seasons, are that they are positioned too early in the curriculum, and that frequently the teachers themselves have a poor understanding of the concepts. Consequently, understanding by the learners tends to be poor, with high levels of misconceptions. These effects could be interpreted as another instance of the failure of the school system to develop good foundational knowledge.

However, in multicultural situations, it has also been found that alternative conceptions can play a role in creating barriers to learning. This perspective provides the opportunity to be like Basho's frog (see page iv) and jump into an ancient pond - here the 'pond' of teaching and learning, with the 'deep resonance' so created making ripples which move beyond simply seeking to improve access to scientific concepts, to questions about the purpose and meaning of education as it is practiced in the context of a 'rainbow nation'. The second section focuses on some of these ripples - i.e. the barriers to learning that cultural explanations can and do present in the context of this study.

International science education research, for example that done by Aikenhead (1996), which has focused on the impact of culture as a barrier to learning, has tended to view culture broadly. The idea of science representing a culture in its own right has led to a large body of research which has clearly indicated that the cognitive demands of moving from one worldview to another require what is now commonly known as 'cultural border crossing'. However, with the exception of a few northern hemisphere studies, research conducted in the field of basic astronomy has not isolated out and focused specifically on the impact of religious beliefs on learning. In sub-Saharan Africa, the absence of this reductionist approach to research framed by worldview theory may be the result of the holism of African culture, where culture and religion are viewed as being so intertwined that to try to separate them would be meaningless.

However, in the context of this study, and it is suggested, possibly in the context of Africa as a whole, this approach may be fruitful for the following reason: the importation of Western belief systems into African traditional culture has occurred in two 'plantings', which while not mutually exclusive, may be regarded separately. The planting of the first belief system, that of Christianity, was the work of missionaries, colonists and returning slaves. Christianity brought with it Western philosophy, which as Shutte (1993) has pointed out, developed hand-in-glove with Western science. As a result, Christianity brought with it the conflicts that had developed between science and religion in the west. The second planting of Western beliefs, in the form of Western Modern Science contained in adopted science curricula, was the result of the demands of a globalizing world, in what Mazrui (2002) has described as 'neo-colonialism'. This Western Modern Science now challenges both the other layers of belief i.e. Christianity, and traditional African beliefs. In the Western world, where religion has occasionally been studied as a barrier to learning in science, traditional beliefs have not acted as another hurdle. But in Africa, the situation is different. Because African epistemology and ontology is religious, with many Africans additionally belonging to Christian churches, the barriers to learning involve beliefs that are shaped by both African Traditional Religion and Philosophy, as well as Christian beliefs.In examining both indigenous and religious beliefs as barriers to learning in science, and the impact that these can have on potential border crossing, this section 6.2 answers the second research question, which was “How applicable are the theories of ‘Cultural Border Crossing’ and ‘Collateral Learning’ in explaining the cognitive difficulties experienced by the students taking this course?”

The third section of this chapter looks at the methodological findings and the limitations to the study, as well as suggesting recommendations for further research, while the last section presents the concluding remarks.

6.1 ASTRONOMY EDUCATION AND THE PRIOR KNOWELDGE OF THE STUDENTS

Research Question 1: "What is the nature and effect of the prior knowledge about selected astronomical phenomena held by students enrolled in a basic astronomy course?"

Constructivism has become widely accepted as an overarching theory of learning. The fundamental principle on which constructivism is based is that learning takes place in relation to prior knowledge. This study was based on the form of constructivism known as socio-cultural constructivism, which suggests that the learners' prior knowledge is shaped by their socio-cultural environment, which is also responsible for shaping the learner's worldview. New knowledge will thus be assessed in terms of the prior knowledge held by the student, and judged according to his/her worldview. The first step in understanding the difficulties faced by the students in learning the content of the Earth in Space course was thus to establish their prior knowledge in this field.

6.1.1 Unexpectedly common misunderstandings

The Earth in Space course was conceived as a basic or refresher course for foundation and first year Geography and Geology students, and as a foundation for further studies in Earth Science. The assumption was that little new information would be added to knowledge already gained at school, especially as far as the very basic concepts were concerned. These included the causative explanations for day and night, i.e. rotation; for the seasons, i.e. revolution and the tilt of the Earth's axis; and for Moon phases - all of which are covered by the school curriculum. Knowledge about stars and the Universe was likely to be more variable, as these were not formally included in any great detail in the curriculum. However, it was found that instead of the course presenting information that was simply a revision of well known concepts, class test results indicated an unexpected lack of knowledge and a plethora of misconceptions. What was also unexpected - for me at least - was what a common phenomenon this turned out to be: a video, which sent shock waves through the science education community titled "A private Universe" dramatically portrayed a similar lack of knowledge, and similar misconceptions, among *Harvard* graduates. In this video, of the 23 graduating students who were interviewed, 21 could not give a scientifically acceptable explanation for the cause of seasons or for the phases of the Moon (Schneps in Bailey and Slater, 2003). However, this iconoclastic video portrays results that have come to be expected in terms of astronomy education research, i.e. that even after twelve years of formal education, and in a world scientifically so advanced that events like manned space travel and cloning are considered common place, it is common for people to *not* have a clear scientific understanding of these everyday phenomena, despite the scientific explanations having been worked out hundreds of years ago.

Misconceptions given frequently by the students in my study included the explanation that the seasons were caused by the distance between the Sun and the Earth and the idea that Moon phases were caused by the shadow of the Earth falling on the Moon. Less common, but still given, were explanations that ascribed the cycle of day and night to the movement of the Sun. Seasons, Moon phases and day and night are all fundamental concepts in astronomy. All are routinely listed as part of school curricula. Yet the answers given in the questionnaires indicated that while the students had clearly been exposed to the scientific explanations for these phenomena at school, many had not understood them correctly. In addition, terms such as rotation and revolution were often muddled or incorrectly used, and the causative explanations that *were* given were incomplete or inaccurate. The questions about the stars and the Universe drew simple *descriptive* rather than *explanatory* responses from the students, possibly because the structure, composition and life cycle of stars, and the structure and composition of the Universe, were not formally included as part of the school curriculum at the time that the students in my sample groups were at school.

It has been pointed out that the historical development of the Western science concepts in astronomy, from a flat Earth perspective to an understanding of the Earth as a cosmic body, echoes the developmental changes that take place in children's understanding as they are exposed, through schooling, to these concepts. It has also been established that not all children pass through all the notions of understanding and explanation characterized by Nussbaum and Novak (1976), and that these stages are not necessarily age related: children in Israel, for example, were found to be older at particular stages of understanding than those in America, and those in Nepal older than those in Israel. Consequently it has been suggested that the development of understanding in each individual depends on the quality of exposure, and the timing of this exposure, to these concepts. There were students in my study at each of the different notional levels proposed by Nussbaum and Novak – even Notion 1, representing a flat Earth conception - although this applied to only one or two students. However, while the vast majority had some idea of the Earth as a cosmic body, many had an up/down notion of the Earth which did not relate to gravity being directed towards the centre of the Earth. This up/down notion is linked to maps, which represent a two-dimensional model of the world. This notion indicates an awareness of something of the dimensions of the Earth and the existence of continents, oceans and poles, and is a pre-cursor to the development of an understanding of the Earth as a sphere, and as a member of the solar system.

The entrenchment and tenacity of what Lemmer *et al.* (2003) refer to as 'pre-scientific ideas' is believed to be related to the fact that these ideas are developed early on in life: the observation of the Sun's daily passage across the sky, the annual progression of seasons, the appearance of stars at night and the changing shape of the Moon, are all viewed by people from around the world using the same personal (i.e. human) scale and reference system. However, these phenomena all have causal explanations that require the understanding of complex concepts and the development of mental models that are not easy to acquire. The modern scientific conception of a heliocentric Solar System can therefore only become part of a learners' body of knowledge through explicit teaching, but studies such as those by Summers and Mant (1995) have shown that teachers often display the same misconceptions as their students. Because conceptual change is very hard to achieve, these misconceptions 'survive' education, and in the case of teachers, even teacher training, and thus are passed from the teachers' own childhood into their adulthood, and thence to their students. It has been pointed out that "for the effective… construction of a model of Earth as a cosmic body, in the Copernican paradigm, it is necessary to work not only with the non-local astronomic phenomena, but, also, with the physical questions associated with these phenomena (gravity, inertia, composition of movements, etc.)" (Albanese *et al.,* 1997, 588), *and* that these ideas need to be understood collectively (Parker and Heywood,1998). It has even been found that misconceptions are actually preferred over the scientifically correct concepts (Sadler in Bailey and Slater, 2003). In South Africa, many teachers are under- or un-qualified in their teaching discipline (Bot *et al*., 2000) and therefore struggle to teach content that they themselves may not understand. The effect of misconceptions and alternative conceptions in South Africa will therefore, no doubt, be felt for years to come. In addition to these problems, the lack of clear scientific conceptions has also been blamed on a lack of physical resources, with Klein (1982) reporting a connection between achievement in astronomy and the socio-economic status of children, and Vosniadou, Skopeliti and Ikospentaki (2005) acknowledging that access to a globe increases the frequency of scientifically correct answers. In South Africa many schools do not even have access to running water or electricity, implying that it cannot be assumed that there would be access to resources such as a globe. This lack of resources compounds the already mentioned problem of inappropriate placement of these concepts in the curriculum.

For those aware of the research, the prevalence of 'hybrid' or 'synthetic' conceptions, and misconceptions, would come as no surprise, but for those unaware of these findings, the poor levels or simply the *lack of* knowledge of students entering university is likely to be shocking, or as described by Lemmer *et al*. (2003), "incredible".

6.1.2 Prior knowledge based on alternative concepts

In addition to the difficulties already mentioned in terms of learning in basic astronomy, the aspect that has proved most interesting is the suggestion that in situations where cultural and religious explanations support observational experience, the acceptance of the ideas of Western science is even more difficult to achieve. Worldview theory and the idea of cultural border crossing both support the notion that it is more difficult for students with a traditional worldview to learn scientific concepts. These students have to overcome epistemological and ontological barriers that separate their worldview from that of science, and while it has been established that peoples' ideas can change, there are students who may prefer to retain a number of traditional beliefs that are regarded as 'non-scientific'. These cultural or alternative beliefs can be so tenacious that Vosniadou (1991) suggested that they need to be *removed* before it would be possible for correct scientific conceptions to be constructed. Vosniadou's idea has subsequently been challenged by work that has shown it is possible to understand scientific concepts without necessarily believing them (for example Brickhouse *et al*. 2000), but it is clear that a difference in worldview can create substantial hurdles in terms of learning.

The fact that the students' levels of misconceptions and lack of knowledge as reported in this study was *not unusual*, has been made clear. However, what was unusual, in the light of expectations developed as a result of the science education literature on multiculturalism, was the *infrequent* reference to cultural ideas. This finding has been supported by the Kelfkens and Lelliott study (2006), which while it represents a small post-graduate study involving a sample of only 22 student teachers, is one of the only other studies available in South Africa to provide this type of data. In the current study it was more common for students to provide either simple descriptive answers, or simple causative explanations based on Western science, than it was for them to provide culturally-based alternative conceptions. The possible reasons for this include that they did *not know* any cultural explanations, or that they did not have the confidence - or felt it was appropriate in the context of a university-based questionnaire - to provide any cultural explanations that they *did* know. The most common alternative explanation to emerge in response to the questions was the connection between the stars and the ancestors, which was a metaphysical explanation that was linked to a finite understanding of space. It was also clear that it was difficult for students who had a Biblical understanding of heaven being located 'beyond the sky', and those students with a cultural understanding of the same undefined space as being populated by the spirits/ancestors, to develop a scientific conception of space in and beyond the solar system.

For a few students, the idea of meteors and meteorites was also difficult, as they associated 'shooting stars' with the 'passing' (death) of people. The idea of this important event - which connected the physically departed to their place with the spirits - simply being ascribed to a piece of rock burning up, was unacceptable. For one student, the lack of mention of big snakes underground - which they understood to cause earthquakes - compromised their ability to take the scientific explanations seriously. However, for most of the students, cultural beliefs did not seem to impede their willingness or ability to learn and understand the scientific concepts. One of the students explained this by saying that while their grandparents, and *their* grandparents before them, only had their eyes to help them observe the world, we now live in a world full of technology that enables us to see differently. However, they also indicated that changes in these ideas did not have to impact on deep cultural traditions such as respect for other people, particularly the elderly and the Elders of the community.

During the time of their attendance at the 'Earth in Space' course, resources such as globes and videos had been available to the students in my study; they had visited a planetarium; they had participated in various practical activities such as constructing a scale model of the solar system; and they had acted out the relative movements of the cosmic bodies to explain day and night, the seasons and Moon phases. All these activities must have served to help them give the correct scientific explanations to the questions in the post-instruction questionnaire, because it appeared, from the comparison of students' answers to the six content questions in the pre- and post- instruction questionnaires, that they had understood and learnt the scientific explanations for these questions (see Table 5.16). However, their responses to the open ended questions in the post-instruction questionnaire, which asked what they had found difficult to understand and believe, indicated that while they were able to 'perform' the correct answers, this did not indicate that they had 'converted' to the Western science explanations. One of the students explained that the scientific explanations were suitable and appropriate for anyone who was going to major in geography, but that their own explanations were 'fine for me'.

6.1.3 The effect of religious beliefs on the prior knowledge of the students

Kudadjie and Osei (1998) pointed out that a study of Astronomy is inevitably linked to cosmology, and any study of the Earth as a cosmological body will at some point encounter the realm of religion, even if this is kept explicitly 'invisible' or out of the way. The origin of the Universe is fundamental to both science and religion, and when each 'way of knowing' makes different truth claims, it is inevitable that there will be some sort of conflict. In Africa, as in other traditional societies that went through colonization by Western powers, cultural religions and philosophies have been infiltrated and permeated by Christianity or Islam. It has been noted that the Christian message brought with it the conflict between science and religion that had been developed over hundreds of years in the west. This conflict would have been implicitly passed on to any converts, with one of the fundamental areas of conflict relating to the formation of the Earth, and more broadly, the origin of the Universe. This, of course, carries implications for education in Earth Science.

African creation stories resonate with Biblical creation stories in their focus on the creation of humans. However, African accounts either present an eternal view of the Earth, with no account being given of a beginning or an end, or present an *ex nihilo* creation of the Universe by God, who is then thought to have withdrawn, leaving humans to communicate with him through the spirits (van Dyk, 2001, Bernstein *et al*., 2004). However, Biblical stories, which provide an explicit account of the creation of the physical Universe and give access to God through the spirit of Jesus, support rather than conflict with African Traditional Religious accounts. There is great appeal in having access to God through Jesus, rather than through local ancestors or spirits that need to be appeased and can be offended. However, there is sufficient similarity between the idea of the ancestors as spirit, and Jesus as spirit, to make Christian teaching regarding the Holy Spirit accessible, acceptable and attractive. For pragmatic converts, the mingling of Christian and African traditional beliefs results in what Shumba (1999) has called an "African product", where there is freedom to resort to different beliefs as the situation demands. However, the scientific account in the form of the Big Bang and Nebula theories is 'doubly' at odds with this 'African product': it goes against traditional beliefs, and it goes against fundamentalist Christian beliefs in terms of creation.

The conflict that is engendered through these different accounts was clear in the students' responses to the post-instruction questionnaire and in the interviews: while some of the students were able to respectfully engage in Fatima's rules, many struggled to balance cultural, religious and scientific ways of knowing. Some appeared to be skillful in moving from the 'cold', individualistic, academic world (where they were determined to succeed), to the 'warm' communities where they belonged. Others struggled with a variety of problems which included the different teaching styles they encountered at university, the academic expectations imposed on them by the university environment, and concern regarding conflict between what they had been taught at home, what they were currently learning, and how this would affect their identity and their relationships to their communities. In the context of this particular study, Jackson *et al.'s,* point that the "history of Earth and life is an emotionally charged subject" (1995, 594) and Sharp's view that "strongly held beliefs…can act as critical barriers" (1996, 686), have been clearly supported in terms of the responses given by students. The beliefs embodied in culture and religion on the one hand, and science on the other, clearly played a critical role in their perception of barriers between their worldview and the worldview of science.

The answer then, to the first research question ("what is the nature and effect of the prior knowledge about selected astronomical phenomena held by students enrolled in a basic astronomy course?") was that a pattern emerged - of very few students providing answers clearly associated with IKS; a minority with a combination of worldview ideas; and many with poorly constructed concepts based on science. The prevalence of misconceptions was reflective of internationally common (i.e. a-cultural) difficulties associated with understanding deep time and deep space, and the fact that it is difficult for anyone to reconcile their personal experience of a geocentric view of the world with the counter-intuitive heliocentric model that is taught as part of science. However, there were also clear indicators in many of the answers supplied by the students of an underlying traditional worldview: each of the questions drew responses that were associated with animism, anthropocentricism, anthropomorphism and teleology - all of which are characteristic of a traditional worldview. The difficulties inherent in reconciling a traditional worldview with that of science was also apparent in the fact that many of the responses to the questions in the pre-instruction questionnaire were descriptive rather than explanatory, and only contained fragments of science which were vaguely remembered from school.

The first research question had thus proved useful in serving to provide a benchmark in relation to international research in astronomy education, in terms of levels of knowledge and the impact of culture on learning in this field. The nature of the prior knowledge held by the students also pointed the way to identifying the barriers to learning in this field. These barriers form the focus of the discussion in the following section.

6.2 CULTURAL AND RELIGIOUS BARRIERS TO LEARNING

Research question 2: "How applicable are the theories of cultural border crossing and collateral learning in explaining the cognitive difficulties experienced by the students taking this course?"

The theories of collateral learning and cultural border crossing were developed respectively by Jegede (1995) and Aikenhead (1996) in recognition of the effect of different worldviews on learning in science. These theories had shaped the research process in this study, in terms of the construction of the instruments used for data gathering, as well as in the analysis of this data. Cultural border crossing and collateral learning were thus key to the emergence of the two main issues affecting learning in the 'Earth in Space' course, i.e. religious and cultural objections and difficulties, which suggested that the cognitive problems experienced by the students were rooted in their worldview, in line with the claims made by the theory of cultural border crossing. The analysis of the data also indicated that the most common means of dealing with these problems was compartmentalization, which is the central idea contained in the theory of collateral learning. As a result, the short answer to the second research question was that both theories were indeed applicable in explaining cognitive difficulties experienced by students during the Earth in Space course. The long answer, however, was that the findings were unexpected in terms of the literature, and that the investigation prompted by the question provided the opportunity to add what may be termed the 'African experience' of border crossing in the field of basic astronomy.

6.2.1 Culture and religion as barriers to border crossing

Most studies in science education, where the impact of culture on learning has been investigated, have concentrated on culture without separately considering the impact of religion. The few studies in science education that have been done on the impact of religious beliefs in the science classroom, have shown that for some religious students, border crossing may be difficult or impossible as a specific result of these beliefs (e.g. Jackson *et al*., 1995; Roth and Alexander, 1997; Brickhouse *et al*., 2000 and Shipman *et al*., 2002). While a comparison of international studies with the current study indicates that African students are not very different to students from other countries in terms of, firstly, the specific difficulties associated with astronomy education; secondly, the impact of culture on learning in science; and thirdly, their responses to the science/religion debate, the research reported from Western countries provided no preparation for - or expectation of - the extent to which religious conflict would be found to impact on the African students in the current study.

However, neither does research that has been done in Africa. Because the African worldview is regarded as holistic, traditional and religious ideas are not viewed separately, and because in many cases Christianity has been indigenized and absorbed into African culture, its impact, as a separate belief system, has been hidden. The application of the theories of cultural border crossing and collateral learning served to separate the impact of culture from the impact of Christianity (and in the case of a few students, Islam), and in so doing, indicated that African students who are Christian (or Muslim) confront a double barrier in relation to science. It has been proposed in this study that the perspective of an African worldview as holistic has prevented religion (here referring to the doctrinally based Christian religion) from explicitly being a focus of attention in studies on African learning in science. Another suggestion, at least as far as South Africa is concerned, is that the attempt to keep abreast of developments in Western science curricula, yet lagging behind in terms of resources and expertise, precludes the luxury of much research involvement in areas other than the 'main issues' - such as how best to teach the content of the science curriculum or the impact of language on learning. The hallmarks of science, i.e. rationalism, reductionism and empiricism, have caused many Western Christians, who are also scientists, to adopt a ‘theology of faith’, where different forms of knowledge are compartmentalized and kept independent of each other. But while the life-world of people within Western culture may involve a dualism related to science and religion, it appears to be taken for granted that *because* they have a Western cultural background, their home worldview and the worldview of science will not be dissimilar in the same way that the worldview of someone with a traditional background will be dissimilar to the worldview of science. African Christians, it may be argued, have to contend then, not just with the science/religion conflicts that some of their Western counterparts may also have to deal with - they also have the challenge of conflict between their traditional views and those of science.

The science curriculum in South Africa, as presented in both the pre-democratic CNE curriculum and the post-democratic OBE curriculum, is made up of what has been termed ‘mythical science’ because it is so far removed from everyday experience. This curriculum has only very recently been made generally available to Black school learners in South Africa, and the introduction of these learners to the conflict between science and religion is also likely to be abrupt: the science curriculum is usually presented without the benefit of a history and philosophy of science approach, and it is not presented as only one of the ways of knowing. It is also unlikely that the average Blearner would have had any exposure to the long history of conflict between science and religion that has been part of Western history, as many are the first in their family to have gained a high school education. Few would thus have a family background which could serve to prepare them for conflict in these ideas, particularly in relation to Earth Science in terms of the creation and evolution of the Universe. The Christian teaching that is followed by many Africans, particularly those belonging to the African Independent Churches, tends to be fundamentalist. The result is that for many of the students entering university, the un-mediated presentation of scientific theories and knowledge as 'truth' presents huge challenges in terms of their epistemology and ontology. In addition, this 'truth' is presented by people who, for the students, are powerful authoritative scientists, who are also in a position to determine their academic future. Neither traditional ways of knowing, nor religious ways of knowing - which for African students might be traditional or Christian or both - are acknowledged or even mentioned by these lecturers.

For African students, two issues bear consideration in terms of conflicts raised by the Earth in Space course and other ways of knowing: the first concerns cognitive difficulties related to religious beliefs, while the second is related to the personal costs involved in learning the explanations of science.

6.2.1.1 Difficulties related to religious beliefs

Several research studies in the United States have indicated that religious beliefs can have a profound effect on students' attitude to learning science. For example, the study by Jackson *et al*. (1995) regarding the teaching of evolutionary theory to religious students made them question conceptual change as a goal for science education, and suggest that the conflict between science and religion represented a *bona fide* example of a multicultural issue in science education. The intention behind their study was to better understand the much publicized conflict between science and religion which has had a major bearing on science education in the southern states of the USA. Their conclusion was that there is a "common tendency among science professionals to view or treat orthodox Christian students in a manner unconscionable with others – to disrespect their intellect or belittle their motivations, to offer judgments based on stereotypes and prejudices (and) to ignore threats to personal self-esteem…" (*Ibid*., 995, 585). This view is not shared, however, by many scientists and science educators who have little patience with religious beliefs in the science classroom. A few other studies carried out in the United States of America (e.g. Roth and Alexander (1997) and studies by the team of Brickhouse, Dagher, Letts and Shipman, 2000 and 2002) indicated similar results to the results in my study: some students were able to integrate the discourses, while others found it impossible to do so - a situation which impacted on their ability to learn the science, or, in the case of students in my study, sometimes resulted in them rejecting their religious views.

However, despite these similarities, there appears to be a significant difference in terms of scale between the findings of studies in the United States and the current study. In making this statement, it is recognised that differences in methodology may be responsible for creating this impression: the American studies have tended to focus on portraits (similar to the vignettes offered in this study) to illustrate different responses to the perceived conflict between science and religion, rather than specifically focusing on the numbers of students involved. In the context of the current study, the most significant finding was in relation to the numbers of students who were affected by the conflict, a finding which led to the suggestion that African students face a double bind in terms of their worldview: the first relates to their struggle with the conflicting views offered by Christianity and science, and the second to conflicts with their African cultural beliefs. So many Africans profess to be

Christian, but at the same time carry a holistic African worldview which is based on a religious ontology, that the conflict between science and religion appears to affect many more students than is the case in First World countries, where religion and science have historically been viewed as separate domains of knowledge, and the conflict only affects those students who are 'very religious'.

The danger of generalization can be seen, however, in the fact that some of the students claimed that there was no clash between science and their traditional beliefs. For some of the students, the theories and explanations of science were attractive simply because they 'made sense'. Others stated that traditional beliefs had been developed by people who had not had access to the technology that had led to the knowledge known as ‘science’, and that evidence supporting the explanations of science indicated that what science taught was true. An interesting perspective of some African writers is that they believe science has simply not yet come up with the technology that will show that what Africans believe is true (Setiloane, 1998(a)). It needs to be recalled that according to African authorities in African spirituality and philosophy (for example Mbiti, Okere and Motshega), the worldview of Africans, even those who fully ascribe to Christian beliefs and practice, or to science, will still, deep down, be permeated by African beliefs. They say that these beliefs will to rise to the surface during times of crisis, even in those who appear to be completely immersed in Western ways and Western thinking, and who appear to be completely alienated from their traditional culture. Examples which support this claim are abundant, particularly in relation to illness.

6.2.1.2 Difficulties related to personal costs

For those for whom the new ideas presented in the Earth in Space demanded a choice, and who did not find a way to solve the conflict, the personal costs to making the choice between science and culture or religion could be very high.

While Western culture is increasingly associated with materialism, secularism and an exaltation of individualism, African traditional culture is deeply religious and monistic. This translates into the idea of the connectedness of all things and the philosophy of ubuntu and community. For Africans, true knowledge is ontological knowledge, based on the idea of God as creator. Within the ontological hierarchy, it is only within community - which extends beyond the living members of the extended family and incorporates the “living dead” (Mbiti, 1969, 25) - that it is possible to be fully human. Consequently, “… a person cannot detach himself from the religion of his group, for to do so would be to be severed from his roots, his foundations, his context of security, his kinships and the entire group of those who make him aware of his own existence… to be without religion amounts to a self-excommunication from the entire life of society, and African peoples do not know how to exist without religion” (*Ibid*., 2). Belonging to a community of people, who share a communal faith, can be seen, then, to be fundamental to African identity.

Some of the students in the sample solved the problem of conflict raised by the Earth in Space course by playing “Fatima’s Rules” i.e. just learning the content in order to pass the exams. But for others, the choice was either to believe what they were learning and reject their religious or cultural beliefs, and in this way risk belonging to their community – or - they had to reject what they were learning because it was just too costly, and risk failing the course because they simply could not countenance learning science that was seen as blasphemous and contrary to their sense of identity.

The responses from the students indicated that for those who were hearing some of the concepts for the first time, and for those especially close to their cultural roots, the extent of what they were being asked and expected to learn was just too much. To move - within the space of a few weeks from Nussbaum and Novak’s Notion 1 (a flat Earth concept) or Notions 2 and 3 (where space is limited to the sky and there is no clearly developed notion of the Earth as a cosmic body), and from the understanding of the sky as a physical heaven and the stars as ancestors watching over them at night - to comprehending concepts such as geologic time, the dimensions of space, and especially the apparent dismissal of God and hence the purpose for human life - is probably virtually impossible. As far as the conflicts with Christian beliefs were concerned, Edwards (1998) has pointed out that the exponential growth of African Independent Churches and membership of these Churches is due to the fact that there are aspects of Christian spirituality that are consonant with the African worldview and therefore tend to reinforce it. Two of the most significant of these aspects relate to the role of community and the role of the spirit. As noted in the literature review, African churches meet a need, in a rapidly urbanizing society, for community and a sense of belonging. People who have suffered the loss of connection to their extended family, village community and even tribe, as a result of moving to large urban townships, can find a new ‘family’ and sense of belonging in a Church, where the deep need to be connected to other people and to the world of the spirit can be met.

The very different worldview of science, with its apparent exclusivity as a way of knowing, is not seen to offer an attractive alternative. The mismatch is exacerbated by a lack of understanding on the part of the predominantly White lecturing staff, who have very little knowledge and understanding of the prior knowledge and worldview of their students, and therefore lack awareness of its potential impact on learning. They are also burdened by strict time schedules and the pressures of their own research. Consequently they may teach year after year without investigating or understanding how these issues, and the content rich curricula they tend to follow, may affect their students’ learning. Tom Settle in his 1996 paper "Applying Scientific Openmindedness to Religion and Science Education", claims that by 1968, the positivist programme on which many science curricula were based had collapsed, but goes on to note that "on some campuses, it must be confessed, the collapse of the positivist programme for interpreting science has not been noticed" (Settle, 1996, 135). While the new South African school curricula (the RNCS and the NCS) do present a nominalist approach (even though this may be on paper only), university curricula in South Africa tend to continue to be essentialist. There is also no warning hint in the science education literature (for any Earth Science lecturer who may be adventurous enough to dip into it!) regarding the scale of the problem among African students, nor any guidelines on how to deal with it.

6.2.1.3 Difficulties related to authority in African culture

Another barrier relates to authoritarianism and the place of authority in African culture. Authoritarianism has been pointed out by Jegede, Wiredu and Kudadjie and Osei as one of the most important African socio-cultural influences on the learning and teaching of science. This problem was clearly demonstrated by the fact that until I had administered the post-instruction questionnaire, with its questions which asked the students about difficulties they had experienced and what their opinion was of the content of the Earth in Space course, and had invited them to come for interviews to talk about their thoughts and feelings, none of the students asked any questions that related to concerns they may have had, or conflicts that had been raised for them by the course.

Kudadjie and Osei (1998) have pointed out that in addition to the African cultural practice of respect for elders, which includes not questioning anything that someone in authority says, theocratic societies do not encourage independent or unconventional ideas. For young first year African students, particularly those from religious homes, the lack of questioning can thus be related to both sources in their socio-cultural environment. However, as has been noted, once the students 'got the message' that I was interested in their ideas, many were willing and even very keen to talk about the difficulties they had experienced.

6.1.2.4 The value of ethnophilosophy

It was argued in the literature review that the ethnophilosophic worldview approach, while not satisfactory in describing African philosophy as far as some African philosophers are concerned, does provide information that can be useful in terms of science education. The information available from this source made possible, in this study, the exposure and explanation of some of the cognitive difficulties experienced by students taking the course.

While the focus of this study has specifically been cognitive conflicts associated with different worldviews and differing truth claims, it must briefly be acknowledged that there are other barriers to learning that also affect the students. One of the most important of these is related to language, with most, if not all of the Black students being taught and having to speak and write in a language that is not their mother tongue. Problems related to clear expressions, as well as the correct use of grammar, were clearly evident in the students' responses to the questionnaires and in the interviews. These widespread difficulties were exacerbated by problems commonly associated with the terminology of basic astronomy.

However, the responses of the students to the post-instruction questionnaire and the interviews had highlighted the fact that it was socio-cultural issues, made explicit through ethnophilosophy that resulted in the cognitive difficulties which caused problems for the students. In line with expectations created by the theories of cultural border crossing and collateral learning, the worldview of the students certainly had a profound impact on their willingness or ability to cross the cultural borders into science. The interviews were especially useful in providing deeper insight into the challenges faced by the students and the reality of the impact of their worldview: sophisticated, sassy Nombuso 'confessing' that "*I have a teeny, tiny belief on this ancestral things";* and Jabulani expressing his fear about losing his sense of belonging in his community "*I do not want to be ostracized".* However, the most important finding to emerge in terms of expectations created by the science education literature was that (Christian) religious beliefs appeared to be more of a stumbling block for these students than beliefs related to their traditional culture. Samson expressed the views of many students when he explained how unsettling it was "*that these things I learnt began to interfere with my religion because they might be true".*

Cultural border crossing was thus found to be very useful in serving to highlight the challenges faced by students in learning science. However, during the analysis of the data, Jegede's own caution, in 1997, that collateral learning was 'difficult, if not impossible to explain or confirm' was shown to be true, and Barbour's Typology provided, in this case, a more suitable explanation for how students dealt with cognitive conflict than did collateral learning. Compartmentalization is an important category in both Jegede and Barbour's Typologies, but the definitions of the different kinds of compartmentalization in Barbour's Typology allowed it to be applied more fruitfully, in terms of the analysis of the data, and in terms of the opportunity to improve pedagogic practice.

6.2.2 Recommendations for pedagogic practice - the dilemma of identity and the hegemony of science

One of the most important benefits to emerge from the concept of cultural border crossing is Aikenhead's notion of teachers acting as 'culture brokers'. Recognition of the importance of students' prior knowledge and worldviews, and the problems that may arise as a result of conflicting knowledge systems, have led to suggestions such as approaching science teaching from a history and philosophy of science perspective, and including modules on the 'nature of science' in the curriculum. It has also been suggested, in multicultural situations, that including indigenous knowledge in the curriculum will increase relevance and interest. The universal goal of all these suggestions is to improve science literacy and the numbers of students taking science. This is part of the broader goal of economic development and the need for people with skills associated with science, which, in turn, is related to pressures that arise from an increasingly globalized world (du Toit, 1998).

South Africa is no exception in its desire to increase access to and success in science learning at school and at university. The most recently instituted programme with this in mind is the development of "Dinaledi" schools, where scarce resources are concentrated at particular schools (Gadebe, 2006). However, the results from this research study indicate that it is also vital to address the ‘Kenneth Kaunda question’: “How can we ‘preserve what is good in our traditions and at the same time allow ourselves to benefit from the science and technology of our friends?’”. This question needs to be considered to ensure, as Ogunniyi (1995) has pointed out, that identity is not lost or neglected in our pursuit of economic development That it is possible to not lose a sense of identity is clear from the fact that this has been achieved in Japan and India (Ogawa, 2002; Peterson, 2003; Koul, 2003). However, Koul points out from his study in India that for Hindu students there is no conflict between school science and their religion, as the ideas of science are simply absorbed into Hinduism. This would seem to reverse the order of the problem of a pyrrhic victory, suggested by Cobern and Loving (2001) as one possible outcome in the battle for the recognition of different forms of science. Koul explains that because Hindu Vedic knowledge is a philosophy of nature, and the nature of Hinduism is universal and inclusive, western science is simply translated into this philosophy: “…encompassment is the traditional Hindu way of dealing with heterodox ideas…it tends to include them in a hierarchic relation subordinated to the ultimate truth of dharma” (Nana in Koul, 2003, 121). This seems to bring its own problems however: Nana, an Indian educator and philosopher “is an advocate for well-defined boundaries between science and traditional Hindu thought. She argues that when Hindu worldview encompasses the methods and findings of modern science, science becomes an inferior, materialistic aspect of Vedic wisdom” (*Ibid.).* In addition Kumar, an Indian science historian, has warned that, in India “…revivalism has created a strong social obsession with the distant past and an engagement in irrational thinking.” (*Ibid*.). Is there a danger in South Africa, where there is a strong focus on IKS in the new curriculum, that this focus, if used in the incorrect way, could also lead to irrationalist thinking?

In South Africa, the Revised National Curriculum Statement (2002) and the National Curriculum Statement (2003) specify as one of their overarching principles the need for educators to recognize and value 'other ways of knowing'. Research has shown that the inclusion of IKS increases interest in science and an understanding of the relevance and usefulness of science. However, the findings of this study indicate that because of the nature of African philosophy, *religious* ways of knowing need to be explicitly acknowledged as one of the 'other ways of knowing', in order that students don't play 'Fatima's rules' or succumb to scientism. Acknowledging these other ways of knowing enables openness on the part of the students, and a willingness to engage, even with ideas that may at first be seen to be unacceptable.

The difficulty is that this is not easy for a number of reasons. As far as IKS is concerned, these include: how should this knowledge be accessed? Who decides which knowledge should be included? How should it be valued? As far as religion is concerned, the questions are similar, and just as problematic. But these problems are not new: Gillborn (2002) points out that ‘other ways of knowing’ have been discriminated against in the classroom through unwitting prejudice, ignorance, thoughtlessness and racist stereotyping.

Jackson *et al*. explicitly note that in situations where other ways of knowing are drawn in, but are in conflict with the standard account of science, the confrontation can be “enlightening but also greatly distressing” (1995, 607), especially because science teachers are usually untrained in the delicate task of managing debate around controversial issues. In addition, Earth scientists, as lecturers, are unlikely to be tolerant of creationism, whether it is ascribed to from a culturally traditional, or Christian, perspective. Shipman *et al*. (2002, 543) also make the point that “for such big questions as the origin of the Universe and the origin of Life …it would seem to be too much to ask for any one course to go that far with all the students”. In making these observations about other ways of knowing, however, Jackson and colleagues and Shipman and colleagues were referring to the conflict between science and religion. The situation in Africa is more complex, as ‘other ways of knowing’ are not just all about science and religion, but are also about IKS.

The other ways of knowing making up IKS are not all just benign and potentially helpful pieces of ‘traditional ecological knowledge’ (TEK) (Snively and Corsiglia, 2000). 'Other ways of knowing' include things like “muti killings, (which) remain a problem in rural South Africa and (especially) in the Eastern Cape, where grisly murders are still committed in the misguided belief that harvested body parts are able to generate wealth, settle family disputes and even cure diseases” (Dimbaza, 2006, 4). As much as it is important to recognize and value other ways of knowing, it is thus also important not to romanticize or validate all indigenous knowledge. In her autobiography, Mamphela Ramphele is succinct about the complexity of the problems facing indigenous minority communities globally. She notes the:

> “…dangers posed by the devastating combination of guilt and deep seated lack of respect shown by the white colonial authorities, and the role of victim adopted by the colonized. Coupled with this role is a glorification of indigenous culture which poses the greatest threat to the ability of indigenous people to transform their social relations. Modernity is a reality they cannot wish away, but engaging it creatively requires a critical appraisal of indigenous culture, and the retention of the good as well as the jettisoning of the bad.” (Ramphele, 1996, 194).

Egunjobi (in Burkhardt, 1999, 7) also cautions that “it’s not every IKS or traditional way of life that is desirable”, so traditional folklore, superstition and spiritism, as much as creationism, are not likely to be welcomed as part of the science curriculum. A challenge will be drawing the boundaries between these different forms of knowledge. At the same time, there needs to be recognition of Horton's point, that there are times when science requires as much ‘belief’ as do other forms of knowledge.

The IKS which could comfortably find its way into the science curriculum is TEK (Traditional Ecological Knowledge) or, as described by Lewis and Aikenhead (2001), ‘non-Western nature-knowledge’. But it is clear that for other ways of knowing to be well handled in the classroom, a situation of “special encouragement and special safety” would be needed (Erickson, 1998, 1158), as would teaching staff who could sensitively handle the distinction between understanding and belief (Sinatra *et al*., 2003; Shipman *et al*.

2002). This is a very tall order for someone hired to teach university level Earth Science, and who has limited time to teach. And, it may be argued, is not the intention of the course to produce mining geologists, not geological philosophers? However, Kincheloe's (1998) statement that teaching astronomy without reference to other ways of knowing can be equated to 'unexamined scientism' must be borne in mind, especially in the light of Peterson's condemnation of scientism as “the greatest intellectual sin” (2003, 751).

Huge efforts have been made in South Africa to move away from rote learning to critical engagement and the development of thinking skills. But one of the noteworthy findings to emerge from this study was the shift towards scientism by the students: the power of the university as an institution; the power of science as a way of knowing; the potential personal power resident in converting to the scientific way of thinking and knowing - including the opportunity, as articulated by Xolani in his interview, to become the geologist in the mine rather than the labourer - all resulted in the students accepting and learning content that was largely unexamined and uncontested by them.

Some of the students mentioned talking about their difficulties with friends, but for most, there was a vacuum of mentorship: Black students in South African universities are often the first in their families to go to university. Consequently, their parents, or elders in their communities, do not have sufficient educational background to engage at the levels required by these students. Neither do the pastors in their churches. The cognitive work required to do any more than superficial interrogation is also difficult and very time consuming. One of the students commented that the course left him/her with a “big task to do” and another that s/he would try to tackle the conflicts “when they had time”, but the general pressure and demands of life at university are likely to stifle any careful consideration of these conflicts.

As far as the 'givers' of knowledge, i.e. the teachers or the lecturers, are concerned, it seems that it is mostly philosophers and theologians, as well as science educators, who espouse a worldview approach to science education and who are concerned about loss of identity and the hegemony of science. For them a purely economic and technological advancement conception of development is no longer tenable. However, it seems that it is extraordinarily difficult to move the idea of other ways of knowing into an education system that is driven by assessment, and into a science curriculum that is crammed full of condensed Western science. It is also difficult to move teachers, who may not be sufficiently qualified for the job they are trying to do, or who may be positivist in their outlook and unwilling to consider any other ways of knowing, to seriously consider the task of 'culture brokering".

How indeed, then, is it possible to “gain access to a Western scientific way of knowing without losing something valuable from cultural ways of knowing?" (Aikenhead, 1998, 4)

Hammond and Brandt (2004, 9) point out that education is inextricably linked to larger social orders, and that twenty-first century schools are defined by dynamic and international forces, “with science education (having) become inextricably bound to a variety of global forces that are interconnected, political and economic, and rapidly evolving”. Their suggestion for science education, based on the ideas of Zembylas, is the creation of ‘spaces’ in which the “local can be performed together with the global” (in Hammond and Brandt, 2004, 33). They draw together the ideas of Turnbull, who said that “…knowledge …will tend towards homogeneous information at the expense of local knowledge traditions…(but) …there is a future for other knowledge traditions, because as the myth of science collapses, so we become more aware that diversity is the key to survival” (*Ibid*., 33), and the suggestion by Aikenhead, that when indigenous worldviews conflict with the assumptions of Western science, science education should be modified to accommodate these views (*Ibid*., 34). Aikenhead thus advocates a ‘multiscience perspective’, and provides an exemplar for how this can be done in his "Teacher Guide to Rekindling Traditions: Cross-Cultural Science and Technology Units" (Aikenhead, 2000). Ogunniyi (2006) has shown how the use of an arguments-discursive course can enhance the ability of teachers to think about and include indigenous knowledge in their teaching. However, it has to be borne in mind that in South Africa, the situation is different from that, for example, in Canada, where First Nations people are in a minority, or in Australia, where the Aboriginal people are also in a minority. In South Africa, the demographic profile is quite different. Black people make up 80% of South Africa's population, but represent a large number of different groups. There are 11 official languages. Lifestyles range from minority extremes of hunter-gatherer on the one hand and urban affluence on the other. On the whole, the struggle in education is for an equal footing with the First World, yet the dream is to (re)discover and maintain a South African identity, which may, in the light of its diversity, take the form of multi-identities.

In South Africa, the motivation behind much of the research in science education is the improvement of teaching and learning, with a view to satisfying broader educational demands regarding the need to produce, for example, engineers, scientists and IT specialists. Much of this research is based on the theory of constructivism, which has given rise to sub-theories such as worldview theory and cultural border crossing which are helpful in assessing where you are (prior knowledge) and where you have to get to (excellence in science teaching and learning). In multicultural situations, the assessment of prior knowledge can also lead to difficulties. The study by Lemmer *et al*. (2003), for example, included a comparative worldview component, in which responses by White students, with an assumed Western worldview, were compared to those given by Black students. Lemmer *et al*. claimed to have “established that European students (sic) responded more in accordance with a modern or mechanistic view of the Universe, while responses of an organistic nature were mainly found among African students” (*Ibid*., 2003, 578). The African worldview is built on the notion of a central God and the existence of a spirit world, populated with “gods, goddesses, spirits, divinities, natural forces, titulary deities, ancestors , taboos, witches, wizards, emeres – children with powers of reincarnation, magic, mysticisms” (Ogunniyi, 1995, 24). Kudadjie and Osei (1998, 45) believe that this worldview, which views people as being subordinate to this host of spiritual entities, is a stumbling block to Africans being able “to engage in any detached scientific thinking." However, Lemmer *et al*.'s view highlights one of the intractable problems associated with multiculturalism: that of “othering”, which posits one form of knowledge as modern, and thereby superior, and by inference, the other as ‘un-modern’ or ‘primitive’ and inferior. The well meaning intention of the Lemmer study, like so many others in research in science education, was that it “hopes to contribute to the knowledge about the origin and features of pre-scientific conceptions and views so that they can be addressed more effectively in the science classroom” (Lemmer *et al*., 2003, 563).

South African education has moved from what may be described as ‘well intentioned paternalism’ to a democratic system, where, while the curriculum is firmly reflective of Western curricula, ‘other ways of knowing’ *are* acknowledged. It is thus critical that educational research in South Africa should be alert and sensitive to issues that may be interpreted as racist. At the same time, South Africa’s aspirations to be part of the global economy requires that many people should be trained in science and technology, and research which serves to improve pedagogic practice and learning in these areas is to be welcomed. Ogunniyi has pointed out that it is naïve to assume that “students can be persuaded by a few hours of exposure to science, to break with meaningful and tenaciously held cultural beliefs for alien concepts they have just encountered in the science classroom” (1995, 26). This would seem to support studies which, through making visible cultural beliefs and their impact on learning, would serve to “help Africans absorb scientific interests, attitudes, thoughts and habits without destroying their identity as people” (*Ibid*., 38). Onwu and Ogunniyi (2006) place the responsibility for meaningful curriculum change and innovation with the teachers. The ultimate goal, wherever the drivers come from, must be to improve access to and success in science education in South Africa, while at the same time promoting the social drivers that sustain a healthy society. These are care, ubuntu, morality, values, community, sustainable development, - all of which require that identity is maintained, because social coherence and maintaining normal social relations is fundamental to harmonious community living.

Happily these values are supported by an international paradigm shift in terms of the role and position of science, reported by Matthews (1998), Sarracino (1998), Schroeder (2001), Barret (2000) and many others. This paradigm shift has seen the strengthening of understandings related to the Nature of Science, where multiculturalism and ethics have highlighted that science only presents one way of knowing, and now physics, for example, is increasingly making room for metaphysics. This means that an approach to science which increases scientism and acts to destroy culture is no longer tenable. This understanding is supported by research such as that carried out by Brickhouse *et al.* who found that when religion was introduced as part of an astronomy course, the end of course evaluation indicated that students “appreciated the inclusion of religion in the course and practically none were offended by it” (2000, 354).

The acknowledgement of other ways of knowing, including recognizing that metaphysical explanations are more appealing to Africans than are mechanical explanations (since these fit better with their religious ontology) could serve to improve learning. The incorporation of IKS has been shown to stimulate interest and increase access to science and this means that the barriers could be reduced, if not removed, by following Roth and Alexander's (1997) recommendation that spaces should be created in the curriculum for students to explore, clarify and possibly integrate their conflicting discourses. George (1999) refers to the teachers' actions in this process as "bridge building". However, as pointed out by Brickhouse *et al*. (2000), the beliefs (religious and/or cultural) of some instructors or their institutional settings might well preclude an effective intervention. Overlying all this debate, however, is the fact that science education is "slow to respond" (Taylor, 1998, 1112). It is more than 20 years since Thijs presented a paper at the International Symposium on the cultural Implication of Science and Education in Nigeria, in which he concluded that in Africa, "the neglect of cultural factors is an important reason for the alienation of people from science" (Thijs, 1984, 50). However, in South Africa, since the change to Outcomes-Based Education, the existence of other ways of knowing in the curriculum is now recognized, even if this recognition still needs to be worked out in practice.

The contribution I hope to offer through this thesis is that in the same way we have been alerted, through science education research, to the impact of culture on learning in science, we need to be alert to the impact of religion, especially with regard to African students and the double bind presented by the religious nature of African philosophy. The dearth of research on the impact of religion on learning in the science education discourse may reflect the historical animosity that has existed between science and religion in the west - but it cannot be ignored in Africa. In the United States of America, where controversies around evolution and creationism are well known, the response of students in the study by Shipman and colleagues gives no hint of the situation as experienced in South Africa. Shipman *et al*. noted that after "…a cautious introduction of the dialogue between science and religion into a college astronomy course … approximately half of the students engaged with the issue of science and religion to some extent" (2002, 526). This does not come close to the passionate response from the students in my study, where only 8.5% (14 out of a sample of 163) stated that they did not find anything in the course 'hard to believe'. What was hard to believe was overwhelmingly connected to conflicts between science and both their Christian and cultural beliefs. For my students, the costs of the choices they made were potentially very high.

My experience of encountering the students' pain - of hearing the dilemmas they faced, of slowly coming to understand the pressures they were under: the reality of being ostracized from Church or community, of being 'forced' to lose touch with their identity or alternatively of giving up on the dream and glamour of science because it cost too much, the lack of availability of mentorship - profoundly changed my understanding of what it meant to teach a course in basic astronomy to these students. Wits is a secular university - but the students were not secular. Science is not value free, but we teach as if it were. The curriculum demands that we cover a certain amount of content to provide the foundation for the next layer of knowledge, but this does not mean that we are achieving learning. We are trying to offer the knowledge of the modern world without recognizing the inheritance of the old one. I found that I needed to encounter the arrogance of my worldview, and in doing so, a sharing began that led to learning in both directions.

The simplest solution, it would seem, that would open the door for students without compromising the personal beliefs of the lecturer, is that they should respectfully make available a list of resources (books, people, videos - the availability perhaps of a discussion group), indicating that the experience of conflict in terms of ways of knowing is common, and that the possibility for real integration exists.

6.3 METHODOLOGICAL FINDINGS, LIMITATIONS TO THE STUDY AND RECOMMENDATIONS FOR FURTHER RESEARCH

6.3.1 Issues related to methodology

The methodology that was used in this investigation was predominantly qualitative. However, the quasi-experimental approach that was used in relation to the questionnaires allowed not only for the emergence of particular types of knowledge and ways of thinking, but also for the establishment of the prevalence of these ways of thinking and types of knowing. Consequently, a multi-method approach was used, where although the 'number crunching' used in the analysis of the data was very simple, it was also very valuable.

Science education research frequently sits at the nexus of quantitative and qualitative research methods. Its focus is on human activities, specifically teaching and learning, with research efforts being directed at understanding these processes with a view to improving practice. While the teaching and learning that is of interest to science education falls within the context of science as an accumulation of factual knowledge - where numerically based evidence is valued for its ability to abbreviate findings and illustrate the weight of these findings - qualitative research has gained in acceptance because of what it reveals about human nature. Recognition has grown that all research is a purposive activity (Lindsay, 1997) and that issues of positionality (Skelton, 2001) inevitably play a role in all the different stages of research, including the construction of instruments and the analysis and interpretation of the data. Consequently, the issues of validity, reliability and transferability associated with quantitative research, have morphed into ‘appropriateness’, ‘meaningfulness’ and ‘usefulness’ (Fraenkel and Wallen, 1990), or ‘credibility’, ‘dependability’ and ‘confirmability’ (Lincoln and Guba, 1985). It has even been pointed out that some types of research, such as ethnographic research, preclude exact replication because it is focused on providing a detailed description of a particular situation at a particular point in time (Lindsay, 1997).

The point of referring here to issues related to the different methodologies is that, as Mokuku (2004), Malcolm and Alant (2004), Keane (2006), and others involved in science education research in South Africa have pointed out, these methods and the checks and balances applied to them have been worked out, commented on, used and refined in the context of *Western* education. Fleer (1997) made a similar comment in terms of her research with Aboriginals in Australia, where she questioned the application of Western methods in traditional Australian cultures. African philosophers have also challenged that information pertaining to African worldviews gained from Western methods is flawed.

How then to proceed?

The answer comes from a bumper sticker that asks ‘How do porcupines mate?’ and where the response is: ‘carefully!’

With regard to this study, ‘carefully’ has meant tentatively and stumblingly: it is very clear that much hinges on the questions that you ask and how you ask them, and these depend on how you interpret the theoretical framework and the literature that has shaped your thinking. In keeping with the standard recommendations for research, my questions were face validated (which, as described in Section 4, caused problems), my selection of categories of responses for analysis were checked by two education specialists as well as my supervisors, the transcriptions of the interviews were checked and validated by the interviewees, the literature reviews were checked by different colleagues who had specialized in the different areas such as astronomy education and African philosophy and religion, and my work had been guided by gracious comment from luminaries such as Professors Ogunniyi, Mbiti and Okere. What then is the problem?

Qualitative research is analogous to a journey of discovery. When research is done in the context of multicultural education, this journey is characterized by complexity. The theoretical framework becomes the road guiding the journey, and the methodology the vehicle one is traveling in. Clearly the road and the vehicle can vary in quality, as can the skill of the driver! However, the landscape in which the journey is being undertaken comprises the people on whom the research is visited, and the human response, in all its complexity, determines the data that is obtained.

This is clear from the differences in the richness of information that was obtained from the questionnaires and the interviews, although this is not unusual. Koul (2003, 114) noted that survey items confined to single questions do not “capture the complexity of student thinking or the full nature of their belief structures”, and that that interviews offer “a more subtle and complex picture”. Keane (2006) notes from her research on ‘understanding science curricula and research in rural Kwa-Zulu Natal’ that “facts come in a variety of categories: information, misinformation and disinformation”, with difficulties relating to data collection including “shyness of respondents, my own not wishing to intrude… and respondents’ wanting to give ‘right answers’” (112). The one on one situation of the interviews, the difference between writing (the responses to the questionnaires) and talking (in the interviews), the fact that all the interviewees were students I had taught and spent time with in practicals and on field trips, with opportunities to make visible my interest in their views during this time - can be used to explain the richness of data that emerged from the interviews. But it raises a host of questions as well: what did the students tell me because I am White? What would they have told me if I had been Black? Were they shy to tell me things that they felt I would not understand? What other questions would I have asked them if I had not felt that I may be intruding, or compromising my position of power as their lecturer? What questions would I have included, and how would I have analyzed the data, if I had known more about social anthropology/philosophy/psychology/theology?

6.3.2 Limitations of the study and suggestions for further research

The questions that have been posed lead to the identification of the limitations to the study, and consequently, to suggestions for further research in this area.

The first limitation has to do with the prior knowledge that shapes the research: collaborative research would allow for a deeper and more informed investigation. Bringing together a racially diverse group of researchers, with grounding in philosophy, theology, social anthropology, sociology, psychology and science education would provide access to a wealth of input and discussion. Broadening this group to include people with an interest in the neurological functioning of the brain would enrich the research by shifting the focus from social, cultural and cognitive aspects to including the physical aspects of learning.

A second limitation is related to the context of the research. While the data for this study was conducted using six different convenience samples, with the data being collected over the time span of three years, the findings are limited to the context of the study. Widening the research to include more students and a diversity of tertiary institutions would provide grounds for generalizations. At tertiary institutions where there are courses in Palaeontology and Archaeology, the findings of this research could be used to stimulate research into the barriers to learning in those fields. Researching the views and attitudes of the lecturers teaching courses involving conflicting ways of knowing, would also be helpful in broadening our understanding of barriers to learning. At school level, fruitful research could be conducted to establish teachers' views (and practice) on the inclusion of IKS and religion in the science classroom.

A third limitation relates to the problem of constructing questions for both the questionnaires and the interviews. Asking the 'right' questions is an 'art', which potentially grows with practice. While the recording of prior knowledge and "post instruction" knowledge was relatively straight forward, it has to be recognized that it is very difficult for people to identify or explain how or why they understand or believe something, or why they might change their minds about something. It is also recognized that it could be difficult to try to get students to identify where their knowledge or belief comes from, without resorting to asking leading questions. In addition there is the pressure that students feel in what may be felt to be a test situation, even when reassurance has been given that this is not the case. The following extract from one of the interviews serves to illustrate this:

Q Ok, Paul, let's have a look at question 5… where we are looking at Moon phases. You say they are because of seasonal changes in your first questionnaire, then in the second one, *after you have done the course, you wrote that you had "no idea"… can you tell me what happened?*

A Mmmm… actually… now… I don't have an idea… what was the question again? Ok… I think with the first questionnaire, I was just trying to impress… I didn't know much, so even now, I don't know what it is. But now I'm used to university life, and ok, I understand that these things are not for marks, but to… try and see… as to where we are going … so… mmm …I don't have an idea, so now, maybe this one was wrong, so… now I didn't want to write a wrong thing again, so that's why I said "no idea"…

Another limitation associated with the formulation of the questions was that the wording of several of the questions provided the opportunity for the students to treat them as closed (yes/no) rather open questions. For example, question 4 in the post-instruction questionnaire asked "Do **you** think the science that is taught in the Earth in Space course is the real truth about natural phenomena and how the world and the Universe works?" elicited 'yes' or 'no' answers from a number of students. This problem was addressed when the questionnaires were handed out to the students: they were asked to answer the questions as fully as they could. Consequently, there were only a few students who actually answered 'yes' or 'no' to these questions.

A fourth limitation relates to the choice of data in writing up the findings. The response of the students, in using the opportunity afforded by this research to voice their protest and confusion relating to the conflict they felt, was incredibly powerful. The student who at the end of his interview nervously said to me - ‘You showed us the poster of the solar system and how it fits into the Milky Way, and how the Milky Way fits into the other galaxies. Where, then, is heaven?’ - captured something of the loneliness and pain experienced by some of the students as a result of the course. I was also shocked that a seemingly harmless course in astronomy could result in another of the student’s saying: ‘I used to go to Church, but I don’t believe that stuff anymore because of what I have learnt in the course’. The result has been that this study has focused on the barriers to learning related to religious and cultural beliefs, rather than investigating particular aspects of the students’ understanding of astronomy or focusing on conceptual change.

6.4 CONCLUSION

> For nearly four hundred years Western thinking has been dominated by modern science. For most of this time it has been a major problem for faith. Today this is changing. There is a new science, a new kind of scientific mentality that opens up vast new possibilities for spirituality and faith in God. This change constitutes one of the truly great signs of our times.
>
> (Albert Nolan, 2006)

The voices questioning Western hegemony and globalization, and the pressure and impact that these two forces have on education around the world, have been growing stronger over the last few decades. In the world of science education and in the context of 'science for all', the focus of research has been on how to improve teaching and learning in classrooms around the world. Constructivist learning theory has highlighted the vital role that prior knowledge plays in learning, and research in multicultural situations has gradually led to the recognition and acknowledgement of other ways of knowing and the difficulties associated with differing worldviews. At the same time as efforts have been directed at identifying barriers to learning associated with these other ways of knowing and ways to assist in border crossing, the question asked by Kenneth Kaunda in 1966 – 'How can we preserve what is good in our traditions and at the same time allow ourselves to benefit from the science and technology of our friends?'- is still relevant in non-Western societies.

In 1997, Jegede stated:

> "for the teacher who shares the same socio-cultural background, the issue (i.e. the difficulties of African students learning science) is as real as it is frustrating. The situation is even worse (and may be horrendous) for the teacher with a western background who has to teach students of non-western backgrounds" (*Ibid*. 9).

In South Africa there is a growing body of research that is making what was previously 'invisible visible' (Keane, 2006). Studies that question the relevance of Western curricula and that highlight different ways of knowing, and the difficulties of learning in a second language, can serve to make educators aware of barriers to learning that were previously unknown or unspoken.

As far as astronomy education is concerned, there are peculiarities related to learning that are specific to this field. Research has shown that despite the fact that the heliocentric model of the solar system has been accepted for hundreds of years, many educated people lack the clear mental models that are required to give causative explanations for phenomena such as day and night, the seasons and Moon phases, tides and eclipses. These explanations require the ability to think abstractly about the movements of the Earth and other cosmic bodies in space; to create a sophisticated image of space beyond the limits of the sky; and to understand the effects of gravity, distance and scale. However, the primary reason for misconceptions related to astronomy is that the scientific explanations are counter-intuitive. But there are other factors: for those people who have religious or cultural explanations relating to these phenomena, the scientific explanations are cold, remote and unbelievable. In addition - from a purely practical perspective - not having a clear understanding of these concepts doesn't mean that the Sun won't come up tomorrow. And for South African students, passing your matric exams is not dependent on your ability to give a scientific explanation for the seasons or the structure of a star.

But people who investigate problems related to teaching and learning are fascinated by what learning is and what the barriers to learning may be. In multicultural situations issues of ontology and epistemology add to the interest, and research has led to the formulation of theories such as Cobern's worldview theory and Aikenhead's theory of cultural border crossing. While these theories are powerful in their ability to be fruitfully applied in many situations, the research based on these theories has focused predominantly on the juxtaposition of traditional or indigenous cultures in relation to science. Far less attention has been paid to the impact of religion on learning in science. In South Africa, in the context of this study, it has been shown that traditional beliefs act as an alternative to science in explaining phenomena associated with the field of basic astronomy. These beliefs are rooted in a traditional worldview and contribute to challenges in terms of border crossing. However, it has also been shown that in this context, religious beliefs are even more important in creating barriers to learning, because the religious beliefs present from two fronts: indigenous traditional, and imported and often indigenized Christianity.

The 2004 Research Report by the Centre for Development and Enterprise on 'reforming mathematics and science education in South Africa's schools' (Bernstein, Clynick and Lee, 2004) lists 3 key factors which have emerged as major determinants of success in science and mathematics. One of these is educator knowledge (the others being language competence and the physical school and classroom environment), but educator knowledge involves far more than subject knowledge. Science education is not value free, and should not be taught as if it were. The intention of science education should not be to change peoples' beliefs (Sinatra *et al,.* 2003), nor their worldview (Cobern, 1994, Shumba, 1999). Nor should it cause any dismissal of, or disrespect of, peoples' beliefs (Jackson *et al.,* 1995). In South Africa, where 80% of the population regard themselves as Christian and 80% are African, researchers need to work at bridging the disjuncture between disciplines such as science and religion (Christian/Muslim and African Traditional Religion) and making the findings available to the science education discourse in a way that serves to highlight its importance.

It is clearly essential that educators be made aware of the need to respect the beliefs of their students, and learn to act as culture brokers, giving their students the tools to continue to respect their own cultures and beliefs, yet deal with the challenges that are presented by science. Acknowledging that there are different ways of knowing, taking time to engage the students with reference to their prior knowledge, creating ‘space’ for students to discuss controversial issues, and providing them with resources to help them deal with their problems, may help to prevent unmediated syncretisms, a refusal to engage, or the development of scientistic thinking. Many studies on improving learning in science education come to the same conclusion: the recognition and valuing of other ways of knowing validates these ways of knowing and in this way increases relevance, interest, and a willingness to engage in learning science in a more meaningful way. Simply explaining the concept of border crossing and providing the students with a summary of Barbour’s Typology could go a long way to helping students understand that there are choices that can be made to how they deal with controversial issues. These interventions need not be time consuming. Aside from this, Nolan's (2006) point that a new kind of scientific mentality that opens new possibilities for spirituality, and that is growing in acceptance, needs to be brought to the attention of educators. Many currently practicing educators who had a typical Western education have not been exposed to what is being called the "new scientific worldview", where the old mechanistic worldview in which God was absent is being replaced by a worldview that recognizes the Universe as a connected whole of patterns and relationships. This new science appears poised, like Basho's frog, above an ancient, but strangely familiar pond.

A study such as this can only claim the findings as revealing some truth within the context in which it has been done. But like a frog jumping into a pond, the findings ripple out into the broader context of the purpose and value of science education as it currently exists in South Africa. Science education in this country must look beyond the demands of the present to what different insights an African worldview still has to offer. Kenneth Kaunda’s question: ‘How can we preserve what is good in our traditions and at the same time allow ourselves to benefit from the science and technology of our friends?’ needs to be replaced by the vision for education expressed by Samora Machel, the first Black President of Mozambique:

> "education must give us Mozambican personality which without subservience to any kind and steeped in our realities, will enable us, in contact with the outside world, to assimilate critically the ideas and experience of other peoples, also passing on to them the fruits of our thought and practice" (in Afonso, 2007, 307).

South Africa has come a long way since the election of its first democratic government in 1994, and its national education system has taken a brave step forward in officially recognizing the existence of, and need to value, other ways of knowing. Samora Machel's recognition of the need for reciprocity is the next key to education in a multicultural context. Thus while Ogunniyi suggested that “science should cater for the mind and religion for the soul” (1995, 38), I would like to suggest that the place to start is in science classrooms, with the science teachers. If they do not make room to recognize and acknowledge the importance of other ways of knowing, including religious ways of knowing, unnecessary barriers to learning will continue to exist. From a practical point of view, it is unlikely that lecturers would make room during lectures for discussions. However, it is critical for them to be aware of the potential impact of alternative beliefs on learning, and for their attitude to be one of tolerance, acceptance, and, hopefully, assistance.

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