# Investigating Pre-service Natural Science Teachers' perceptions of earth in space through spatial modelling and argumentation

**Degree** **Master in Education**

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# Declaration

I declare that**, "Investigating Pre-service Natural Science Teachers' perceptions of earth in space through spatial modelling and argumentation"** is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Full name: Ngonidzashe Mushaikwa

Date..................................

Signed.........................................

# Acknowledgements

To God is the Glory for the great things he has done and continues to do. Because of His graces we are and I am. Thank you to my maker.

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# Abstract

This study involves a group of pre-service teachers who are specialising in Science and Mathematics education at a university in the Western Cape province of South Africa. The aim of the study was to investigate perceptions about the earth in space held by the pre-service natural science teachers. A related aim was to create awareness among the prospective teachers about various views that people hold about the earth as against the scientifically valid view (Govender, 2009, Plummer & Zahm, 2010, Schneps & Sadler, 1989). To determine and improve the prospective teachers' perceptions and awareness about the significance of the earth in space the study adopted the dialogical argumentation model (DAIM) and spatial modelling as a theoretical framework (Ogunniyi, 2013).

Further, the study used pre- and post-test data based on the responses of the pre-service teachers to questionnaires, focus group interviews and reflective diaries. The data set was analysed using a mixed methods approach (qualitative and quantitative).

Results from the study show that most the pre-service teachers involved in the study hold both scientific and alternative conceptions about the earth in space. However, they seem to suppress the latter because they believe them to be unscientific. In addition they believe that their role is to impart scientific knowledge to learners. As has been revealed in a number of studies, some of the prospective teachers did not have much background in geography.

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# List of abbreviations

| | |
|---|---|
| **BCT** | **Border crossing theory** |
| **CAT** | **Contiguity argumentation theory** |
| **CLT** | **Collateral learning theory** |
| **DAIM** | **Dialogical argumentation instructional theory** |
| **IAC** | **Indigenous astronomical conception** |
| **IK** | **Indigenous knowledge** |
| **IKS** | **Indigenous knowledge systems** |
| **NCS** | **National curriculum statements** |
| **NOIK** | **Nature of indigenous knowledge** |
| **NOS** | **Nature of science** |
| **NOSIK** | **Nature of science and indigenous knowledge** |
| **SMDAS** | **Spatial modelling and argumentation strategy** |

# Chapter 1

# Introduction to the study

## 1.0 Introduction

The history of the South African education system will be incomplete without mentioning the changes that took place in the 1990s. Before 1994 the education system and curriculum were based on the apartheid political ideology of separate development on the basis of race. As a result the apartheid system of education had 19 separate departments of education to cater for the different cultural groups. However, in 1997, the first democratically elected South African government led by the African National Congress, introduced a new curriculum. The new curriculum was called the Outcomes-based Education, commonly known as the OBE or curriculum 2005 (C2005) to depict the year of its full implementation (Ogunniyi, 2004, 2007a). The rationale for developing this new curriculum according to the Department of Basic Education (DBE) was to unite the national education system under one curriculum as opposed to the multi-system curricula used prior to 1994 (Jansen, 2001). According to the DBE and the Department of Science and Technology (DST) a new curriculum was necessary to promote scientific knowledge within the South African context whilst participating in and acknowledging global interventions (DBE, 2011, p. 5; DST, 2004). It was also of this curriculum reforms that the need to integrate science with indigenous knowledge was conceived as a measure to make school learning more relevant to learners' life worlds as well as begin the process of decolonizing the curriculum which for the past three hundred years has been essentially Eurocentric (DBE, 2002; Ogunniyi, 2004).

Since 1994, the new curriculum has undergone three revisions as a way to simplify the aims and content of what to teach and learn in the schools as well as to ease the implementation process (DBE, 2011). A review in 2000 produced the Revised National Curriculum Statement (RNCS) 'grades R-9 and the National Curriculum Statement Grades 10-12 (2002). However, the revised curriculum still faced implementation problems which led to another revision in 2009. This resulted in the combination of the two 2002 revised curricula, namely the RNCS grades R-9 and the NCS grades 10-12, to produce the current National Curriculum Statement (NCS) for Grades R-12, which was implemented in 2012.

With the new curriculum also was the introduction of the ‘Earth and beyond’ strand to the Natural Sciences Curriculum.  This strand consists of astronomy a topic which used to be under geography at high school. Its introduction into the Natural Sciences has caused challenges to some teachers who express difficulties due to lack of knowledge of basic astronomy, which then translates into their failure to teach it (Lelliott, 2010, Lemmer, M., Lemmer, T.N., & Smit, 2003, Sanders, 2006). Besides the difficulties experienced by some teachers, Govender’s (2009) study also reports that pre-service rural Basotho students’ experiences of astronomy is culturally holistic and a way of life. Govender’s (2009) findings also confirm other findings in the area (Lemmer et al, 2003).

In light of the above, the need to equip pre-service teachers with valid conceptions of the earth in space, the central concern of this study became warranted. The study is premised on the assumption that if teachers are to teach valid conceptions of the earth in space (including the new emphasis on relevance and indigenization of the curriculum) they must first of all be thoroughly  knowledgeable of what to teach and how to teach it. Introducing the earth in space at the basic education level i.e. grades R-9 also implies that the teachers can no longer carry on business as usual so to speak but to adopt a radically different instructional approach to the ones they were used to e.g. traditional expository instruction in which the teacher is largely concerned with the transmission of knowledge and her learners copying down her notes verbatim from the chalk board. In addition, teachers should also become well aware of the new emphasis on making science teaching and learning relevant to the daily lives of learners. To change this implies that the teachers undergo in-service training to acquire new skills to enact the new curriculum in their classrooms. The best place in my view to achieve this goal is to include these new instructional strategies into the teacher training programmes in higher education institutions. It is precisely this belief that galvanized the present study. When teachers have rich understanding of the phenomenon, they also tend to adopt teaching strategies which influence the learners’ understanding of the earth in space (Meyer & Crawford, 2011, Ogunniyi, 2004, 2007 a & b).



Some of the reasons why a considerable number of teachers find it difficult to teach the strand: “The Earth and Beyond” include the fact that: (1) they did not do geography even in the high school; and (ii) astronomy is a very abstract subject; it deals with space-related phenomena that are not easily perceivable here on earth. This problem is not peculiar to South Africa; it is experienced by teachers worldwide (Plummer & Zahm, 2010). A study by Schneps and Sadler (2007) showed a lot of misconceptions among high school and university graduates. More about this will be discussed in chapter two.

Perception is a process whereby an organism organises and interprets awareness of its environment (Lindsay & Norman, 1977). The perception which a person has about something affects the way s/he behaves. My own perception of science before I joined the Science and Indigenous knowledge systems project (SIKSP) in 2011 at the University of the Western Cape (UWC) was that science was the knowledge possessed by the elites from western countries and passed to us by science teachers and from books. SIKSP consisted of a group of lecturers, post graduate students, pre-service teachers and in-service teachers. We met once every two weeks on Fridays and Saturdays for workshops and seminars where we discussed various topics including the curriculum, the nature of science (NOS), the nature of indigenous knowledge systems (NOIKS), and how to integrate science and IK as recommended in the new curriculum. The group also developed resource books for teachers with exemplar lessons for an integrated contextualised science-IK curriculum based on two theoretical frameworks namely, Toulmin's (1958) argumentation pattern (TAP) and Ogunniyi's (2007a) contiguity argumentation theory (CAT). The participants in the SIKSP were also exposed to the dialogical argumentation instructional model (DAIM) underpinned by TAP and CAT.



My exposure to the NOS and NOIK seminars and workshops also helped me to become aware of what I need to know, teach or expect while enacting an inclusive science-IK curriculum lesson especially in a multicultural classroom context. The open discussions, arguments and dialogues (features of DAIM) gave all the participants the opportunities to clarify their misgivings, clear their doubts and increase their understanding of NOS, IKS, the science-IKS curriculum and how to implement it. Further, my exposure to DAIM brought me to an "aha!' moment when I recalled an experience I had of a 13 year old learner who asked me why people do not fall off the orbiting and spinning earth. Such a question suggests that this particular learner had not grasped the essentials of the lesson taught. Due to my participation in SIKSP, I am now aware of instances when a teacher can go through a lesson without engaging learners conceptually. In such cases, a teacher may never know whether learners have grasped the scientific concepts so as to own them, or just to be able to answer test questions on them.

SIKSP awakened in me the consciousness about the existence of different ways of knowing and interpreting experience with nature. It made me reflect on the need for reconciling school science with the learners' own understanding of how nature works, in order to maximise meaningful learning by learners.

The scenarios which might emerge from the curriculum about teachers and learners are three fold. This includes:

-envisaging teachers who are subject specialists;

-teachers who can facilitate meaningful learning among learners as well as motivate them to be actively involved in the teaching-learning process;

-envisage learners who actively learn through hands-on activities, participation in discussions thus linking current knowledge with prior knowledge (DBE, 2011).

Of course, the above expectation of the new curriculum about what should be accomplished in the classroom does not only apply to the teaching of astronomical concepts but all science concepts. The extant literature has reiterated the same point of view namely that teachers should strive to guide their learners in such a way that they are able to develop scientifically valid concepts through experiential activities (Lelliott, 2010, Sanders, 2006, Sneider & Ohadi, 1998, Shulman, 1986). A paradigm shift in which inquiry based teaching strategies are adopted as opposed to teacher dominated approaches are viewed as beneficial, especially when dealing with conceptual change (Abel, Martini, & George, 2001, Akerson, Hanson and Cullen, 2007).



There are various arguments regarding the teaching of astronomy in view of pre-conceived knowledge of learners. On one hand Vosniadou & Brewer (1992) argue that pre-conceived astronomical perceptions are deeply ingrained in culture, therefore scientific conceptions are usually assimilated. On the other hand science educators propose teaching for conceptual change (Cobern, 1996). The argument is that learners themselves should be actively involved in the reconstruction of scientifically acceptable astronomical conceptions. For this reason, there is need for teacher awareness of alternative conceptions in astronomy in order for them to use suitable teaching strategies.

In a study of 13-15 year old learners, Lelliott's (2007, 2010) successfully enabled most of the participants to reconstruct conceptions about the relative size and distance between the earth and the sun. This was achieved by using social constructivism in teaching. For example, taking learners to the planetarium several times, and engaging learners in dialogue. Through interactive methods, Lelliott also reveals that the success of learners varied from learner to learner. Through this study, there is further affirmation of seriously considering learner individuality when teaching (Kozulin, Gindis, Ageyev, & Miller, 2003).

In another study, Lemmer et al. (2003) investigated the perceptions of the universe by 232 undergraduate first year physics students from two South African universities. Their findings revealed that some of the students especially the Black African students have an organismic worldview about the universe compared to the one held by their European counterparts. These findings concur with the findings of Zeilik and Bisard (2000) who found that most students go to the university with deeply seated misconceptions of astronomy. Schneps & Sadler's (1989) study also reveals that people from all walks of life have individual universes and ideas about astronomy which often vary quite widely from the scientific worldview. With all these findings, the question that comes to mind is, 'So what are science teachers' perceptions about astronomy and teaching it?'

Findings from literature on pre-service teachers' perceptions regarding the teaching and learning of astronomy as espoused by various scholars (e.g. Abel, Martini, & George, 2001, Govender, 2007, Marbach-Ad & McGinnis, 2008, Sanders, 2006, Tobbin & McRobbie, 1996) will be discussed in chapter two. A review of the literature and my personal experiences in the Science and Indigenous Knowledge Systems (SIKSP) at the University of the Western Cape as well as my own teaching experience have motivated me to undertake the present study. As an environmental science teacher I found that the topic "The Earth in Space" is generally difficult for learners to grasp because of the level of abstraction involved in conceptualizing it. However, my involvement with SIKSP for a period of two years has convinced me that such a controversial topic can be successfully taught by using argumentation and modelling instruction (e.g. Erduran et al, 2004; Ogunniyi, 2006, 2007a & b; Ogunniyi & Hewson, 2008; Simon & Johnson, 2008; Osborne, 2010). A plethora of studies using such a model has shown model of instruction.

### 1.1 Background to the study

The current National Curriculum Statement (NCS) defines science as "...a systematic way of looking for explanations and connecting up the ideas we have," (CAPS, 2012, p. 8), thus linking of scientific knowledge with the participants' life experiences. In other words, learners are expected to be actively involved in the learning process rather than receive lectures passively. The new curriculum is premised on the belief that if learners get chances to experience in the production of scientific knowledge while tackling cognitive tasks they would be able to retain what they learn much better than would have otherwise been the case.

The notion of getting learners to be actively involved in the learning process, as opposed to just listening to the teacher and copying down his/her notes verbatim, accords with the constructivist view of learning. Constructivism also stresses the importance of linking prior knowledge of a learner with the new knowledge (Kozulin et al., 2003, Vygotsky, 1978).

In contrast to the image of science portrayed in the NCS the teacher training institutions generally do not seem to be equipping prospective science teachers with adequate knowledge of nature of science (NOS). Otherwise, teachers will not continue to present a faulty image of science i.e. by presenting it as a host of readymade knowledge to be committed to memory by learners for examination purposes (Brickhouse, 1990, Gallaher, 1991; Ogunniyi, 2006, 2007a & b).

Teachers' beliefs tend to guide what they do and how they teach science in the classroom. In the past three decades many science educators have also pointed the fact that science presented in the textbooks and the classroom is largely Eurocentric with little or no reference to the sociocultural context of learners (e.g. Aikenhead, 1996; Aikenhead & Jegede, 1999; Jegede, 1995; Ogunniyi, 1988, 2004, 2006, 2007a & b; 2011a &b; Ogunniyi & Hewson, 2008; Ogunniyi, Jegede, Ogawa, Yandila, & Oladele, 1995; Ogunniyi & Hewson, 2008, Ogunniyi & Ogawa, 2008). This new emphasis has come in the wake of calls for making scientific knowledge accessible to all as envisioned through the adoption of a multi-cultural science education which is still at the inception stages in most countries (Atwater, 2013, Abd-El-Khalick & Lederman, 2000, Lederman, 1999).



The above notions are based on constructivism of which science educators argue that knowledge is not transmittable from one person to another. Constructivists value the prior knowledge of a learner in the learning of new knowledge (Kozulin et al., 2003, Vygotsky, 1978). In contrast to the NCS, for many years the training of science teachers excluded Nature of Science Courses (NOS) and this led teachers to have misconceptions about what scientific knowledge is (Brickhouse, 1990, Gallaher, 1991). These teachers' beliefs then guide what they do and how they teach in the classroom. Other think tanks also argue that science tend to portray Eurocentric worldviews only such that non-western learners' views are hardly sorted after when it comes to teaching and learning school science (Aikenhead, & Jegede, 2001, Jegede, 1997, Ogunniyi, 2008). This comes in the wake of calls for making scientific knowledge accessible to all as envisioned through adoption of multi-cultural science which is still in the inception stages in most countries (Atwater, 2013). Because of this entrenched perception of viewing science as the only authentic way of knowing nature, teachers tend to use teacher centred approaches in science since they perceive themselves as the knowledge holders (Abd-El-Khalick & Lederman, 2000, Lederman, 1999).

### 1.1.1 Conceptions about astronomy education

Previous research findings reveal that most learners' astronomical conceptions differ from the scientifically acceptable notions. These notions are regarded as naive/intuitive or misconceptions (Lelliott, 2007, Vosniadou & Brewer, 1994). Furthermore, it has been revealed that some of these misconceptions persist to institutions of higher learning in which prospective teachers fall (Lemmer, et al., 2003). Akerson (2005), Plummer, et al. (2010), Trundle, Atwood & Christopher (2002) also assert that pre-service elementary teachers' misconceptions are similar to those of learners. On the other hand, misconceptions in astronomy were found to be present but minimal in high school teachers (Brunsell, & Marck, 2004). Nonetheless, labelling of non-scientific knowledge as misconception is perhaps not the best way to represent another way of knowing and interpreting experience with nature. This is because it gives one the impression that there is only one way of knowing and interpreting experience even though there are different ways of knowing phenomena.



### 1.1.2 Teacher's perceptions

The extant literature has shown that a teacher's beliefs/perceptions and attitude guides her/his classroom practice (Bryan, & Atwater, 2002, Brickhouse, 1990, Bryan, 1997). In fact, Stuart &Thurlow (2000), propound that teachers' perceptions about the subject (science and the learners) influence teachers' choices of teaching strategies. Therefore a teacher, who believes that learners' prior knowledge has no role in school science, will objectify learners at the expense of science. Reynolds (2009) also affirms the views of Stuart and Thurlow (2000) about the impact that teacher's knowledge, values and beliefs have in the effectiveness of science teaching.

### 1.1.3 Contextualizing science

It is well known that a teacher's beliefs do impact his/her professional practice. Likewise, his/her knowledge of the subject matter, knowledge of learners and the learning environment are also critical to the success of instruction. If the teacher's knowledge of a given topic is inadequate so will that of his/her learners. At times a teacher's experiences also influences awareness or lack thereof of the learners' alternative beliefs about the topic. It is argued that when a teacher is aware of learners' alternative conceptions his/her teaching becomes focused on engaging them in meaningful learning (Sanders, 2006, Shulman, 1986). It is in this regard that calls have been made for teachers to be sensitive to the sociocultural context in which their learners live and to organize instruction in a way that is compatible with such an environment e.g. by deploying inquiry teaching strategies suitable for a multi-cultural science classroom (Aikenhead & Jegede, 1999; Ogunniyi, 2004, 2007a & b).

In South Africa, great strides are being made to include the nature of science (NOS) and nature of indigenous knowledge (NOIK) modules as part of science methods courses in teacher training programmes (Ogunniyi, 2008). The goal is to prepare prospective teachers to teach a contextualised integrated science-IK curriculum. Japan has also shown a good example of how science should be contextualized within the Japanese cultural notion of science as Shizen (Ogawa, 2002).

Soudien's (1998) argument about the notion of integrating science and IK "depends on how the concept of difference is defined" (1998, p. 89). It is well known that science and Indigenous knowledge (IK) share commonalities and distinct differences in the way they interpret experience with nature (Jegede, 1997). However, whereas science has been accepted as universal knowledge, IK remains the local knowledge of a given community (Odora Hoppers, 2004). There are also differences in perceptions of what constitutes knowledge worth studying in school which has generated much debate among science educators especially with regard to the issue of integrating the two knowledge corpuses (Hormsthemke, 2008, Ogunniyi, 2004).

The challenges of poverty and climate change faced by the world are also associated with the turning point towards valuing and investing in IK research (Agrawal, 2008). International bodies such as UNESCO, the World Bank and others have come to the realisation that science and technological advancement alone cannot solve all human challenges. It has been in light of this that suggestions have been made to include relevant and environmentally enhancing aspects of IK into the science curriculum.

The fact that nature is viewed holistically by most non-western learners is believed to negatively affect their attitudes to science (Johnson, 2002, Lemke, 2001) which is assumed to be value free.

Besides, the contextualisation of science also leads to meaning making and applicability of content in learners' real life situations. However, South Africa's strides towards affirming a science-IK infused curriculum is also seen by many scholars as a way to redress past political mistakes under the apartheid system of government and as a means to attain a sustainable development (Odora Hoppers, 2004, Ogunniyi, 2013).

Some teacher training institutions now introduce NOS courses as a way to prepare teachers for inquiry based teaching in a contextualised multicultural classroom setting (Marbach-Ad & McGinnis, 2008). Others have argued that the new emphasis has been to demystify the belief that science can only be done in the laboratory but also in the homes of learners (Meyer & Crawford, 2011).

The development of an integrated science-IK curriculum is therefore established in terms of the following needs:

a) The need to make science relevant to the learners' contexts and experiences (The Department of Basic Education [DBE], 2011; DST, 2004, Ogunniyi, 2008).

b) The need to integrate science concepts with the learner's IK, thus helping the learners to make sense of what they learn (Aikenhead, 2001, Scott, 1999).

c) The need to help learners to apply scientific principles in solving their local problems,

d) And the need for learners to bring their local knowledge to bear on the science they learn (Aikenhead and Jegede, 2001, CAPS, 2011, Ogunniyi, 2007a).

Through my personal exposure to NOS and NOIK in the Science and Indigenous Knowledge Systems Project (SIKSP), my view of science has changed. My experience in the project has made me realise that science is a systematic way of understanding nature. The SIKSP workshops and seminars have also alerted me to the importance of the emphasis of the National Curriculum Statement (NCS) to make science relevant to the life worlds of learners. The diversity of the members of SIKSP which includes pre- service and in-service teachers, post graduates Master's and doctoral students as well as lecturers has enriched my understanding of NOS and NOIKS, where they resemble and where they differ.

The SIKSP provided ample opportunities to become familiarized with topical issues and various challenges faced by teachers in schools with regard to the sociocultural issues in science education which I was not aware of before joining the project. The experience garnered in the SIKSP together

with my teaching experience motivated me to focus my study on pre-service teachers. Realising the important roles played by teachers, I am driven to focus on the pre-service teachers' perceptions of the earth in space using spatial modelling and argumentation.
The earth in space falls under the 'Earth and Beyond' strand which is a very abstract topic. The concepts which are under the earth in space include; the shape of the earth, its relative size compared to other planets and its relationship with other planets. In this study, my focus is on the relative size of the earth to that of the sun. I will also include rotation and revolution which causes days and nights including years, and will also cover biospheres of the earth.

My choice of this topic came as a result of realizing the gaps between the teachers' intentions in a lesson and those of learners. Due to the complexities of some concepts, teachers in most cases tend to drill the scientific facts without engaging learners about their own perceptions of the earth (Tuson, 2000). By using mainly teacher centred methods, learners' misconceptions about the spherical earth have tended to persist. Also learners are left with questions about why at school they learn that the earth rotates and revolves whereas in reality the sun is seen as travelling from east to west. Such gaps between what is experienced, perceived and scientific knowledge about the earth certainly warrant a close investigation using a different instructional approach than has been the case in many a classroom (Sanders, 2006). The present study was premised on the belief that the best place to begin the process of change in pedagogy is with the prospective teachers who are more likely to be amenable to new instructional strategies than the older teachers.

### 1.1.4 Spatial modelling

Spatial modelling in this study refers to the use of three dimensional (3D) models e.g. the globe which represents the shape of the earth in space. Modelling was considered suitable for this study because it involves participants could have ample opportunity to conceptualize earth within a 3D representation than would have been the case in a two dimensional setting in a textbook. Modelling entails providing the participants the opportunity to physically manipulate the globe model with their hands, and in the process, develop the concept of rotation and revolution. Finally, the participants would be able to make their own models of the earth or the solar system. For modelling, newspapers, play/flour dough and other suitable materials were to be used. Spatial modelling is used to enhance participants' understanding of mental models of the earth in space in relation to the sun as usually represented in books. Text books have 2D models which are at times quite difficult to understand at first hand, hence the use of spatial modelling (Sanders, 2006, Barab, Hay, Barnett & Keating, 2000).

There are advantages in using spatial modelling; namely, they are used initially to gather information about what learners know, to teach scientific knowledge actively and also to assess the success of how much participants have learnt (Lelliott, 2010). The use of 3D models does not rule out using 2D models but it is used to help participants build a richer understanding of the concept as presented in books (Barab, et al., 2000).

#### 1.1.5 The earth in space

As mentioned earlier, this topic is quite abstract to most learners. It is also difficult to demonstrate because the astronomic theories are very abstract and differ greatly with the people's beliefs and experiences. The models which are provided in textbooks are also abstract and two dimensional. Another difficulty with diagrams is that they do not specify where the viewer is when looking at diagrams of the earth hence some misconceptions arise in learners (Sneider & Ohadi, 1998). Furthermore, these misconceptions are held by college students which includes prospective teachers, as well as in-service teachers (Akerson, 2005, Lelliott, 2010, Mosoloane, 2012, Sanders, 2006).



Bryan and Atwater (2002) advocate for tutors of prospective teachers to teach them NOS as well as introduce them to reflecting about their belief systems for self-awareness of beliefs. Such teacher exposure during their formative years is argued to create awareness of learners' beliefs also (Shulman, 1986). The learners' prior experiences provide anchorage under which new concepts are developed. Due to this reason a teacher's role is to mediate between learners' pre-conceptions and those of science (Aikenhead and Jegede (2001).

Cooper and McIntyre in (Osborne, Simon, & Collins, 2010) link students' subject interest to teacher's ability to employ 'effective pedagogy.' Effective pedagogy is when learners are actively involved in knowledge construction (2010, p.1067). In the same vein, Meyer & Crawford (2011) equate the marginalisation of learners' ways of knowing nature in favour of science to symbolic violence. Therefore, the teacher's understanding of subject matter and the knowledge of learners' likely conceptions are important in guiding the teacher's choice of a teaching strategy.

## 1.2 Rationale for the study

As indicated earlier the teacher's belief about astronomy is likely to influence the way he/she teaches the topic. Most prospective science teachers believe that their roles are to transmit scientific knowledge and prepare learners for examinations (Tosun, 2000). Such beliefs are likely to influence their teaching of astronomy. Perception guides the way a person behaves in many instances. It is apposite to state that changes in the curriculum do not necessarily translate to successful implementation of that curriculum especially if the implementers are not part of the change.

According to Ogunniyi (2007a) several reasons were adduced by the Department of Education in South Africa for implementing the new curriculum. These stemmed from demands for different teaching strategies from ill-prepared teachers [learner centred as compared to teacher centred]. The teachers were also not conversant with the requirements of the new document (Carrim, 2001). Some of the requirements needed teachers who understand the NOS and NOIK. In the instance of an integrated science-IK curriculum, considering that most of the teachers were schooled in the western science worldviews, an infused science-IK curriculum would mean in-service teacher training for it to take off. Besides, the curriculum lacked clarity on how to implement such a curriculum (Onwu & Mosimege, 2004). All these issues constituted challenges especially for educators who held distinctly different beliefs about science and their roles as teachers.



Perception as indicated earlier is gained by paying attention to occurrences, learning them, remembering them and making sense of such occurrences and finally taking action. People perceive things differently depending on personal and social experiences (Brickhouse, 1990). Without exposure to the nature of science (NOS) courses, prospective teachers are bound to model their teaching from the teachers who inspired them during their school years (Plummer & Zahm, 2010). The fact that the existing curriculum adopts a constructivist view of teaching and learning implies a paradigmatic shift in teacher training which gears teachers towards inquiry teaching methods (Meyer & Crawford, 2011). These reasons contributed to heighten my interest in studying pre-service teachers' perceptions in relation to the topical subject of "earth in space" through the use of argumentation and modelling instructional strategies.

Teaching as an art is quite a complex activity. According to Shulman (1986):

> The teacher need not only understand that something is so; the teacher must further understand why it is so, on what grounds its warrant can be asserted, and under what

> circumstances our belief in its justification can be weakened and even denied... for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations,...the ways of representing and formulating the subject that make it comprehensible to others" (p. 9).

Shulman's view above depicts a lot of arguments which a teacher must make in order to justify and convince learners by making them question their beliefs when s/he presents a new concept to them. The justification of scientific knowledge must be so convincingly plausible and acceptable with reasons which make learners see the sense over their prior beliefs. Such knowledge of powerful models presented skilfully is usually gained through years of teacher's classroom experience and awareness. However, exposing prospective teachers to NOS courses in a way prepares them for classroom teaching and also increases their sensitivity to learners' individual needs including their prior conceptions (Bryan & Atwater, 2002, Meyer & Crawford 2011).

Research findings have indicated claim that misconceptions are a result of learners trying to fill in knowledge gaps created in science as they explain for example astronomical theories (Sneider & Ohadi, 1998, Vosniadou, 1992). The fact that in astronomy, there is a disparity between reality and abstract science also increases the chances for misconceptions which is reportedly rife in all ages (Akerson, 2005, Brunsell & Marcks, 2004, Lemmer, et al., 2003, Plummer, et al., 2010). The abstractness of the earth in space concepts and the notions of a spherical earth, rotating and revolving around the sun as presented in science call for specialised skills in participants to be able to decipher these meanings. The teacher's knowledge content as a subject specialist may not be sufficient if s/he does not use appropriate teaching strategies which link the scientific conceptions with what learners already know in order to offset misconceptions.

I therefore chose spatial modelling and dialogical argumentation as inquiry based teaching strategy by which teachers can bridge the gaps between the learners' conceptions or misconceptions and the scientific conceptions of the earth in space.

### 1.2.1 The earth in space conceptions

The CAPS document (2011) section of *Planet Earth and Beyond*, lists the "earth in space" concepts as including:

- the earth's shape and size in relation to the sun;
- day and night which introduces rotating/spinning and revolving/orbiting.
- Gravity- the earth is held in its position by the sun's gravity

These concepts are introduced from grade 4 up to grade 8 in the Natural Sciences.

### 1.2.2 Spatial Modelling and argumentation

In this study, participants were involved in modelling. As explained earlier, spatial modelling involves making three dimensional models to represent the earth as a planet within the solar system. By using spatial modelling, it is hoped that the involvement of participants in such activities would deepen their understanding of earth in space conceptions and equip them with knowledge of how to teach astronomy for understanding. In most cases, teachers use two dimensional models which were readily available in textbooks but these also present the various challenges to the different learners depending on their age and individual differences (Gilbert, 2004, Mosoloane, 2012, Shulman, 1986).

Spatial modelling is believed to act as a bridge between the experienced world and scientific knowledge. It also supersedes language barriers and brings visibility to abstractness which science is synonymous with (Coll & Lajium, 2011, Francouer, 1997, Gilbert, 2004, Paivio, 2010). The use of models in science is seen as a way of making scientific knowledge more accessible, applicable and understandable by learners hence reducing the usual trends where teachers impart scientific knowledge for assessment (Haney & McAurthur, 2002, Wallace & Kang, 2004). Spatial modelling is seen as a medium which can invoke dialogue and expose the prior conceptions participants had which results in re-organisation of knowledge.



The production of scientific knowledge is achieved through social interaction of scientists who participate in dialogical argumentation as they present the empirical data as evidence (Ballenger, 2010, Jiménez-Alexandre & Erduran, 2007; Newton & Osborne, 1997; Ogunniyi, 2006, 2007a & b). Dialogical argumentation is an inquiry-based teaching method used in the study with the aim of exposing prospective teachers to scientific argumentation. It is envisaged that using spatial modelling will promote engagement leading to making meaning.

### 1.3 Purpose of the study

South Africa, like other countries around the world embarked on educational reforms with the aim of responding to the needs of the nation. In science, the reforms included revisiting science content and teaching science that is infused with indigenous knowledge (IK). The justification for this new emphasis was based on the fact that IK encompasses the wisdom of the past, especially the knowledge and skills that have been used to manage the environment without causing so much damage to it as has been the case in the last 300 years of colonial domination by western countries. However, implementing the curriculum has been facing challenges which are capacity related (Ogunniyi, & Hewson, 2008).

In light of the problem elucidated above, the purpose of this study was to investigate effects of spatial modelling activities in an argumentation instruction strategy to a group of pre-service Natural Sciences teachers' perceptions of the earth in space. It was hoped that by their participation in the study, the pre-service teachers would deepen their understanding of the scientific concepts of the earth in space as well as improve their pedagogic skills in teaching the topic and other topics. The study adopted a strategy which exposed the pre-service teachers to NOS using a dialogical argumentation teaching strategy as well as spatial modelling activities of the earth in space conceptions.



Studies in South Africa on astronomy have identified the following: learners from non-western cultural background sometimes struggle to understand astronomy as presented in science due to their culturally embedded beliefs; some learners struggle with conceptions of relative distances and sizes of astronomical bodies; some teachers also exhibit little knowledge of some of the concepts associated with the topic of the 'Planet earth and Beyond' because it used to be in geography therefore teachers who did not study geography struggle to teach it; some textbooks do not have enough or may have too much information for learners to decipher: the diagrams which may not be clear especially the phenomenon of seasonal changes; etc. (Govender, 2009; Lelliott, 2007 & 2010; Lemmer, et al., (2003), Mosoloane, 2004; Misser, 2005, Sanders, 2006). The listed problems present challenges which teachers should be aware of so that they adopt effective teaching strategies.

## 1.4 Research problem

Teachers still remain central sources of knowledge in a science lesson since they are the curriculum interpreters and implementers. However, the method/strategy that a teacher chooses in every lesson impacts on individual learners either in a positive or negative way. For that reason, the National Curriculum Statement (NCS, 2009) calls on teachers to adopt learner- centred approaches appropriate for each lesson and to present scientific knowledge in engaging manner in order to provoke learners to actively learn in science lessons.

In addition to the above, the third aim of the NCS/CAPS (2011) emphasises on helping learners to understand the applications of natural science in everyday life. It is accepted that careers in science are amongst the most sought after positions. Yet there are very few students graduating in science and mathematics. The problem is that science and mathematics are regarded as difficult subjects. However, if teachers of science through mastery of scientific knowledge are exposed to teaching strategies which expose learners to experience and generate scientific knowledge like scientists, then more learners might take up sciences (Gilbert, 2004). This would require teachers to link the relationship between learners' experiences and science. In spite of the shortfalls in explicitness of the curriculum, if prospective teachers are equipped with pre-requisite teaching skills during formative years, then they may be able to promote learner involvement in learning (Onwu & Mosimege, 2004, Shulman, 1986).

Furthermore, there is consensus amongst science educators that teacher beliefs about what scientific knowledge is tends to influence their choices of teaching strategies (Abd-El-Khalick & Lederman, 2000, Lederman, 1999). Through exposure to NOS, the participants may deepen their understanding of scientific knowledge and how to teach learners. The aim is to introduce meaningful learning through deeper understanding of what science is (Bryan & Atwater, 2002).

In this study, in order to address the above problems the researcher aims to equip prospective teachers with teaching skills which may lead to meaningful participation and learning of science by learners when they join the teaching profession. This entails their participation in spatial modelling activities and in argumentation. The pre-service teachers will also be exposed to the NOS and NOIK in order to bring to their awareness the fact that there are many ways of interpreting phenomena of which science is one of them.

### 1.5 Research questions

In pursuance of some of the problems highlighted in the sections above, answers will be sought to the following questions**:**

i. What indigenous and scientific conceptions of the earth in space did the pre-service teachers hold before and after being exposed to an argumentation/spatial modelling activities?

ii. To what extent did their participation in an argumentation/spatial modelling instructional model enhance their understanding of the earth in space?

iii. What cognitive shifts did pre-service teachers exhibit in their attempt to use an argumentation/spatial modelling instructional model to implement an integrated science-IK curriculum?

### 1.6 Significance of the study

The findings from the study may be significant in:

- Teacher training institutions as they prepare prospective science teachers.
- Adding to the repositories of science educational knowledge.
- Contributing to the growing calls for multi-cultural science teaching.
- Adding value and knowledge of indigenous knowledge within school system.
- Providing insights and interest in contemporary science education issues and the teaching profession.



### 1.7 Operational terms

**Biosphere-**the part of earth that is inhabited by all living things

**Earth-** the third planet in the solar system which is rocky and the only planet known to sustain life, it is also commonly known as the world.

**Intermediate phase-** in the South African School system curriculum it is from grades 3 to 6.

**Senior phase-** it is from grade 7 to 12 but the strand "Earth and Beyond" in the Natural Sciences learning area is taught from grades 4 to grade 9. In grade 9 the topic is more focused on mining.

**Multi-cultural science**-incorporating different worldviews about the natural phenomena in school science

**Socio- cultural science-** Scientific knowledge that is contextualised into learners' cultural and social experiences

**Educator/s, or teacher/s-**used interchangeably but they mean the same, school instructor. In the South African school context, a teacher is an educator. The two mean the same, school instructor.

**Learner(s), student/s, pupil/**s- In a South African primary and high school context a scholar is regarded to as a learner. In the study I used student and learner to mean the same.

**Indigenous Knowledge System (IKS) -** IKS entails, "technological knowledge in agriculture, fishing, forest, resources, basketry, beadwork, crafts, jewellery, brass work, it encompasses climatology management, indigenous learning, including knowledge transmission, architecture, medicine and pharmacology," (Dah-Lokonon, 1997; Doussou, 1997, p. 9). It is knowledge system developed by an indigenous community to describe, explain and predict natural phenomena (Ogunniyi, 2007a)

**Indigenous knowledge-** According to Warren (1991):

Indigenous knowledge is the local knowledge - knowledge that is unique to a given culture or society. IK contrasts with international knowledge system generated by universities, research institutions and private firms. It is the basis for local-level decision making in agriculture, health care, food preservation, education, natural-resource management and a host of other activities in rural communities (p5).

**Nature of indigenous knowledge (NOIK)**-all practices of any local community guided by ethos of that community and developed over many years through interaction with the natural phenomena.

**Nature of science-**relating to the processes involved in producing scientific data, Scientists strive to rid their study of natural phenomena of subjectivity through rigorous regulatory systems that are agreed upon. Such regulatory procedures entail processes such as: peer reviews; repeated tests; rigorous criticisms, etc (Ogunniyi, 1992, 1986; Ziman, 2000).

**Spatial modelling-** Spatial modelling is the simulation of real world conditions by models representations e.g. systems like solar system which cannot be visualised directly.

### 1.8 Outline of thesis

This thesis has five chapters which are as follows; chapter 1- deals with the introduction to the study. It briefly introduces what the study entails. Chapter 2 reviews relevant literature to the study. Chapter 3 describes the methodology used in the study in terms of the design, sampling procedures, data collection and analysis. Chapter 4 presents the analysis and discussions of the results. Finally, chapter 5 highlights the main findings and their implications for curriculum development and instructional practice. The chapter concludes recommendations for future studies.

# Chapter 2

# Literature Review

## 2.1 Introduction

In this chapter, I discussed the literature relating to the earth in space perceptions. This was done by looking at the South African curriculum in the context of teaching science. From there I went on to discuss the teachers' beliefs about scientific knowledge and how the beliefs could influence their teaching of science e.g. the astronomical concept of the "The Earth in Space."

Science educators generally acknowledge that teachers need to be introduced to the nature of science (NOS) courses during their formative years (Abd-El-Khalick & Lederman, 2000, Bell & Schwartz, 2002, Lederman, 1999). Furthermore, arguments for culture sensitive science on the basis that non-western learners struggle to get to grips with western science culture were also highlighted (Aikenhead & Jegede, 2001, Battiste, 2002, Ogawa 2002).



The current Natural Sciences curriculum was designed with the aim of inculcating in learners the importance of science as it exists in many cultures (DBE, 2011). For this reason, the literature on multi-cultural science was consulted in this study. Furthermore, teachers need to adopt strategies which promote interaction between learners and the teacher so as to get the learners actively involved in the knowledge reconstruction. Thus the study used a dialogical argumentation teaching model and spatial modelling as a tool which enhances dialogue.

## 2.2 Why interactive classrooms?

The Natural Sciences curriculum is modelled after what scientists do. It is geared towards learners who are curious about their world, the natural phenomena and the importance of responsible use of scientific knowledge in solving social problems (CAPS, 2011). All this can be achieved when educators facilitate learning through the selection of suitable teaching methods. In this backdrop, the science teacher is seen as someone who through careful adoption of suitable teaching approaches, evokes the curiosity and excitement in learners about their natural environment and the world at large.  According to Sessoms (2008, p. 87)

> ...current social trends require citizens to be more analytical thinkers and to synthesize information, current teaching practices must develop these higher order thinking skills. This should start with a teacher's philosophy and pedagogy development during preparation for the profession... (p. 87).

Sessoms (2008) reiterates the critical role of teachers in the development of learners who are able to critique situations. This starts with teachers adopting the constructivist instructional approach. The constructivist teaching approach is premised on the belief that learners are not blank slates to be written upon or empty vessels to be filled when they come to school. Moreover, the use of tools helps to maximise restructuring of conceptions through meaningful engagement of learners and the teacher. Consequently, having interactive classrooms is a way of moving away from the teachers-centred approach towards effective teaching and learning as propounded by social constructivists.

### 2.1.1 Social constructivism

Social constructivists believe that children learn through socialising with their peers as well as from the adults. Therefore, when they come to school they have some knowledge about nature which can be used to reconstruct the intended knowledge. This was made possible by engaging them in focused discussion which induced critical thinking. However, the development of critical thinking happens in social situations under the guidance of peers and adults who are knowledgeable (Vygostky, 1986). Vygotsky elaborates further by claiming that mediation has to be goal oriented. Successful mediation is then measured by the zone of proximal development (ZPD) which is the difference between a learner's actual development level and potential level of development which is achieved after mediation. To that, Kouzlin, Gindis, Ageyev & Miller (2003), further attests that human socialisation is a precursor to self regulated learning.



Constructivists are champions of active learning as opposed to banking methods whereby a teacher as a knower assumes that learners are tabula rasa hence she can deposit knowledge into a learner who is empty of knowledge. In the same sense Hedegaard (1998) elaborates that "...the teacher guides activity both from the perspective of general concepts and from the perspective of engaging students in 'situated' problems that are meaningful in relation to their developmental stage and life situation..." (1998, p. 120). It can be summed up that a teacher as mediator of learning should be knowledgeable enough about learners' developmental levels on astronomy so as to plan appropriate content.

### 2.1.2 Cognitive development levels

The teacher's knowledge of learners' levels of cognitive development informs him/her about the lesson outcome, knowing that his/her responsibilities are to create conducive learning environments (Piaget, 1963). Piaget proposed that the creation of experiential learning environments should be provided for learners. He also asserted that learners are capable of regulating new information into existing schemas or creating new ones. Both Piaget and Vygotsky (ibid) believe in learning through interaction and experiential learning.

It also follows that in a class with diverse learners a teacher should be aware that the individual cognitive development levels are bound to differ due to cultural differences. Therefore inquiry based learning should be promoted (Meyer & Crawford, 2010). This will enable learners to regulate and organise new knowledge by linking it with prior knowledge about the earth in space conceptions with new knowledge.

### 2.1.3 Science and the learner's culture on nature

Lederman (2000), Aikenhead & Ogawa (2007) claim that science is characterised by deductive and inductive reasoning of what the universe is and how it works. On the other hand, indigenous knowledge (IK) which is part of culture is characterised by beliefs in metaphysics, community participation and oral transmission of knowledge from the knower to the apprentice, thus making it a way of life (Jegede, 1997).



Based on the above explanations, some scholars claim that the nature of school science disenfranchises non-western learners' participation in sciences worldwide (Aikenhead, 1994, Atwater, 2002, Battiste, 2005, Maddock, 1981, Ogawa, 1986, Ogunniyi, 1988, Pomeroy, 1994, Wilson, 1981). However, highlighting the differences is a way of conscientising science teachers when planning lessons to consider the learners' backgrounds in order to minimise misconceptions.

The same applies in astronomy; learners come to school with a prior knowledge (Lelliott, 2007). Besides that, language barriers which affect non-western learners should also be taken into account. Furthermore, Jegede (1997) was concerned about the difficulties non western learners encounter in understanding the specialised science language used. These challenges combined may cause non-western learners to be disinterested in science especially if teachers are unaware of alternative knowledge about nature (Wilson, 1990). This realisation has led to the emergence of culture sensitive science in schools in most countries (Aikenhead, 1994, Battiste, 2005, Jegede, 1997, Ogawa, 1986, Ogunniyi, 1988). It also led to the redefining of indigenous knowledge to which Battiste states that:

> As a concept, Indigenous knowledge benchmarks the limitations of Eurocentric theory–its methodology, evidence and conclusions reconceptualises the resilience and self-reliance of indigenous peoples, and underscores the importance of their own philosophies, heritages, and educational processes. Indigenous knowledge fills the ethical and knowledge gaps in Eurocentric education, research, and scholarship (Battiste, 2002, p. 5).

Indigenous knowledge of astronomy was also differentiated from scientific astronomy by Little Bear's (2000) explanation of what indigenous astronomy entails;

> The idea of all things being in constant motion or flux leads to a holistic and cyclical view of the world. If everything is constantly moving and changing, then one has to look at the whole to begin to see patterns. For instance, the cosmic cycles are in constant motion, but they have regular patterns ... as the seasons of the year, the migration of the animals, renewal ceremonies, songs, and stories. Constant motion, as manifested in cyclical or repetitive patterns. ...It results in a concept of time that is dynamic but without motion. Time is part of the constant flux but goes nowhere... (2000, p. 78).



Both Battiste (2002) and Little Bear's (2000) explanations reveal the distinctions between science and culture. The holistic nature of indigenous astronomy which entails observance of local changes in nature such as wind direction, the moon and animal migration are usually marked by song and dance. Whereas indigenous people tend to view nature as mysterious, scientists on the other hand study nature in order to conquer it. To date, research on indigenous astronomy propounds that most non-western learners hold different astronomical conceptions to those put forward in school science (Vosniadou & Brewer 1992). Vosniadou and colleagues claim that children struggle to conceptualise the scientific spherical earth concept especially its rotation and revolution.

However, some critics of Vosniadou et al's findings claim that children can conceptualise the scientific concepts of the earth as a sphere that rotates. They went on to propose that children can conceptualise scientific astronomy provided suitable support is given in the form of globes to represent the rotating earth (Ivarsson, Shoultz & Saljo, 2002, Shoultz, Saljo & Wyndhamn, 2001).

### 2.1.4 Indigenous astronomical conceptions (IAC)

Findings on indigenous astronomical conceptions (IAC) conclude that indigenous astronomy is culturally transmitted. Furthermore, it is acquired through interaction with one's environment. This is done through participation in traditional ceremonies (Vosniadou, 1994). Besides that, findings on various aspects of astronomy claim that astronomical conceptions held by non- western learners can be so deeply rooted such that traditional teaching methods will not alter their indigenous astronomical conceptions of learners (Govender, 2009, Lemmer, Lemmer & Smit, 2003).

### 2.1.5 Multiculturalism

In science this is a way of infusing western science with other ways of knowing nature. In recognition of the importance of science, technology and culture, non- western countries are pushing for multiculturalism in science. Japan has successfully infused western science with its own ways of knowing nature called "*Shizen*" and this has been used to produce a curriculum which is called "*Rika.*" Ogawa defines the characteristics of Rika as follows:

> Rika encourages pupils to: (1) commune with Shizen (nature), (2) perform observations and experiments with insight, (3) acquire the ability of problem-solving, (4) acquire the feeling of loving Shizen (nature), (5) understand natural things and phenomena with reality, and (6) acquire the scientific view and way of thinking (Ogawa, 2008, p. 25).



Inferring from Ogawa's description, Rika exposes Japanese learners to western science as well as their indigenous cultural ways of knowing. Research shows that the integration of science and IKS yields positive results in enhancing the learning of "western modern science" to non- western learners (Ogawa, 2008a). Integration happens when teachers infuse scientific concepts, for example astronomy, with learners' indigenous astronomical conceptions and use it to teach science. In this case, the success in integrating science with IKS will largely depend on teachers adopting a paradigm shift in the ways classroom science is taught. Trumper argues that, reforms in science education need teachers to be "knowledgeable in science content, process and inquiry pedagogy," (Trumper, 2001, p.1112). However, science teachers were only exposed to western astronomical conceptions during their formative years; hence the lack of knowledge on IAC by most qualified teachers hinder integration (Tosun, 2000).

Despite the challenges faced by teachers, many countries besides Japan have adopted multi-science education for example Australia, Canada, America and South Africa. Likewise, several African countries in response to the emerging multicultural classrooms have undertaken curricular reforms in science which give due recognition to other ways of knowing and interpreting human experience with nature.

### 2.1.6 Teachers' beliefs about teaching astronomy

Firstly, most African science teachers believe that astronomy is a body of knowledge produced strictly through scientific methods. This is true and due to this belief, teachers as holders of this body of knowledge therefore see themselves as knowledge transmitters. Due to this belief, there is also a danger of treating learners as empty vessels whereas learners have some pre-conceived albeit knowledge about astronomy which should be considered in order to avoid misconceptions (Brickhouse, 1990, Gallaher, 1991).

Secondly, teachers believe that as curriculum implementers they therefore need not discuss socioscientific issues with learners because they are not specifically pointed in the science curriculum. Thirdly, teachers tend to perceive themselves to be responsible for preparing learners only for examinations (McAurthur, 2002). All these perceptions of teachers tend to prompt them to adopt teaching methods which do not require interaction between learners and between or between learners and the teacher. This is so because in their formative years, science teachers have a belief that they will successfully teach science to smart learners who will pass and slow learners will fail science (Tosun, 2000). These perceptions including the lack of knowledge on IK-science integration slows down curriculum implementation due to the fact that teachers cannot teach what they do not know. Therefore, Marbach-Ad & McGinnis (2008) opine for pre-service teachers to be exposed to inquiry based teaching methods despite the challenges which teachers face.

### 2.1.7 Perceived limitations to the inquiry based methods

Usually the requirements from the department of education hinder teachers from using inquiry based pedagogies. These requirements include assessments such as annual assessments whereby very high pass rates are expected from learners. Due to these reasons, teachers use question and short answers during discussions. Besides, most public schools have very large classes with little resources hence the fear of indiscipline from learners by teachers. Due to these pressures, teachers have a tendency to drill learners for exams (Botha, 2010, Onwu & Mosimege, 2004). Furthermore, there are learning theories which seek to inform science teachers on how non western learners can be helped to understand science better.

## 2.2 The learner's worldview versus that of school science

As stated earlier, learners come to school with their worldviews which may be distinctly different from that of school science. However, teachers' construal the learner's mind as tabula rasa prevents them from recognizing the ecological model of learning prevalent in traditional societies where most learners in South Africa live in. The ecological model of human development describes the inter-connectedness that exists between a child and its environment.

### 2.2.1 The ecological model of human development

Bronfenbrenner's (1994) ecological model of human development argues that a child goes to school with all his/her experiences from his/her home and culture. He contends further that a child goes to school as a whole human being with pre-existing knowledge about phenomena.

The implication of Bronfenbrenner's theory to science teachers is that, they should be aware that learners' pre-existing knowledge differs from learner to learner. Hence the use of traditional teaching methods in science may alienate some learners from science. Therefore a teacher should use teaching methods that help learners to reorganise their knowledge on astronomy and further develop it so that it can be used intelligently and meaningfully within learners' environment. Not doing so may cause a disconnection between a child's worldview and that of science or even isolate learners from home culture. Hence science becomes relevant only to a few who can relate its scope to their milieu (Cobern, 1993). This is further clarified by Meyer in Cobern (1996) who argues that:

> ...the human mind is not like some public plaza where all may come and go as they please. On the contrary, it is a unity, it has an exigency for unity, and it imposes unity on its contents... Every grasp of data involves a certain selection, every selection effects an initial structuring, and every structuring anticipates future judgments (Cobern, 1996: 592).

Meyer's remarks reminds teachers that teaching should not be like depositing money in a bank but teachers should be conscious that learners are not empty vessels willing to be filled with scientific knowledge. Instead, learners select what makes sense to them based on existing knowledge and reject views that are arbitrary to their experiences. Aikenhead and Jegede, explain through their theories what should happen in a science lesson which has diverse learners (1999).

### 2.2.2 The border crossing theory (BCT)

Aikenhead's (2001) theory stems from Phelan, Locke, & Cao's (1991) classifications of transitions of high school students as they interact with families, peers and school culture and how they move from one culture to another. However, the border crossing theory further goes on to describe different cultural contexts by which people exist and adapt. These are characterised by differences in language, gender, social class, geographic location, religion and so on. Due to these differences, people tend to experience these subcultures with ease in their day to day living of which Aikenhead refers to as cultural border crossing.

Based on the BCT it can be argued that learners whose culture is different from that of western science experience is likely to experience cognitive conflicts with varying degrees depending on home culture. It therefore follows that a teacher's ability to mediate between the learner's culture and that of school which enables learners to understand scientific concepts.

Moreover, based on the BCT, it can also be argued further that not all learners in a science class will understand the scientific worldview even if a teacher mediates between the different worldviews. However, Jegede came up with another theory that explains how a non western learner constructs and stores scientific knowledge side by side its cultural knowledge.



### 2.2.3 The collateral learning theory (CLT)

Jegede (1997) claims that a child from a non-western culture can construct scientific knowledge on a concept side by side his/her culture with minimum cultural interference. This new knowledge is then permanently stored in the brain by creating a new schema where it can be retrieved and used strategically and correctly whenever the need arise whether from the indigenous or scientific worldview.

Piaget (1963) refers the same process where a new schema is formed as adaptation and accommodation. The CLT has four categories which are parallel, simultaneous, secured and dependent learning. In the same vein, Ogunniyi (2013) in another study agrees with Jegede that it is possible for a person to hold more than one belief system and still use them appropriately.

#### 2.2.3.1 The border crossing and collateral learning theory

Aikenhead and Jegede (1999) like social constructivists, argue that knowledge is not transferrable from one person to another but suggests that a teacher can help learners to make connections between existing knowledge and scientific knowledge which leads to acquisition of higher order knowledge. They assert further that success in science dependents upon three tenets namely; the differences between a learner's world and that of the school science's worldviews; how well learners can navigate different worldviews from their own and lastly, how well a teacher can guide learners to navigate between the two worldviews.

In response to the border crossing and collateral learning theories, Cobern (1996) disagrees with Aikenhead and Jegede that learners can reconstruct their conceptions about nature from a scientific viewpoint only if the scientific conception on the same topic is plausible, fruitful and intelligible enough to entice a learner to want to adopt a scientific worldview of knowing over his/her prior knowledge.

Cobern presents a different perspective about the teaching and learning of science. His argument seems to suggest that non-western learners would only learn a science concept provided they find the same concept from their cultural perspective less attractive as compared to science. In view of this Cobern (1996) stresses that, "...It is pointless to say that this student needs to break with his everyday thinking because, ...that would mean breaking with a long-held concept steeped in meaning for an alien concept newly encountered" (p. 584).
From the foregoing, it is obvious that research has not yet presented clear-cut findings regarding how the integration of science and IK takes place in the mind of a learner from a non-western culture.

The border crossing theory does not clarify how a teacher can guide learners practically to cross the perceived borders from one worldview to another. This view is also echoed in Fakudze's (2004) study about teaching science from a sociocultural environment. In her study, Fakudze could not easily identify the transitions from the learners' perspectives of phenomena to the scientific worldview.

However in reality people perform different responsibilities with ease daily be it a church pastor who is also a physicist, a father, a court judge or policeman so long as he is aware of the context in vogue. I will elaborate this further under the contiguity argumentation theory (Ogunniyi, 2007a & b). Whilst Cobern assets that conceptual change comes through the teacher's ability to entice learners into the world of science, Ogunniyi and Hewson, argue that meaningful scientific engagement can be attained by involving participants in dialogical argumentation. In their study of in-service teachers, participants were reportedly able to change their worldviews as a result of being exposed to a dialogical argumentation instructional model (Ogunniyi & Hewson, 2008).

From the above arguments, it can be concluded that people are learning all the time by adapting to new situations when there is need to do so. For example, in this age of technological advancement people are always adapting to new technologies e.g. mobile phones. Therefore, the same can happen in a science lesson if the lesson was contextualized and involve participants in meaningful engagement. Hence there is need for school science to be relevant, so that scientific knowledge becomes part of an individual's life after the exposure.

## 2.3 Role of a science teacher in multi-cultural learning environments

A science teacher in such an environment assumes a role of a tour guide who takes learners on a tour trip into the world of science following a structured route to arrive at the intended outcomes. As a tour guide a teacher is a specialist in his profession (Aikenhead, 2001, Cobern, 1996, Jegede, 1997).

The prerequisites of a science teacher in a multi-cultural environment include knowledge of content, being a subject specialist; knowing the curriculum; an awareness of learners' levels of understanding including levels of difficulties and knowledge of alternative conceptions of learners. Such a teacher should be aware that the scientific knowledge which s/he disseminates is targeted at learners who already have their own worldviews. Finally such a teacher should use suitable teaching strategies to engage learners into meaningful dialogue (Sanders, 2006, Shulman, 1986).



Essentially, prospective teachers need to be introduced to NOS and NOIK courses to guide their pedagogy (Lederman, 2000, Tomasselo, 2000). The teachers' awareness of NOS equips them on knowledge of alternative worldviews besides the scientific one (McComas, et al, 1998). This awareness may inform a teacher on the teaching strategy to use.

Meyer and Crawford's (2011) findings on prospective teachers after exposing them to a NOS course reveal that teachers become self aware. They assert further that self awareness leads to consciousness in beliefs. Furthermore, Bryan & Atwater (2002) concur with Meyer and colleague's assertion that such teachers may seek to know how learners know similar concepts from their cultures. Accordingly, they emphasise that,

> ...inquiry-based instruction without culturally relevant pedagogy and instructional congruency, may not be sufficient to support non-mainstream students in science learning, and may even serve to challenge students' cultural ways of knowing (2011, p. 525).

Again Meyer and Crawford (2011) presented another controversy in the science-IK integration. Although their view tallies with Bryan and Atwater's (2002) argument, there is no clarity on how to attain congruency in instruction.

In my view meaningful learning takes place when learners are meaningfully engaged such that in the end they can apply the learnt knowledge in their own contexts. In that sense there is no violation of learners' cultural understanding if the learners update their prior knowledge with scientific knowledge after dialogue. A lot of responsibility is then pressed upon the teacher to use strategies which are inclusive but most scholars do not provide clear cut solutions. All the same, the relationship a science teacher has with learners can affect her/his subject immensely. For this reason calls for teachers to adopt effective teaching strategies that are culture sensitive and recognise the prior knowledge of learners in a multi-cultural environment are growing. Thus, Kuhn (1999) sums it up categorically that:

> To know how to know puts one in charge of one's own knowing, of deciding what to believe and why, and of updating and revising those beliefs as one deems warranted...control of their own thinking, is arguably the most important way in which people both individually and collectively take control of their own lives (1999, p. 23).

The implications of Kuhn's assertion above could be inferred as the reasons why most non- western learners find science too difficult for them. Because most science curricula used in most African schools were previously adopted from Europe or America thereby lacking African contexts (Jegede, 1997). This results in science being too abstract leading to the disenfranchisement or violation of learners' culture. If a science teacher in a multi-cultural class just teaches without taking time to know individual learners, then the aforementioned violations happen. This will result in frustrations by learners for instance, in Phelan, et al.'s (1991) study a learner says this about his teacher:

> The class I am getting an 'F' in, he to me seems like, he doesn't pay attention to anybody in particular in class. It's just a whole class, and this is math....there is really no one who could talk to him. So I don't know what he actually means. He does not

> look at me, and he knows when I do work, I do work, and I do listen to him (Phelan, Lock and Cao, 1991, p. 240).

The above sentiments show how demoralized the learner in a math class is due to the detachment created by a math teacher who just comes to present math content to a classroom full of learners. There is no interaction between the teacher and students. To avoid such scenarios, teachers should plan lessons with learners in mind so as to create a learning environment that is conducive to avoid treating learners as objects.

Hence in Paulo Freire's (1972) views, "education is liberating provided it avoids authoritarian teacher-pupil models and is based on actual experiences of students ... based on continuous shared investigations" (p. 3). Again, it can be inferred that science teachers need to make science as interesting as scientists do.
Similarly, science teachers teaching astronomy in multi-cultural environments need to link scientific astronomy with existing knowledge of learners according to their cognitive development levels.

### 2.3.1 Teaching astronomy to multi-cultural learners

Research done on astronomical conceptions has shown that most people from a lay person to undergraduate university students and indeed all learners alike may hold alternative perceptions to the orthodox scientific perceptual framework (Peña and Quilez, 2001; Snepps & Sadler, 2007,Troadec, Zarhbouch, & Frède, 2009,Trumper, 2001). These alternative perceptions are termed misconceptions in science and alternative conceptions in cross-cultural studies.
Vosniadou's (1994) study on Indian, Samoan, Greek and American children expose the complexities that are encountered in conceptualising the scientific theory of the earth as an astronomical object. She further argues that this leads to misconceptions if a teacher fails to adopt teaching methods that are interactive. In the same vein, similar claims are made by Troadec and colleagues in a study of Moroccan children (2001).
Although Vosniadou's research is hailed, it can be argued that her questionnaire provided different diagrams for learners to choose from which might have misled some children. Hence, some critics of Vosniadou and colleague's findings claim that children can conceptualise the scientific concepts of the earth as a sphere that rotates. The critics propose that children can conceptualise scientific astronomy provided suitable support is given in the form of globes to represent the rotating earth (Ivarsson, Shoultz & Saljo, 2002, Shoultz, Saljo & Wyndhamn, 2001). The same claim was also

brought forward by Snepps and Sedler (2007) in their long standing interactive research of students at different levels of academic growth. They claim that lack of interaction by use of models and diagrams leads to participants having their own constructs of the universe.

Again, researchers in astronomy cited above further asserts that alternative conceptions in astronomy are so deeply rooted such that teachers in multi-cultural environments need to use teaching strategies which involve learners in meaning making. Peña & Quilez's (2001) online study, found that the proliferation of astronomical information in the media has not really helped in improving the students' conceptions. Furthermore, they argue that some textbooks meant to be used by teachers contain wrong information. However, in the same study, they nonetheless posit that dedicated teachers search the internet and benefit from the information on astronomy.

In a study by Sanders (2006) on pre-service and in-service teachers in South Africa, recommendations were made for the use of three dimensional models in the teaching of astronomy before using textbooks. This comes after discovering that misconceptions about moon phases were prevalent amongst most participants. These findings further endorse the claims that astronomical misconceptions amongst people from different walks of life are prevalent (Snepps & Sedler [ibid]).

Additionally, Govender's (2009) study of the rural Basotho prospective science teachers' ethno-astronomical knowledge reveals that their knowledge was holistic.



For example agriculture was performed depending on interpretation of the sky especially the stars, moon then the winds. He concludes that indigenous people translate what they see in the sky interlinking with practices which give meaning to life. The intertwining of weather patterns and food production culminates into ways of life where harvesting ceremonies are performed in Zulu, Tswana and Chinese cultures (Holbrook, 2007).

Again in Lemmer, et al.'s (2003) study on perceptions of the universe, findings claim that most South African first year undergraduate physics students of African origin tend to hold 'organistic' views about the universe. Organistic world views perceive nature as a living being; this view is synonymous with Greek philosophers like Aristotle. Therefore from the reviewed literature, it can be concluded that scientific astronomy differs from indigenous astronomy hence the need to use different teaching aids to help learners to conceptualise.

### 2.4 Implications of the literature

Findings on astronomy report that indigenous African conceptions differ from canonical astronomy (Govender, 2009, Lemmer et al., 2003, Vosniadou & Brewer, 1994). Due to these reasons, teachers need to be aware of such conceptual variations. The awareness will lead teachers to adopt teaching methods which involve inquiry into learners' prior knowledge and the use of models before diagrams are introduced especially in the intermediate grades (Sanders, 2006, Ivarsson, et. al, 2002). This is in line with Piaget's stages of cognitive development.

In order for a teacher to come up with a suitable teaching strategy, s/he will be aware of the challenges and easiness of the earth in space concepts. A teacher will then need to know the suggested teaching aids and how to access them. Globally, literature reveals the need to have a relook at school science teaching to give students chances to experience what scientists do. This would make scientific knowledge part of everyday experiences that bring innovation to participants and not only academic knowledge (Lelliott, 2010, Sundriyal & Kumar, 2009). Below is a glimpse into the South African Curriculum on the earth and beyond Strand.

#### 2.4.1 The Curriculum



The Curriculum introduces the Earth as a blue planet in grade 4. Then the differences between planets and stars; the concept of earth revolving around the sun causing a year and seasons was also introduced. *Here teachers were instructed not to explain*. The earth's structure was introduced as a rocky ball in space. The learners are also expected to know that most of the earth is covered in water then the continents and islands (NCS; Intermediate Phase, 2011, p. 30).

In grade 5, the learners are introduced to composition of the earth's inner structure and surface structure and fossils. In grade 6, learners go further into the sun, earth and moon in relation to the environment and the ecosystem (NCS; Intermediate Phase, 2011).

The curriculum introduces teaching of NOS in grade 7 as learners start high school and gets introduced to the Natural Sciences. It covers the history of science and how scientific knowledge is produced. In grade 7 the *Earth and Beyond Strand* covers most of what was done in primary school in detail including relative sizes of earth to other planets and practical.

In grade 8, same as grade 7 the teachers start by NOS and scientific processes. It links the content of *Earth in Space* to grade 7 content. The planet earth's structure is revisited including the green-house effect, and human impact on climate change. Careers in astronomy were also covered. Then in grade 9, mining and mineral exploration was covered. In all these concepts, the teacher must develop the skills such as analysing and evaluating, they do this through discussion and debating (DBE, 2011). Through learner centred approaches the Department of Basic Education (DBE, 2011) aims at fostering in learners responsible citizenry.

Responsible citizenry comes about when learners during their schooling days are allowed to participate in knowledge construction through meaning making and not treated as puppets who just echo what is said. According to Driver et al. (1994, p. 7) "*making meaning is ... a dialogic process involving persons-in-conversation, and learning is seen as the process by which individuals are introduced to a culture by more skilled members...*". The adoption of teaching strategies that engage learners in a science lesson may be very enriching to both the educator and learners if planned well. This allows learners to be actively involved in knowledge construction, thus the need to expose teachers to multi-sciences approaches (Bryan &Atwater, 2002, Crawford and Meyer, 2011).

Ballenger argues that lessons are like a journey which has a pick up point, a route and a destination, which means taking learners from where they are to the intended conceptions through mediation to help them in crossing difficult borders (Ballenger, 2010; Lee & Luykx, 2005). So how are teachers supposed to get learners from point A to B in science?

### 2.4.2 Integrating science with indigenous knowledge (IK)

The Department of Basic Education through the NCS attest to the recognition of indigenous knowledge of the diverse peoples in the country. To achieve this, one of its principles is attributed as part of Aim C in the Curriculum which envisages "*...valuing indigenous knowledge systems: acknowledging the rich history and heritage of the country as important contributors to nurturing the values contained in the Constitution...*" (DBE, 2011, p. 5).

### 2.4.3 Challenges to science-IK integration

However, very little change is happening on the ground in the teaching and learning of science. The challenges for slow changes have been explained in the previous chapter. I have to mention however that the challenges include opposition to an integrated science-IK curriculum.

Some scholars like Horsthemke's (2008) argument against indigenous knowledge is as follows*; "...indigenous knowledge' involves at best an incomplete, partial or, at worst, a questionable understanding or conception of knowledge*..." (2008, p. 129). He sees IK as full of fear due to witchcraft and myths among other objections. Horsthemke opines for teaching science explicitly as a universal knowledge.

However, my counter argument to his contention is that scientific knowledge is produced by scientists who are humans and with their own beliefs. Furthermore, teaching science as universal knowledge implies that it will be context free meaning that learners in sciences become tabula rasa waiting to be filled with knowledge.

I am of the view that teaching scientific conceptions that are void of contexts of learners is tantamount to frustrating the majority of learners whose worldviews are parallel to the scientific views. This would then defeat the advantages science and technological advancement brings and reduces non-western learners to mere consumers. This will defeat the benefits which scientific knowledge is proclaimed to give to its holders. This actually promotes dichotomy of knowledge that is school knowledge [science] and knowledge which is emancipatory for the holders, it is tantamount to gate keeping, whereby a rich few scientists and technologists will continue producing products for the majority of the poor consumers, thus maintaining the status quo.



Another challenge is language of instruction, within the eleven official languages, English and Afrikaans are the two languages that are used in most examinations although teachers are encouraged to use the learners' mother tongue to clarify concepts as specified in the South African Constitution on "language rights,' (section 3). However, what the constitution states and what happens on the ground differs, due to the fact that learners are still required to write the examinations in English or Afrikaans which may pose as a hindrance to learners whose home language is neither English nor Afrikaans. In actual fact teaching learners through their mother tongue might not work in science because most indigenous languages have not developed terminologically to match scientific English or Afrikaans terms (Fakudze, 2004). These challenges can however be abridged by borrowing the original scientific terms whilst using the mother tongue. Such learners [i.e. the non English speakers] are likely to think in mother tongue then translate their thoughts to English or Afrikaans and usually languages are culture specific meaning scientific concepts may not be easily explained in venacular (Fakudze, 2004). This means that if an educator teaches in the learners' mother tongue, the learners are likely to encounter difficulties in examinations and later also at the university depending on what they choose to do due to poor English language proficiency.

So the use of other nine African official languages can be impediments to learners wishing to advance in studying the sciences but whose home language is neither English nor Afrikaans. Also to note is the fact that when one thinks in mother tongue and translates thoughts to English/Afrikaans, in most cases the meanings may change, then the lack of vocabulary, and so on, which is another debate altogether.

Anyway this is just to illustrate the challenges that educators and learners alike face. The ethos of social constructivism rests upon educators adopting culture responsive pedagogies which accept plural worldviews (Turner, 2006). Teachers should at the same time empower learners with critical scientific knowledge. The challenge which remains is how teachers can use culture responsive strategies whilst empowering learners with critical scientific knowledge.

### 2.4.4 Using argumentation to promote interaction in science

Argumentation involves justification of conclusions or claims by means of rational reasoning. Jiménez-Alexandre & Erduran (2007) surmise the successful construction of scientific knowledge to involvement in argumentation. They further argue that argumentation relates to the power of persuasion hence scientists use it in presenting their discoveries to fellow scientists. Masson cited in Erduran, Simon, & Osborne (2004, p.916), defines argumentation as "a form of discourse that needs to be appropriated by children and explicitly taught through suitable instruction, task structuring and modelling."

In teaching the Natural Sciences, learners will be able to analyse and evaluate through argumentation. This tie together with being responsible for one's learning by knowing how to know and what needs to be updated (Khun, 1999). Learners are supposed to construct scientific knowledge about the natural world through experimentation, presentations and argumentation as they present their findings. Tiberghien, in Erduran (2008) then further extrapolates the three goals of argumentation in science education to be namely, bringing to the fore the knowledge of the nature of science, developing responsible citizenry among participants as well as empowering participants with scientific language when thinking and writing. This kind of learning which is participation based through argumentation closely imitates how scientists engage each other (Cross, Taasoobshirazi, Hendricks and Hickley, 2007).

However advantageous scientific argumentation may be it is all up to the teacher/educator's ability to set up an enabling environment where all learners will be able to participate. It also depends on teacher's familiarity with the strategy as findings in Shulman states that best teachers are those who are seasoned teachers, with years of experience and knowledge of difficulties and challenges (Shulman, 1986).On the other hand, this might not be the same when there is a whole range of new topics and teaching strategies which require a teacher to facilitate learning. In this case, such teachers would require in-service training. This study used Ogunniyi's contiguity argumentation theory (CAT) to analyse the qualitative data from questionnaires (2013). Besides, CAT was also introduced to pre-service teachers during intervention as another example of interactive teaching strategies.

### 2.4.5 Contiguity argumentation theory (CAT)

Contiguity argumentation theory (CAT) (Ogunniyi, 2013) has evolved from various theoretical constructs e.g. the Aristotelian association theory, Bohr's principle of complementarity of nature and Ubuntu, the central African worldview theory that stresses the interrelatedness and reciprocity of ideas. According to him, opposing theories can complement each other philosophically and scientifically. Similarly the CAT opines that: "*when two cultures or systems of thought meet*," several possibilities can happen that is to say; *conflict, co-existence, collaboration, assimilation, integration, harmonisation and even adaptation*" (Ogunniyi, 2013, p. 17).



Ogunniyi postulates that two distinctive worldviews can co-exist if they can converse with each other. Thus through CAT, dialogue is a medium through which conflict in conceptual framework is resolved. Taking this further, in real life situations, people are protective of their territories and anything foreign is seen as a threat. With the emergence of multi-sciences in education, the challenges of integrating science and IK, which usually are opposing worldviews, CAT is proposed as a scaffold for two or more schools of thought to operate in harmony.

Japan's Rika is an example of harmonising western science with Japanese way of knowing (Ogawa, 2008). Australia, New Zealand and North America have integrated science with knowledge of their indigenous people. South Africa has the same vision like other African countries such as Nigeria, Ghana, Namibia and Ethiopia though not well articulated in the curriculum.

CAT allows dialogical argumentation to happen in participants from intrapersonal dialogue/argumentation within an individual, to inter- argumentation within a group to trans-argumentation across groups and/or whole group argumentation. It is premised on scaffolding which stimulates critical thinking processes individually, in groups and in the whole group.

Partaking in dialogical argumentation in earth in space conceptions can assist participants from different cultural backgrounds to talk about these conceptions from their belief systems which can inform the teacher/facilitator on how to introduce the same conceptions but through scientific views. With appropriate teaching aids, the facilitator guides participants in meaningful, plausible and fruitful interpretations. At the end of it all, participants reflect on what they did and these spaces create the [*Zone of proximal development*] for re-organising and updating own perceptions on nature. Ogunniyi opines that adaptations happen within individuals, group and whole groups after participating in dialogical argumentation. This happens if the two opposing conceptions are given the same status at the beginning of engagement and when one is proven to be conceivable. There are five categories by which individuals and or group conceptions on a certain topic can adapt into after using CAT. These are dominant, suppressed, assimilated, equipollent and emergent conceptions. These will be explained later. It might be difficult to venture into meaningful and plausible dialogue and presume equality especially in a classroom situation where learners only have prior knowledge; therefore this study used spatial modelling as a medium by which meaningful, credible and logical dialogue can be accredited to be equal.



### 2.4.6 Spatial modelling in the study

In this study the phrase '*spatial modelling,*' is used to refer to; the making of three dimensional representations or models of the earth in space in relation to the sun and other solar system planets; it also refers to the use of three dimensional earth in space models like the globe; and the modelling of processes such as rotation and revolution using the body as a model. This is used as a learning/teaching aid on to help participants gather and construct logical, liable and rich scientific data on the earth in space. It is used to aid in the sense-making processes side by side the posters and textbooks.

Lelliott's (2010) study involving grades 7 and 8 learners was successful in influencing their understanding of spatial scale and size. He had to take these learners to visit the planetarium after school several times and do other activities with them before notable change was evidenced in learner expressions on the earth's size and scale in relation to the sun. Sanders on the other hand recommended highly the use of models before introducing diagrams as presented in textbooks (Sanders, 2006, p. 83).

Ornek (2008) identifies three types of models, namely the conceptual models which are tools invented for describing phenomena or systems. They are socially invented and agreed as standard external representations of systems used in teaching and learning of scientific concepts like the solar system model or the earth's globe (Khine & Saleh, 2011). There are three types of conceptual models namely mathematical, physical and computer models (Ornek, 2008).

Mental models on the other hand are psychologically perceived representations which are conceived from an understanding of nature. This comes as a result of observing and interacting with nature for a long time (Franco & Colinvaux, 2000). For example, rural Basotho prospective teachers were found to have enhanced observational skills of interpreting astronomy holistically and linking their observations with their way of life (Govender, 2007).

Whereas conceptual models have agreed upon standards, mental models are shaped by ones' cultural environment or worldview, so they are generative, inferred knowledge and synthetic as well (Franco & Colinvaux, 2000). Hence in this study physical conceptual models were used to help participants construct mental models which ascribes to the scientific knowledge of the earth in space conceptions.



According to Schwartz and Heiser, (1990), spatial modelling can enhance learning of science, mathematics and language if used well. In science, spatial modelling enables learners to do science and be active in the acquisition of scientific knowledge. It also helps in explaining scientific phenomena thereby enabling participants to make predictions. Due to interactions between participants there is development of critical reasoning (Erduran, 1999). Spatial modelling stimulates critical thinking which invokes meaningful debate about the concept at hand. This results in active knowledge construction by participants (Passmore & Stewart, 2002; Ramadas, 2009; Reiss et al., 2007). In this study, spatial modelling was used together with argumentation in order to enrich the participants' involvement in dialogical argumentation. The researcher used this approach to maximise meaningful dialogue between participants.

The essence of engaging learners in problem solving activities agrees with the popular Chinese adage about human learning that you: tell me and I will forget; show me and I may remember; involve me and I will understand. Due to the interactive nature of spatial modelling, when properly planned for and well guided, educators have greater chances of attaining the targeted lesson objectives. The reason being that the intentions and concepts are externalised which bridges the language barriers that may hinder effective learning.

Research on the uses of models and modelling in education postulates benefits across the curriculum. These entail development of language skills, such as reasoning through interactions, critical thinking also develops and reflective thinking which enables conceptualisation of abstract data assisting in formulation of mental models (Kallery, 2011). Most importantly conceptual models stimulate most or all the three domains of learning, namely the psychomotor domain-attributes to skills development, the cognitive domain-to do with the mental growth and the affective domain which influence the emotion (Bloom, 1956).

Modelling activities are also acclaimed to supersede language barriers through participants' interaction of visualising, touching, and feeling to aid expression and formation of mental models. Wadsworth (1978) proposes that the conceptualisation process takes place at an individual's own space and at different times even when instruction is whole class or individual. Furthermore, spatial modelling helps participants in cognition of intended content and may act as a bridge between participant's perception and reality (Ornek, 2008).
In a class learners who are at different levels of development are supported through conceptual models if they are developed for that particular purpose and they consolidate textbook information which is generalised. In addition, in a diverse class (Furth & Wachs, 1975) argue that conceptual models bridges language and cultural barriers. For example, South Africa has 11 languages where English or Afrikaans is the languages commonly used for instruction and testing in science teaching and learning. The use of modelling may bridge the language barriers of learners whose home language is neither Afrikaans nor English.

The concept of rotation and revolution within the earth and sun system can be very difficult to understand using complex 2D illustrations from the text books and this requires an imaginative mind at times. In most cases these illustrations are complex yet representing objects that fill up space. Hence comprehending how they are related to others may be difficult for learners in terms of actual sizes and distances unless a lot of engagement with model is done (Lelliott, 2010). It becomes more challenging for learners in the concrete operational stage to meaningfully understand the working of systems against their perceptions using textbook illustrations only (Piaget, 1978). Therefore if a teacher is able to make 3 dimensional models with learners, this may enhance learners' conceptions (Martinez Peña and Gil Quilez, 2001).

Therefore involving pre-service teachers in spatial modelling helps them to understand the nature of science, its philosophy, history and processes and this awareness in turn makes them better science teachers in terms of knowledge of pedagogy (Hodson, 1992, Sanders, 2006, Shulman, 1986). It also helps participants towards achieving inclusive learning environments. When prospective teachers are equipped with adequate pedagogical skills they will not shy away from involving learners in using learner centred teaching strategies (Vosniadou and Brewer, 1994).

A study by Kallery (2011) on teaching astronomical concepts to kindergarten children aged between 4 to 6 years, asserts that the adoption of social learning environments, contextualising concepts and the use of models enabled them to acquire scientific knowledge about earth, sun and moon.

Moreover, teachers are cultural beings as well who hold alternative views to scientific astronomical interpretations hence their involvement will help them cope with the differences between science, culture and their own worldviews (Kallery & Psillos, 2001).

For example most cultures describe the day and night causes as movement of the sun from the East to the West. However, in scientific conceptions, day and night is caused by the earth's rotation once on its axis. Such differences can be demonstrated in order for learners to see and understand. Models can be used to help learners reconstruct logical meanings from their experiences without being forced.

Since most scientific data about the universe is obtained through inferences, exposure to how conclusions are obtained give meaning and enthusiasm to learning close to what scientists do. It is assumed that some of the pre-service Natural Science teachers hold various ontological conceptions about the biosphere including the scientific one. And engaging them in this study may help them develop deeper understanding of nature of science which will in turn empower them in teaching.

Meyer and colleague are of the opinion that when teachers understand the nature of science, they avoid teaching science as dogma. A study on attitudes of students towards scientists, by Welch and Huffman (2011) concludes that students who participated in a robotic building activity had positive attitudes towards scientists and their work. The students also viewed science as a study done by normal people although they still stereotype scientists as 'smart people.'

It can be surmised therefore that spatial modelling in learning creates social environments which are conducive to higher order learning as propagated by Piaget, Bruner, and later Vygotsky. Spatial modelling foci according to (Bransford et al., 1999, p. 28) are as follows;

- -Learner builds knowledge whilst teacher creates environment for knowledge construction.
- Prior knowledge, prior skills and individual differences are catered for.

This further reinforces the constructivists' constructs about learning and cognition that knowledge is not non-transmittable from one person to another. It recognises that new knowledge is built through interaction of possessed knowledge and new information when participants are engaged in dialogical argumentation creating the spaces for knowledge growth also termed zone of proximal development (ZPD) by Vygotsky. This in turn brings in 'creativity and originality' as opposed to assimilation of knowledge (Groccia, 1997, Solomon, 2003).



It is generally agreed that the prior knowledge that individual learners bring act as platforms on which they use to connect and construct new knowledge. It is therefore important to acknowledge prior knowledge and make use of it in the planning of lessons so as to enable scaffolding. Conceptual models can be used in obtaining learners' pre-perceptions about the earth's shape which will act as a guide for the teacher.  Then also in reconstructing these perceptions into scientifically plausible meanings and finally they can be used to summarise a topic's main concepts. Therefore models are suitable throughout the lesson and after the topic; they can be used for revision purposes.

Therefore modelling helps the educators with baseline and formative and summative assessments of learners and how to intervene when there is need. They are tools used to assist teachers in how effective their strategy is and can inform a teacher on how to improve on their work (Sanders, 2006; Vygotsky, 1978).

Gilbert (2004:115) sums up the teaching of science as requiring, *"a broad range of knowledge at some considerable depth of understanding, conditions often not supported by the 'modular' structures of courses provided by many universities."* Since indigenous knowledges have not yet been documented in textbooks, the participants' exposure will broaden their knowledge on how to access the knowledge from the learners as holders through engagement.

It must be noted however that, spatial knowledge in science also uses creativity and originality besides the knowledge of shapes in space, position in relation to other objects. This is a benefit to participants who are aesthetically gifted and eradicates rhetoric that usually characterise science teaching, (Hespanha, et al., 2009, Lemke, 2001). The facilitating role of an educator becomes vital in identifying individual uniqueness and levels of cognitive development of learners and their varied worldviews about the earth's biosphere besides those put forward in science. There is connection between what the teacher intends to teach and enables learners to envision the concept an educator is communicating to them. Though not regularly used in science education, modelling enables understanding of complex abstract data through the use of visuals and interactions which resemble the way children are socialised in their homes and communities (Gilbert & Boutler, 1998, Svinicki, 2004).



Lohman (1987) attests that:

> The essence of spatial image is that it is a relation preserving cognitive structure. Many complex relationships among elements are contained in a spatial image. Relationships among a complex set of ideas can be maintained as a single chunk in working memory in a single image, thereby substantially increasing the amount of organised information that can be maintained in an active state at a given moment. Thus, when used ... spatial images can substantially improve our ability to think about and communicate complex ideas (p. 269).

The exposure to spatial modelling also enables participants to reflect and bring to the fore their inner thoughts. This is an added advantage in teaching in that reflections promote professional growth and can bridge existing language barriers. The use of spatial modelling initiates dialogue thus promoting critical thinking and in so doing, enabling participants to express their beliefs and to appreciate the similarities and differences that exist between their predominant views and science which can result in new knowledge acquisition. The curriculum is not prescriptive on teaching methodologies but suggests that teachers use suitable teaching strategies that are learner centred. Therefore having a variety of interactive activities to support interaction amongst learners may help the educator to be versatile and effective (Meyer & Crawford, 2011, Sanders, 2006, Shulman, 1986).

Groccia (1997) in a study about modelling on preservice teachers argues that teachers need to understand who they are and what they are going to take into teaching and learning in order to be effective in their pedagogy. On the other hand (Reiss, Boutler, and Tunnicliffe, 2007) point to the fact that scientific worldviews, though authentic, teachers as subject specialists should be aware that there are valid diverse worldviews held by learners that should be explored through modelling. To that, von Glasersfeld, (1987, 1995) elaborates on usage of models in education as to compliment the constructivist notion of knowledge being constructed in the individual's mind (Piaget) as well as 'collectively in science and in society' (Vygotsky) cited in (Gobert & Buckley, 2010, p. 892). As participants grapple with pieces of data mentally the models which they form can be described through reasoning or through modelling the phenomena.
Spatial modelling by nature stimulates argumentation, and lays bare the characteristics of science versus IK. Spatial modelling and argumentation are therefore used to create spaces for conceptualization of abstract concepts, because as participants model, they engage dialogically within themselves and with others, as they argue and discuss, they are able to observe, manipulate, this leads to reflection which can start the reconstruction of previously held perceptions (Cobern, 2001, Khun, 1999).

### 2.4.7 Implications for teachers

From the literature on modelling, it can be extrapolated that science teachers must use conceptual models in order to make learners' experiences in science lessons captivating. This will result in motivation of participants to do science actively and make scientific knowledge part of them. This means that a teacher as a model herself should stimulate by:

- Using good models to represent systems.
- Make sure models do not replace the real system if it is available.
- Plan lessons well and anticipate challenges like space, noise and others in order to minimise them and maximise active and meaningful learning.

- Possess knowledge of the content crucial in contextualising what the model represents and what is real.
- Explain clearly what the model is representing for example; a model of the earth as viewed from space.
- Guide learners when making own models, step by step. Such guidance and supervision is crucial for constructing a replica, unless if the purpose is to obtain baseline information.
- Text on the model is minimal but important information should be included
- meet the needs of all learners be it the visually impaired and deaf learners
- make sure that models are used to consolidate the theory which textbooks usually presents
- make available physical models like the globe, but also to have posters with diagrams of the same model side by side so that connections can be made

### 2.4.8 What a teacher should know

With a few exceptions, there are alternative worldviews about the shape of the earth especially among most indigenous cultures. But in science the spherical earth theory is considered universal knowledge (Govender, 2007, Lemmer, et al., 2003, Vosniadou and Brewer, 1994). These disparities can be easily explained through modelling. In teaching about the structure of the earth for example, learners can use play dough or Styrofoam to model its structure. The use of globes should be encouraged even to ask learners to bring from home if they have them to use for identification of good models. In so doing learners are actively involved in the generation of new knowledge.



Therefore since the purpose of using models is to simplify abstractness, models should be simple but true and effective in representing the intended phenomena. According to Penny Ur (2001) the characteristics of a good model include the following:

- Plausibility- it is a true representation of what is known.
- It is as simple as possible.
- It is explicit –represented in clear terms.
- It is comprehensive- encompassing all data and variables.
- Limited –it clearly indicates what it does.
- Usefulness – it is useful and practical.
- Consists of testable and verifiable ideas.
- It has aesthetic appeal, visually, verbally, and graphically elegant (2001, pp. 37-38).

From the above description of a model by Penny, one can extrapolate that the use of a good model in a particular lesson may aid to the understanding of abstract concepts thereby increasing retention. It also makes teaching and learning more social because of it being participatory in nature as long as the model conforms to the above descriptions.

In addition, since there are alternative conceptions to the earth's shape in space, modelling and argumentation will assist towards learning of scientific conceptions of the earth in space without ridiculing learners' alternative conceptions. Spatial modelling may complement the cognitive logic formations in participants thereby lessening conflict (Dean and Kuhn, 2006). It is hoped that through spatial modelling and participation in argumentation there will be more engagement by participants.

### 2.4.9 Summary

On one hand argumentation is found to be effective in allaying people's "fears, misgivings anxieties about world views that differ from their prior knowledge resulting in reconstruction of knowledge" (Friere, 2007, p.12). Thus, an argumentative discourse helps participants in this study in reconciling their worldviews with that of science. In this way educators ceases to be transmitters of scientific facts. They become facilitators who guide learning and engage learners in critical thinking that is scientific, supported with views, explanations and elaborations (Cross et al., 2007). Argumentation is also a handy tool for skilful educators in handling diverse classrooms' discourses, particularly controversial issues such as the different interpretations of nature or phases of the moon and others.



Spatial modelling on the other hand is a way of mirroring indigenous ways of knowledge transmission. It allows people to envision things that they have not seen because it is visual and is three dimensional. In spatial modelling internal thoughts are brought out to the fore when modelled. The structure of earth as scientifically portrayed is not what is perceived in daily interactions by many other cultures. Using spatial modelling can accord the educator and learners the spaces to visualise the scientific concepts which are usually theorised. This enables learners to construct scientific knowledge. It will also smoothen learners' crossing from their daily cultural ways of interpreting earth and the biosphere into the scientific knowledge when involved in dialoguing with peers whilst engaging with a model. In indigenous ways of knowing perceptions about the earth and biosphere are holistic, making them part of life and not compartmentalised as done in science and these differences should be explained to learners.

Therefore using spatial modelling in an argumentation framework provides data which will promote greater chances of successful conceptualisation (Aikenhead and Jegede, 2002). Hence by using argumentation and spatial modelling, knowledge acquisition becomes an active process as compared to teacher centred instruction. The awareness and acknowledgement that indigenous practices are still in use, is crucial in informing participants not to regard IK practices as history since IK is still sustaining millions of people (Agrawal, 1995). Hence, when engaging with participants care must be taken not to discuss in retrospect because by doing so, some participants may feel isolated and looked down upon and withdraw from sharing.

### 2.5 Nature of school Science and the need for enculturation

Emphasising the notion that learners come to school with varied knowledge which is embedded in cultural practices and nuances, it is therefore perceived that school science experiences vary from learner to learner (Aikenhead, 2001). To some learners, school discourse is closely related to what they already know so they fit in comfortably yet "*to others, it is difficult to gain access to what may appear to be very foreign ways of talking and acting*" (Ballenger, 1997, p. 5). Thus Ballenger bemoans the existence of a lot of canonical science found within non western science curricular meant for learners such as 'Haitian Creole'.

Therefore, educators should reach out to such learners, and tap into their cultural experiences in science topics and not just dismiss them as anthropomorphic and irrelevant. It therefore remains the educator's duty to use pedagogies such as argumentation that accommodate all learners by giving them spaces to discuss about their interpretation of phenomenon under discussion then link it to scientific worldviews. Also science can be learnt explicitly as another worldview or 'culture' (Meyer & Crawford, 2011).

To that effect, Turner (2006) spells out border crossing theory to mean educators having to make efforts to meet their students where they are and crossing borders with them into conceptual change learning. However, I do not think that the goals of teaching science should be to change learners' conceptions of nature but to harmonise their ways of knowing nature. Teaching for conceptual change would be cultural imperialism because one will be exposing them to a foreign culture which is similar to uprooting a tree from its natural habitat to plant it in a pot. This way disconnects learners from their culture which leads to disconnection of young generations from their elders leading to some cultures dying. So the goal should be to amalgamate scientific and indigenous practices for best practices (Aikenhead & Ogawa, 2007). Hence the goals of education should aim to develop the participants beyond examinations. Thus Cobern and Aikenhead (2001) argue that:

> Students need a contextualised approach to teaching science that draws upon the cultural worlds of students and make sense in those worlds. We need to develop teaching that allow the incorporation of the content or aspects of another culture into a student's everyday culture (autonomous acculturation) and enable students to enjoy and construct meaning out of Western Science without the need to assimilate science's cultural baggage...(p. 50).

The adoption of culture sensitive pedagogies in science by educators can help learners conceptualise scientific concepts without violating learners' indigenous beliefs. Conceptualisation of scientific knowledge side by side indigenous knowledge through creation of schema in the brain is referred to as collateral learning by Jegede. He asserts further that the developed schema stores new knowledge for use when situations which need this knowledge arise.

However it must be noted that some scientific conceptions especially physics and chemistry are too abstract and unrelated to learners' experiences (Driver et al., 1992). In this regard, Vosniadou (1991) underscores the need for conceptual restructuring with regards to conceptions of the physical world. For example in studies carried out by Vosniadou with the collaborations of other scholars (Vosniadou & Brewer, 1990, 1992, 1994) in America, Greece, India and Samoa, about the children's conceptions about astronomical objects reveal that the children's prior knowledge about the physical world are incompatible with the universally accepted scientific conceptions. Whilst the children's initial conceptions of the physical world are experienced in socio-cultural environments, in the science classroom teachers pass scientific knowledge to learners, (Dziva, Mpofu and Kusure, 2011). Teachers' awareness of differences in ways IK and science are acquired is crucial if teachers are to help learners construct scientific knowledge meaningfully.

I reiterate that the nature of scientific conceptions are in most cases very academic and abstract rendering them incoherent with some learners' beliefs; therefore, hence the adoption of inquiry teaching strategies is believed to make learning learner centred. Thus learner centred environments guide learners into actively discovering some of the knowledge themselves.

The need for enculturation of learners into school science is based on the discussed perceived differences that exist between science and African indigenous knowledges. Table 2a below elaborates on the differences between IK and science:

*Assumptions underlying science and indigenous knowledge systems*

Table 2a

| **A indigenous knowledge systems mode of thought** | **Western science mode of thought** |
|---|---|
| Nature is real and partly observable and testable | Nature is real observable and testable |
| Space is real, has both definite and indefinite dimensions | Space is real and has definite dimensions |
| Space is real and exists within time, space and the ethereal realm | Space is real and has definite dimensions |
| Time is real, continuous and cyclical | Time is real, continuous and irreversible |
| Events have both natural and unnatural causes | All events have natural causes |
| The universe is orderly, partly predictable and partly unpredictable, etc. | The universe is orderly and partly predictable i.e. nature is not capricious, etc. |

*Adapted from Ogunniyi (2013)*

Table 2a depicts some differences in the ways these two worldviews interpret nature. Learners from an indigenous mode of thought learn through apprenticeship under the guidance of elders whose knowledge may not be challenged. At school the opposite is true, in science in particular learners are expected to be critical in what they learn yet the reverse is true in indigenous practices. These disparities between science and IK are reasons why some scholars view the two as incommensurable (Horsthemke, 2008).

Lemke (2001) however, argues for multi-cultural science curricula for meaningful learning because he views contemporary science as Eurocentric. Additionally, he argues that science may not reflect important socio-cultural perspectives relevant to non-westerners, a view also echoed by Jegede. The epistemological disconnection between scientific views and other worldviews require some negotiations for the two to make sense in learners without violating their underlying beliefs. Thus some scholars such as Aikenhead and Jegede argue that learners from non western world views are constantly moving from home culture to that of school science, hence the need for culture brokering by educators.

In dispelling the differences between science and indigenous knowledge systems, other researchers have argued that science, just like IK, is a human activity, shaped by human culture and values hence it should be contextualised to the environment of learners (Cobern, 1993; Freire, 1980; Jegede, 1997). In the same context, Gibbons, Limoges, Nowotny, et al (2005) further attest that;

> Science does not stand outside of society dispensing its gifts of knowledge and wisdom; neither is it an autonomous enclave that is now being crushed under the weight of narrowly commercial or political interests. On the contrary, science has always both shaped and been shaped by society in a process that is as complex as it is variegated; it is not static but dynamic. (p.22)



Gibbons and friends argue that science as a human enterprise is influenced by human culture and beliefs therefore it is up to the users to decide on technologies that benefit them. Hence the assertion that it is man who shape science within the society that he lives in and not the other way round. In this light then, the Department of Basic Education's initiative for an integrated curriculum should be welcomed as a way forward to making science reflect the South African contexts rather than just drilling scientific knowledge into learners for examination purposes only.

Even though the importance of science and technology in the twenty-first century cannot be downplayed to the economy, there are those who argue that other ways of knowing have been overlooked and oppressed yet they are still sustaining the livelihood of millions of populations. Therefore by giving them the same platform in education they can contribute largely to sustainable environments which are now under threat (Odora Hoppers, 2004). To this Montecinos (1995), Odora-Hoppers (2002), Aikenhead & Jegede (1999) abhor what they call a systematic way of privileging Western-European perspectives whilst silencing non-western worldviews as myth ridden. They Lament how the defeated or oppressed lost their space and their word in deciding what counts as knowledge. Therefore, in their view IK is worth to be studied because it sustains millions of people.

Generally, there is a contrast of learners' values of science and technological tools they are glued to and learning school science. The reason is that school science in no way reflects scientists who are actively producing models of technology instead lessons are theory ridden with no models to support them. The nature of school science does not allow critical thinking and is taught in 'retrospective' instead of 'prospective status' (Zoller & Sundberg, 1994).

On the other hand, Cooper and McIntyre (1996) propound for "effective pedagogy for effective teaching," in science. Effective pedagogy entails contextualisation of content in terms of learners' experiences and knowledge as a way forward to science teaching and learning. These pedagogies develop critical thinking through utilisation of cognitive styles and ways of engaging with the learning processes amongst the learners. The cognitive styles mean illustrations and different modes of representations and experimentation that lead to innovations by students, just as scientists do to achieve meaningful learning. That is what is envisaged in learners in the National Curriculum Statement (NCS).



Although science may be foreign to some learners, Ogunniyi (2013) asserts that a person can hold two or more worldviews harmoniously and use them within the appropriate contexts as the need arises. His assertion agrees with Jegede's (1997) collateral learning theory. The reason is that we as humans are always moving in and out of roles in our homes, communities and work places. This can be further elaborated by an example of the different roles and contexts that a woman can have daily. For example, a woman can be the president of a country, a wife to her husband at home, a mother to her children and a congregant in her church. In the way that these roles can interplay with each other so can science and culture interplay. Furthermore Hodson (1992) concurs with Ogunniyi as she posits that "the task of science teaching is to help all children acquire scientific knowledge, interests, skills, attitudes and ways of thinking side by side their particular cultural beliefs and experiences"(p.16). This can be done by using learners' experiences as contexts of concepts development and learning.

### 2.5.1 The inclusion of IK about Earth and Beyond in the science curriculum

Indigenous knowledge systems (IKS) entail ways of living of local community or society. It is holistic and culture specific in nature but it is not universal. IK has been orally passed for generations and the apprentice learns through active participation guided by elders (Odora Hoppers, 2002). The validity of indigenous knowledge can be attested to by the way it has helped to sustain the indigenous peoples of the world for centuries. Such communities have gained their knowledge of the environment through careful observation of diverse natural phenomena such as the sun, moon, tides, stars, floods, the flora, fauna and so on. The knowledge derived from such observation has emerged in form of artefacts, drawings, paintings, songs, storytelling and poems (Mushayikwa and Ogunniyi, 2011). The ethos of indigenous knowledge is participatory learning, togetherness or group spirit also called *ubuntu* in South Africa (Apffel-Marglin & Marglin, 1990; Hewson & Ogunniyi, 2008).

Literature about the biosphere from an African perspective is very scanty. But there is a lot on herbal medicines, land usage and some relics which show that the Africans like other people of the world were quite interested in studying the night sky. The African indigenous practices do not isolate what happens in the skies from what happens on the earth. The cultural astronomy of Africa is interlinked to the everyday living and to religious beliefs. According to Holbrook, "The night sky is the heritage of all peoples and each took countless generations to watch, justify and map the heavens in addition to defining their relationship with it," (1998, p. 76).



The relics prove that Africans throughout the continent were fascinated by the night sky. Astronomical researchers have identified different sites that are believed to be astronomical sites of long ago across Africa namely the Great Zimbabwe ruins in Zimbabwe, Nabta, Nomarotunga in Kenya, Mapungubwe in Limpopo South Africa and many others. The night sky knowledge links the everyday activities, the weather interpretations which enabled them to do agriculture and fishing. The pastoralists also depended upon knowledge about the sky which is interlinked with religious ceremonies.

Archaeological reports also show that Africans were developing technologically before its occupation. A study by Jeffrey, Hughes and Solomon (2000) on rock paintings by the San people reveal that they were quite advanced in the dyes used in rock paintings which we still see today. Nyong and Adesina (2007) in their study of the Sahel pastoralists unveiled some strategies they adopted in order to avert the adverse effects of climate change to include sustaining the balance of eco-system. These examples and many others are proofs that indigenous practices adapt to change for survival and infusing them to school science may influence a rich development in technologies.

The recent turn around strategies by governments and other organisations such as UNESCO, CIDA, The World Bank, scientists included is due to the realisation that science and technological development alone are not adequately addressing environmental issues such as land degradation that leads to desertification, pollution and other disasters affecting human kind. In traditional resource management, resource monitoring is done by use of folklore and taboos (Alcorn, 2009, Colding, 1998).Thus the need for relooking at incorporating indigenous practices where possible within the school curriculum since there is an acknowledgement that some indigenous practices are eco-friendly. There is also a realisation that promoting science literacy to all citizens would create awareness in people of how fragile planet earth is. In this case, it makes sense for African governments to be in the forefront in adapting their school science programmes in order to start developing the African technologies adopted from African culture.

Relooking at ways of augmenting science and indigenous practices with the aim of bringing sustainable development to the indigenous communities of the world is a way forward to achieving that goal (Agrawal, 2008, Driver, et al., 1992, Odora-Hoppers, 2002). This realisation is also the driving force behind contextualising school science.
However, finding the teaching strategies that accommodate IK and science integration remains a challenge. Another big challenge is faced by in-service teachers who have been trained in Eurocentric science and lack the knowledge on IK. Jegede, (1997), Ogawa, 2008, Osborne et al. (2003) acknowledge that science and technology are valuable to the development of any country's economy; however, scientism must accommodate and not suppress peoples' dominant cultures.



The educators therefore will need to be exposed to different pedagogies that promote critical thinking in learners through pre-service or in-service training. If teacher training institutions continue with the business as usual, way of training teachers, then teachers as curriculum interpreters and implementers will continue using the same strategies of teaching that they experienced during their schooling days. Thus, Van Wyk (2002. 310) calls for the change in institutional culture so as to achieve the goals of developing responsible citizens after exposure to the Grades R-12 NCS. It is true that for effecting change in the society, institutions of higher learning and schools play major roles; ironically, these same institutions were used by oppressive governments to implement and create exclusive societies that flourished in South Africa prior to its independence.
The inclusion of IK within the school curriculum should focus at how to develop the practices for the benefit of the users and not just to append IK into science.

In essence, I agree with some scholars who argue that integration of IK and science will always be in the form of appending IK examples into science therefore rendering IK inferior. Their call is for

IK to stand alone as a subject because its characteristics differ from science (Fensham, 1992, Odora Hoppers, 2002). The Japanese successfully harnessed their culture by adopting the practical part of western science and technology leaving out the epistemological part of it (Ogunniyi, 1995) to develop science for all Japanese juxtaposed to the AAAS adopted in America. Now Japan is a world competitor in science and technology. The same can be achieved in South Africa if the integration of indigenous knowledge (IK) with science goes beyond awareness creation and appreciation of it to being assessed.

Although the benefits of social constructive pedagogy have been well documented, the on-going debate amongst academics about the validity of inclusion of indigenous knowledge practices into the school science curriculum in this country continues. Those who are against inclusion of IK in school science believe that it is outdated, thereby portraying science to be a privilege of the powerful elite (Delpit, 1995, Driver & Oldham, 1986). Additionally, problems of repositories that teachers can use if they are to integrate science and IK in their pedagogy are setbacks hindering implementation and can only be overcome through co-operation of all stakeholders (Prakash & Esteva, 1998). However the success to integrate science with Indigenous knowledge squarely depends upon teachers adopting a paradigm shift in their beliefs and in practice (Kawagley, et al., 1998; Osborne, et al., 2003).



### 2.5.2 Summary

Researchers and scholars on NOS and school science concur that school science tend to be historical and teacher dominated (Lemke, 2001; Osborne et al., 2003). They further argue that scientists collaborate and debate their findings in order to agree or disagree with new discoveries (Cross et al 2007) whereas such experiences lack in school science with learners. They also attribute some degree of difficulty faced by learners in learning school science to its nature as elaborated earlier on. However, it has been noted that science’s foreignness is not just experienced by learners from non western countries but by all learners. Some learners whose culture is slightly similar to the western scientific worldview can cross borders smoothly from their daily experiences to that of school science, yet some will need the expertise of a mediator/teacher to help them to cross the borders from home culture to that of school science because of the disparities (Aikenhead, 2001, Cobern, 1996, Ogunniyi, 2009).

In cases where teachers use traditional methods, some learners may just memorise the scientific facts for examinations. Others will just not be interested if their worldviews clash with that of school science. However, the benefits that science has contributed to humankind make it apparent for learners to be enticed into taking interest in science.

The integration of science and indigenous knowledge is envisaged to be on equal bases and not appending one worldview to the already dominant other, through adoption of a multi-cultural science teaching approach (Atwater, 2010, Ogawa, 1995). The aim of this approach is to enable learners to acculturate scientific knowledge so that it becomes part of the learner's identity. However for this to happen, a lot of hard work and togetherness is needed from all stakeholders so that the integration does not end in theory only.

Socio-constructivists argue that scientific discoveries and theories are culturally bound therefore science in itself is a subculture within multi-cultures (Ogawa, 1995). It is through argumentation that new scientific discoveries are adopted by scientists (Khun, 1993). Therefore the same opportunities should be accorded to learners by teachers in classrooms in their quest to allow critical engagement which leads to acquisition of scientific knowledge by participants.

It must be noted that some form of dialoguing being called for is inherent in some indigenous knowledge practices since learners from the indigenous communities learn their culture by participation not theory. However, from a scientific perspective, and to help the participants to be able to argue effectively in science, they need familiar contexts otherwise they will not have anything to argue about. Therefore, spatial modelling can be a tool used to bridge the knowledge gap that exists between a mediator's planned topic with its abstract data and the participants' worldviews. Through modelling, participants engage amongst their peers as well as with the facilitator, leading to development of better understanding of concepts. The scaffolding provided through spatial modelling and argumentation aid in accelerating development of cognition.

There are insurmountable advantages of adopting argumentation in a multi-science class. These entail learners' prior knowledge bearing on new science concepts, development of critical thinking through discussions, sharing of ideas during group work, language development and meaningful acquisition of scientific knowledge.

The question which arises though is why adopting argumentation as a teaching strategy; yet, there are other strategies that support learner-centeredness? Well, earlier on I identified some of the differences that are between science and indigenous knowledge practices which may make learning science difficult for some learners. These epistemological differences can be bridged through some form of teaching strategy that is oriented towards argumentation (Erduran, 2007). Therefore Ogunniyi (2008) opines that dialogical argumentation teaching strategy provides room for participants to journey through cultures creating the desired understanding the two worldviews. This then allows for purposeful acquisition of knowledge from both sub-cultures. For this reason Ogunniyi's contiguity argumentation theory (CAT) is used together with Toulmin's argumentation pattern in a bid to bridge the differences.

## 2.6 Theoretical framework for the study

### 2.6.0 Introduction

Toulmin's (1958) argumentation pattern (TAP) and Ogunniyi's (2002) contiguity argumentation Theory (CAT) are used together to form the dialogical argumentation framework for this study. Whereas TAP is used to assess the type of discourse in a learning situation where inductive-deductive reasoning is required, it is useful in assessing the quality of argumentation displayed and quantifies it. CAT on the other hand is useful in that it entails diverse ways of negotiating in a discourse involving both logical and non-logical arguments as would be the case where people's value system, interests and emotions are used to justify an argument (Ogunniyi, 2008). It engages emotions, physical body, beliefs, nature and a lot more. Aikenhead (1997) argues for use of learners' prior experiences in science classrooms, this in a bid to accommodate the shift involved from internal to external dialogue that takes place within and between learners as they cross borders (Ogunniyi, 1995). Engaging in discourses create room for learners alternative belief systems besides their own cultural beliefs and experiences allowing them to construct new knowledge (Hodson, 1992). This makes a suitable methodology especially when science and indigenous knowledge practices are integrated to study the earth and the biosphere. In this case, the involvement of pre-service natural science teachers is aimed at equipping them with one of inquiry based teaching methods. For meaningful participation in argumentation, participants will make models of the earth as viewed from space.

Having discussed earlier on about the teaching and learning of science from a multi-science approach and the challenges that non-western participants experience cognitively, it is argued that the combination of TAP and CAT help in transcending across the cultural borders of the experienced world to the scientific one (Ogawa, 1995).

**Two advantages of argumentation in science are namely for the:**

- construction of scientific knowledge through discourse (Knorr-Cetina, 1999, Latour & Woolgar, 1986), and
- Socio-cultural perspectives of learners can act as tools for learning as underscored by Vygotsky and Wertsch, cited in (Jiménez- Alexandre and Erduran, 2007) in order to enhance critical thinking processes in the science classroom.

On the other hand, Jiménez-Alexandre and Erduran (2007) further project potential benefits of participating in scientific argumentation to:

- The development of higher order cognitive processes due to participation in public reasoning which promotes critical thinking. Participants become reflective as a result.
- Through argumentation participants become acculturated into the scientific culture, enabling them to become literate in science through dialoguing and writing science.

The rigor entailed in argumentation when properly planned for is emancipatory. The reason being that argumentation mirrors the social environments under which people acquire knowledge at home (Duschl and Osborne, 2002, Jiménez-Alexandre and Erduran, 2007). It is therefore apposite for teachers to understand the scope of argumentation, as well as NOS, content knowledge and how best to unpack that content. The teachers' knowledge must be above that in the learners' textbooks. This enables them to model scientific ideas creating spaces for the development of the cognitive and metacognitive processes. Furthermore, understanding of the nature of science may enable them to navigate from one culture to the other easily.

Globally, most conglomerates' policies are envisaging for scientifically literate citizens (Jiménez-Alexandre and Erduran, 2007) and South Africa as part of that global arena has similar goals for its citizens. Hence the DBE aims to develop learners who are actively involved in the acquisition of knowledge in learner centred environments (NCS, CAPS, 2011).

As indicated earlier argumentation is a critical component of NOS. However, within the IKS context argumentation may be a bit toned down or more correctly, presented in various forms such as: drama; songs, storytelling, proverbs, idioms, etc. rather the western style of equivocation (Ogunniyi, 1988, 2004, 2007a & b). CAT can be used to trace the perceptual shifts in the worldviews mobilized by the arguers in the course of an argumentative discourse.

### 2.6.1 Toulmin's Argumentation Pattern (TAP)

Stephen Toulmin is a British philosopher, a writer and educator who studied the logic of reasoning. Toulmin's (1958) argumentation pattern is a methodological tool used in analysing scientific data. Stephen Toulmin opines for consistency in argumentation, the work which was contributed to by Aristotle, Dewey and others who studied the science of logic. His work in ethics was motivated by Ludwig Wittgenstein's lectures that he attended after which his doctoral dissertation was based. In an introduction to his book, "The uses of argument," Toulmin asserts that:

> Logic, they argue, is like medicine—not a science alone, but in addition an art. Its business is not to discover laws of thought, in any scientific sense of the term 'law', but rather laws or rules of argument, in the sense of tips for those who wish to argue soundly...From this point of view the implicit model for logic becomes not an explanatory science but a technology, and a textbook of logic becomes as it were a craft manual (1958, p. 40).

Toulmin in this case posits practical reasoning which is contextual, justifiable and logical. I have to reiterate that logic will lead to understanding the meaning of the argument, if the argument is based on something a learner has no clue over, and then the teacher has to create environments that could familiarise the participants with the theme of the argument. In this case Ogunniyi's (2008) motivation for combining TAP and CAT in DAIM is to enable the integration of scientific discourses with the social cultural aspects that learners are likely to introduce from their experiential knowledge of phenomena.

Toulmin's Argumentation Pattern (TAP) consists of a claim, evidence, warrants, backing, qualifier and rebuttal (Erduran et al, 2004, Jiménez-Alexandre and Erduran, 2007). Below are brief explanations of the elements of TAP:

Claim –this is an assertion, or a main point. For example in the NCS/CAPS, (2011, p. 30) a claim is made that "The earth moves (revolves) around the sun once a year. It goes on to claim that as it revolves, it causes seasons and the educator is warned that s/he does not need to explain (no explanation, CAPS, 2011, p. 30). This is meant for grades four learners, I however argue that this explicit claim needs a lot of discussion and explanation especially with the nine/ten year old learners since in their everyday experiences they see and may hold the perception that the sun is moving from east to west and not the earth. There is need for discussion in order to accord these learners the chances to deliberate and understand the scientific theory besides their social cultural experiences.

Evidence –this is data/ grounds – the thesis that support the claim, it consists of facts, analogies or statistics. The evidence in this case can be in the form of modelling using a globe and a flush light to illustrate the earth's revolution around the sun.

Warrant –statements that link data to the claim, it can be beliefs which are rational to substantiate the claim. In this case the warrant is that one revolution of the earth makes one year.

Backing-general statements that support the claim or further support the warrant. On the same topic the backing is that, as the earth rotates on its axis and revolves around the sun it causes day and night and also seasons of the year.

Qualifier- it is used to justify or tone down an outright statement or claim, it admits to exceptions to claims. An example of a qualifier can be; Indigenous knowledge practices are about witchcraft and taboos. This claim is not absolutely correct about indigenous practices in that there are many knowledge practices that are indigenous and eco-friendly such as crop rotation, using taboos as a deterrent in cases of dwindling fisheries or certain trees as a way of allowing breeding and growth of tree species which will be under the threat of extinction. Implicit statements are also used a lot in multiple choice questions and through participation in argumentation participants gain the ability to critique statements which are incorrect (Diwu, 2010, p. 60).

Rebuttal-this is a contradiction to the general assertions put forward, it can be an alternative way of looking at issues. It is through engagement in scientific argumentation that participants are exposed to all these characteristics as alluded to by Toulim's argumentation pattern.

Besides deductive reasoning exposure to TAP is believed to improve participants' report writing skills and promotes personal reflection argues Kelly and Bazerman, cited in (Kelly, Regev and Prothero, 2007).

In a different context Erduran (2007) modified the elements used in analysing data in TAP due to the overlap of its elements. This comes after most of the practitioners in her study found it difficult to follow the argumentation methodology, especially in distinguishing between data and claim.

Additionally, participants claimed they had difficulties in identifying what counts as arguments when learners argue. Because of these criticisms Erduran and her colleagues modified TAP elements to three only namely claim, ground and rebuttal. Besides that, the use of TAP has the potential of creating learner-centred environments in classrooms as learners are given chances to express their beliefs and critic scientific assertions during argumentation. In doing so, the teacher can assess the levels of development of individual participants and be informed whether participants understand the topic under discussion.

Therefore educators need to be familiar with TAP and evaluating arguments using for example Blooms's (1956) taxonomy for good questioning skills such as open ended questions which require learners to justify their assertions. Argumentation creates classroom discourse between learners, and between teacher and learners. TAP's theoretical framework can be used to analyse classroom discourse and the more opposition there is in argumentation, giving rebuttals and alternative facts to the norm, and then higher levels of argumentation are reached. Table **1** in the appendix will be used to assess argumentation quantity and quality. In summing up, the use of TAP applies to school science and not to Indigenous knowledge systems because there is need for step by step reasoning and the application of syllogistic reasoning as opposed to value-laden conductive reasoning (Ogunniyi, 2007a).

### 2.6.2 Contiguity Argumentation Theory (CAT)

Ogunniyi (2008) espouses CAT as a learning theory that draws on the Aristotelian association theory of the interplay between different ideas. The Aristotelian contiguity association idea asserts that two distinctly different ideas can co-exist to achieve cognitive harmonization. The basis of contiguity theory is that human beings can associate ideas when they need to remember events. This means that humans are capable of holding more than one belief systems and use them accordingly, just as a married woman can be a mother and wife to her children and husband. Likewise, she can be a student at a college and pastor in her church. In all these situations she will be shifting from one role to another as the conditions change, making CAT a context- based theory. Unlike TAP which has inductive-deductive characteristics, CAT's ethos is to resolve conceptual conflicts and to attain cognitive equilibrium e.g. the conflict that arises between science and indigenous knowledge.

The framework in contiguity argumentation theory (CAT) is harmonious dualism which works well where two world views with different epistemologies come together. Harmonious dualism entails the ability of an individual to maintain cognitive homeostasis or more correctly allostasis in the face of conceptual conflicts (Ogunniyi, 2007a). It is possible that participants in this study, though they are training to be natural science teachers, may also hold other ways of explaining the natural world.

CAT's framework has five categories or conceptions within which an individual's mind can operate. These conceptions can be used as tools of assessing the movement of participants' assertions after argumentation. According to Ogunniyi (2008, p. 162), "concepts in the five categories exist in a dynamic state of flux in a person's mind." The conceptions are namely dominant, suppressed, assimilated, equipollent and emergent. Due to their adaptability, they can allow an individual to shift and accommodate other world views, argues (Ogunniyi, 2008, 2007).

**The cognitive categories of CAT**

**The dominant cognitive conception-**

This conception is powerful within a person. For example in a science lesson, a teacher will enforce the views s/he is most familiar and convinced about within a lesson. This is guided by overwhelming evidence that the person has been exposed to through institutionalisation.

**The Suppressed cognitive conception**

This conception stays inactive within a person and can become dominant or even assimilated after engagement. For example a person who believes that lightning strikes are manmade may suppress this belief in a science lesson for fear of being ridiculed.



**The assimilated cognitive conception**

It is newly learned ideas/conceptions or experiences which a person acquires after being exposed to new concepts or beliefs. For example most of the indigenous learners get assimilated into the school science culture whilst at school, however when they go back home after school the assimilated conceptions are suppressed resorting back to the everyday experiences.

**The equipollent cognitive conception**

This happens when more than one worldview co-exist within a person and used as per need. For example, my beliefs in traditional herbal and modern medicine are equipollent. I know when to use herbal medicines and when to visit a doctor.

**The emergent cognitive conception**

It emerges when a person is exposed to new views/theories about nature as in science causes of day and night. Most children believe that the sun travels from East to set in the West. At school they are taught that day and night is caused by the earth's spin. This new knowledge is the emergent cognitive conception.

### 2.6.3 Dialogical argumentation in the study

At the core of reviewed literature is a bid to make science learning relevant to recipients. Dialogical argumentation is a teaching methodology that can be used in science classrooms to make them interactive. It accommodates learner to learner interactions as well as between teacher and learners. Through argumentation internal thoughts are externalised in participants enabling peers and the mediator to question the rationality of these thoughts or to clarify some misconceptions. This kind of debate allows participants to be active in the construction of new knowledge. However, it must be acknowledged that argumentation as a teaching strategy takes time to master, as witnessed in Erduran's (2008) study of in-service teachers who were overwhelmed by requirements of TAP. Therefore teachers need to understand that argumentation involves a lot of prior planning if lesson objectives are to be achieved.

CAT's adaptability and flexibility in multiple worldviews makes it a suitable teaching strategy in integrating science and indigenous knowledge in the South African school science curriculum (Ogunniyi, 2013). It allows movement of conceptions which arise as participants engage in argumentation stating claims with evidence and others refuting them leading to reflections and shifts in their conceptions of nature. In addition to that the conceptions fluctuate depending on the context allowing spaces for growth in knowledge. It also allows two or more thought systems to co-exist in individuals and be used as per need.

Central to teaching and learning within the NCS is the social constructivist learning theory (Vygotsky, 1978, Feuerstein, 1999) which propounds for use of prior learning in learning new concepts. It proposes for contextualised learning which is socially mediated by a capable other. In that sense the DAIM's characteristics is centred on interactive learning as in constructivism

The use of DAIM eradicates the foreignness that some learners sometimes experience in science is reduced due to the fact that there is cohesion as the lesson progresses ending with a consensus where applicable. This enables a teacher to play mediatory roles in helping learners to transcend different worldviews (Donnelly, 2001, Osborne & Collins, 2000).

It is therefore imperative to expose educators during their training to different teaching styles so that they use effective pedagogies that are learner centred. It is hoped therefore that the participation of pre-service Natural Science teachers may be equipped with strategies that enhance their pedagogy.

#### 2.6.4 The spatial modelling and dialogical argumentation strategy (SMDAS)

Dialogical argumentation is a cyclic methodological teaching tool that can enable the integration of science and indigenous knowledges. However, in order to enhance dialogue amongst learners, an educator has a duty of creating enabling environments through the use of experiments or activities such as spatial modelling whenever possible. Through spatial modelling, participants are able to apply data in the modelling and visualise the entity. This enables them to make claims of what they have modelled and give evidence as they put their model to use. In so doing participants are actively involved in knowledge deconstruction and reconstruction.

Science learning following the SMDAS involves a process whereby a teacher directly engages learners in meaningful hands-on activity within a dialogical argumentative discourse. Due to the complexity involved in a worldview, modelling is the mirror through which a teacher views what the learners know. It is also to a learner a mirror through which s/he views what the teacher intends in a lesson. In a way the teacher's intentions are understood by learners who start intrapersonal dialogue, then interpersonal dialogue with science data represented by NOS at the apex of *Figure 2b*.

As mentioned earlier, models play important roles throughout a lesson in the acquisition of scientific knowledge. It is important in mirroring where a learner for basement assessment is and what the teacher mean in science. The teacher and learners are accorded chances to engage meaningfully. Diakidoy & Kendeou (2001), Vosniadou (1994), Vosniadou & Brewer (1994) underscore Ogunniyi's (1988) and Cobern's (1996) assertion that scientific conceptions about the physical world may not replace learners' experiential knowledge about the physical world in their findings. But the use of models provides lee-ways for learners to re-evaluate their beliefs. If they find the data comprehensible, with enough evidence to complete their worldviews then this informs whether they need to revisit their perceptions or not. This is done by allowing learners to manipulate and explore for themselves the astronomical models in activities creates spaces for knowledge growth. In order to eradicate misconceptions which have been reportedly found in students of all ages in astronomy, lessons should be more activity based than theoretical (Lelliott, 2010, Lemmer, et al., 2003, Mosoloane, 2012, Sanders, 2006).

The spatial modelling and dialogical argumentation strategy (SMDAS) (see figure 3.1), was developed as an interaction model for the integration of science and IKS through spatial modelling and dialogical argumentation. The model demonstrates how argumentation is central to the teachers' accessing of the learners' levels of development in astronomy by involving them in constructing their own conceptual models of the earth in space as NOIK entry level.

In the SMDAS model, argumentation is encouraged to enable learners to describe their models. The teacher then brings in physical scientific models of the earth in space (the globe) for learners to engage with individually, in small groups and as whole group. Argumentation is encouraged with what, how and why questions. The teacher also refers learners to 2D picture models to connect with 3D ones. The figure 2 below mirrors the complexity of learning. This model will be discussed in more detail in chapter 3.

### 2.6.5 Conclusion

In this chapter the literature reviewed bears evidence that the prior knowledge of students forms a strong basis for the development of metacognition (Freire, 2007; Vygotsky, 1978, 1986). It also affirms that meaningful learning takes place in socially mediated environments. This further shows the need for relooking at school science teaching in the hope of trying to contextualise it. In order to integrate science and indigenous knowledge, teachers need to be exposed to a valid understanding of the nature of science and that of indigenous knowledge systems.



Teachers are the implementers of learning, therefore the involvement of prospective teachers in such a study is deemed necessary. Moreover, different studies also recommend for change in the way school science is designed and taught. There is consensus among these various findings that learners who are actively involved in participatory learning activities tend to retain and own what they learn directly hands-on experiences than when they are simple told by the teacher. This translates to exposing learners to experiential learning through experimentation such as modelling, carrying out investigations and then letting learners present their findings to their peers as scientists do (Driver et al., 1996; Erduran, 2004; Odora-Hoppers, 2002; Osborne et al., 2003; Ogunniyi, 2011;

Toulmin, 1958). In this sense the teacher's role is to mediate and scaffold learning for learners rather than transmit readymade scientific knowledge.

In chapter three that follows the procedures used to gather the study are presented. This includes: the design of the study; the sampling procedure; instrumentation development; the analytic methods used; the implementation of the dialogical argumentation spatial modelling and finally the steps taking to ensure that all necessary ethical conditions are adhered to throughout the course of the study.

# Chapter 3

# Methodology

## 3.0 Introduction

This study investigated the pre-service natural science teachers' perceptions about the earth in space using dialogical argumentation and spatial modelling instruction. As mentioned in the last chapter, social constructivists emphasise the need to use learners' prior knowledge as stepping stones for learning. They also stress that teaching and learning should mirror the sociocultural environment of learners. The South African National Curriculum Statement (NCS) is underpinned by Vygotsky's social constructivist theory. This theory views learning as a social activity mediated by a knowledgeable adult (Kozulin, Gindis, Ageyev & Miller, 2003, NCS, 2011). In a school set up, a teacher is seen as a knowledgeable adult who mediates learning activities. In the same vein argumentation is viewed as another vehicle which can be used by teachers to engage participants into doing science the way scientists do science. Scientists use argumentation, dialogue, positing hypotheses for testing and peer reviews of their discoveries.

The literature which was reviewed in the previous chapter attests to the existence of varied perceptions of the earth in space among learners and even prospective teachers which are different in some cases to the universally accepted scientific worldview. These differences especially in astronomy are due to the fact that astronomers have developed artefacts that are different from the cultural artefacts. These technologies are used to probe into the universe for example; telescopes for clearer interpretations beyond what the eyes can see. Whereas indigenous conceptions of astronomy are mostly sociocultural scientific or western astronomy is very theoretical and abstract. These differences are believed to cause misconceptions in learners if teachers do not actively involve learners in construction of scientific knowledge (Vosniadou, 1992). The reason for misconceptions is that alternative perceptions held by learners from infancy to adulthood tend to clash with the scientific views if not properly mediated (Govender, 2007; Vosniadou, 1992; Plummer, et al., 2010).

Taking the pointers above as standpoints, prospective teachers' participation was viewed as appropriate in trying to foster in them cultural sensitivity as they mediate and deliver lessons in science classrooms. This implies that while teaching science they should be equally sensitive to their learners' socio-cultural backgrounds. Otherwise the learners might feel alienated from what is being taught. Taking into considerations that the NCS has undergone three reviews due to implementation challenges, the participation of prospective natural service teachers was also viewed as an important part of their training. It was hoped that the participation of pre-service teachers would increase their awareness about the fact that the learners should be subjects and not objects during the learning process (Botha, 2010). To that effect, Ogunniyi (1988) with regards to African culture and science emphasises that participants in science should be allowed to let their religious affiliations nourish their souls while science is allowed to cater for their physical needs. He believes that the two worldviews should be considered as complementary to each other as different ways of knowing rather than regarded as polar opposites. It was in light of this that the study explored various procedures to collect data.

Cohen, Manion and Morrison (2007, p. 47) cite Kaplan's proposition that; "the aim of methodology is to help us to understand, in the broadest possible terms, not the products of scientific inquiry but the process itself." The methods used in the study aimed at addressing the following research questions as delineated in chapter 1;

i. What indigenous and scientific conceptions of the earth in space did the pre-service teachers hold before and after being exposed to spatial modelling and a dialogical argumentation modelling activities?
ii. To what extent did their participation in an argumentation/spatial modelling instructional model enhance their understanding of the earth in space?
iii. What cognitive shifts did pre-service teachers exhibit in their attempt to use an argumentation/spatial modelling instructional model to implement an integrated science-IK curriculum?

### 3.1 Research Design

Bryman (2008) and Cresswell (2007) define a research design as a framework under which data is to be collected and analysed. This framework includes the site, the targeted sample or population, the instruments used including the data gathering process. Additionally, Ogunniyi (1992) likens a research design to a building plan or a road map that an investigator and other interested parties can use to reach a given destination. In that sense study used spatial modelling activities are used in a dialogical argumentation strategy (SMDAS).

This study used a case study approach to answer the three research questions. It used pre and post test questionnaires. The pre-test was administered to pre-service teachers before the intervention and the post test after. Data will also be collected throughout the intervention through reflective diaries, group projects, argumentation and modelling activities.

### 3.1.1 The spatial modelling and dialogical argumentation strategy (SMDAS)

As reported in chapter 2, the spatial modelling and dialogical argumentation strategy (SMDAS) was adopted for this study. In this case spatial modelling activities are intended to enrich participants' data as they participate in dialogical argumentation. The (SMDAS) emphasises on the continuous interactions that take place within an individual's cognition when confronted with new concepts. This happens whether the concepts being introduced are similar or in conflict with the participant's prior knowledge, which is usually a reference position to incoming information. The SMDAS model is therefore at the centre of the research design in this study.



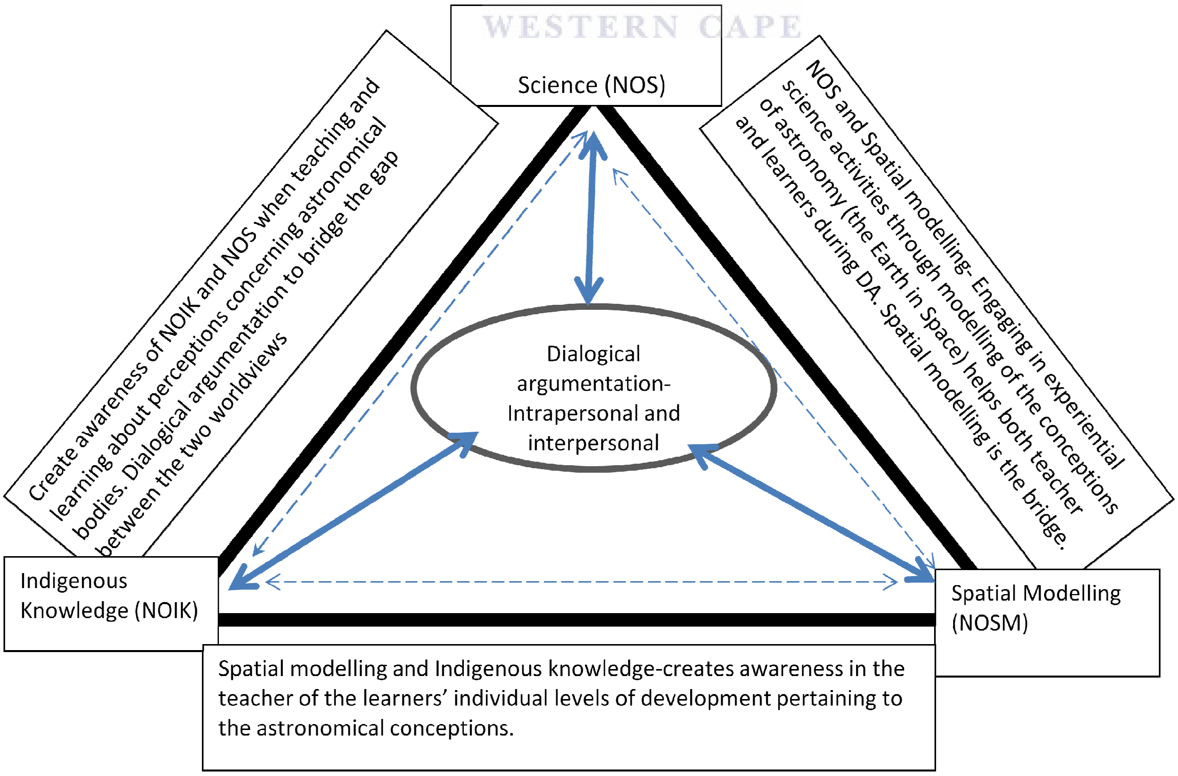

**Figure 3.1: The spatial modelling in a dialogical argumentation strategy (SMDAS) -** *Adopted from Mushaikwa, Langenhoven & Stone (2014)*

Through modelling activities and dialogical argumentation, it was envisioned that participants would be able to harmonise their prior beliefs about the earth's conceptions with scientific knowledge. Schneps & Sadler's (1987) study found widespread misconceptions regarding the earth and sun's conceptions ranging from kindergarten to university graduates. The cyclical nature of dialogical argumentation enables continuous intra-inter argumentation between participants. This in turn enhances reflection, which can lead to reconstruction of ideas and in this case, earth in space conceptions.

On the other hand, the knowledge of NOS and NOIK as shown in the model are crucial constructs which informs participants about the existence of different worldviews. Spatial modelling activities therefore bridges the differences between science and prior or indigenous knowledge usually held by participants. The cyclical nature of dialogical argumentation strategy can bring two different worldviews to speak to each other without one worldview dominating the other. Hence Ogunniyi (2013) concedes that, "... two distinctly different thought systems can only occur through conceptual interlocution ...otherwise the two thought systems would remain incommensurable," (Ogunniyi, 2013, p 17). Due to this reason, the study followed the sequence below to deal with the notion of the Earth in space.



### 3.1.2 The case study

This project was a case study of fourth year pre-service teachers. A case study involves a focused study of a focused group of people to give generalised information about people in similar conditions (Cohen, et al. 2007). In addition, case studies have the power to "establish cause and effects in real life contexts," (Cohen, et al., 2007, p. 272). They are therefore reputed for being less controlled. Hence qualitative research methods are commonly used in case study designs. Thus this project focused on pre-service science teachers' perceptions about the earth. These pre-service teachers were undergraduate students in their final year at an institution of higher learning. The case study was conducted within the framework of argumentation and spatial modelling. With this in mind, I will discuss how this study took place.

### 3.1.3 The Research setting

In an attempt to find answers to the topic under investigation, this research was based at an Institution of higher learning. The institution is located in the Western Cape Province of South Africa. The participants from the institution were mostly representative of the South African population groups.

Morse & Field in (Boeije (2009), propose that a researcher needs to choose a research setting that provides maximum results of the case under study. Likewise, questions on teaching and learning can best be answered by in-service teachers, prospective teachers and also in the classrooms by both teachers and learners.

The importance of science teachers to a country is of paramount importance to South Africa's growing economy. Industrialists, economists and educationists alike invest heavily in science and maths education (Tubbs, 2013). The Department of Science and Technology (DST) in its 1996 White Paper inferred that a science literate nation results in a wealthy nation and in turn results in an improved quality of life of that nation (DST, 1996). Contrarily, year after year, the numbers of science teachers who are being trained seems to be dropping (Mji, & Makgato, 2006, Tubbs, 2013). This means what the DST envisaged is still to be fulfilled because there is not enough teachers to teach science especially in Africa (Ogunniyi, 1996).

That being the case, a group of 17 pre-service natural science teachers was chosen. The participants were Bachelor of Education (BEd) specialising in science, and mathematics teaching. They had been going to practice teaching in schools within the Western Cape Province. The schools that most of the participants practised teaching were located near the institution that they were studying. There were changes effected with regards to pre-service teaching practice which disabled this researcher to observe the students in the classroom as they taught as originally planned. Instead of going once a week the pre-service teachers started teaching practice after the first semester holiday before I had contact with them.



### 3.1.4 Sampling

The sample I chose consisted of seventeen pre-service science teachers. However, out of 17 of them fifteen [15] actually participated in the whole study. The other two participants participated in the whole intervention but both of them did not write either pre or post test for unknown reasons. Therefore, where I discuss pre and post test results I use a sample of 15 participants. I however acknowledge the participation and contributions made by two [2] participants in other activities such as projects and group work. For that reason fifteen (15) pre-service teachers were purposely chosen because it best suits the topic under research.

Marshall and Rossman in Creswell (2007) argue that a researcher should target the research towards the best participants who suit that particular study by providing rich data. This consideration is so important in providing valid results pertaining to the research problem. Furthermore, Pattern (1987) ascribes purposive sampling as sampling which permits a researcher to select information-rich participants who are knowledgeable about a particular in-depth study. Additionally, information-rich cases can provide data from which one can learn a great deal about issues important to the study.

Unlike a convenient sample whose choice is largely based on access and cost considerations, a purposive sample was preferred because it permits the researcher to obtain data that can yield more critical information than those obtained within the shortest space of time as is usually the case with a convenient sample. The small sample consisting of seventeen fourth year student teachers was not only convenient but also moderate enough to permit an in-depth analysis of the various issues at stake in the implementation of an arguable science-IK curriculum. In addition, the participants' exposure to the NOS and NOIK and argumentation teaching strategy was considered crucial to them. Therefore, this researcher was not only interested in findings but also in enriching the prospective teachers' pedagogical knowledge.

Rogan and Grayson (2003) argue that when introducing a new curriculum the how and why questions have to be addressed if successful implementation is to be realised. Therefore, in choosing pre-service teachers as participants, may enhance the implementation of reforms in the teaching and learning of science. Prospective teachers were ideal because the knowledge gained through participation constituted part of the pedagogy.

I met the group a week after they had returned from 4 weeks of teaching experience from different schools situated near the institution. Teaching practice is an integral part of teacher training. Since they had just returned from teaching practice, it was believed that some of the issues they encountered would feature in the intervention. It was also believed that the participants were familiar with the South African National Curriculum Statement (NCS) and the Curriculum and Policy Statement (CAPS). The CAPS document, an assessment and policy document was still being implemented from 2012 and hoped to be fully operational across all grades R to 12 by 2014. The CAPS provides guidance to teachers on what is expected in learners in order to be promoted to next grade levels. For example, from grades 4 to 6, the following cognitive levels are also expected in learners;



- 40% on knowledge of science and technology through naming, stating, labelling etc.
- 30% in understanding science and technology by explaining, describing, comparing and so on.
- 15% assessment on learner's ability to apply science and technology, through comparisons, predicting, designing, demonstrating etc and,
- 15% evaluative, analytical, synthesising scientific and technological knowledge (DBE, 2011, p. 62).

From the above weighting, which follows Krathwohl's (2002) revised taxonomy of Bloom's; it means teachers need to make learners' experiences in science exhilarating. With this in mind, the participants in this study were purposely chosen to answer the following questions:

- What are the preservice teachers' indigenous and scientific perceptions about the earth in space and the biosphere before and after they have been exposed to an argumentation/spatial modelling?
- To what extent did the participation of pre-service teachers in an argumentation/spatial modelling instructional model enhance their understanding of the earth in space?

- What cognitive shifts did pre-service teachers exhibit in their attempt to use an argumentation/spatial modelling instructional model implement an integrated science-IK curriculum?

## 3.2 The research methods used

This study used qualitative research methods in collecting data from pre-service teachers. Quantitative research methods were very limited to ordinal data on Part B, assumptions about science and IK in the questionnaire.

On the other hand mixed methods developmental approach was adopted in the study in order to get rich and valid data from the sample. The rich data was obtained from the pre-post test questionnaire, reflective diaries, focus group interviews, projects and argumentation from the pre-service teachers. Johnson and Onwuegbuzie (2004) define mixed methods research as a "...class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study," (p. 17).

### 3.2.1 Qualitative research methods

Qualitative research methods were used to obtain data. This was in the form of participants' responses to pre and post tests earth in space questionnaire. Data was also derived from reflective assignments. Recorded dialogue from presentation of solar system group models was also part of data. Other data came from participants' assessments of learners' conceptions of earth in space results. This data was analysed using the TAP and CAT framework to determine the participants' cognition between pre-test to post test claims. Data from first and last participants' reflective assignments and audio recorded data were also analysed using the same framework comparing claims made before and after intervention. Measures were also put up to avoid inaudible dialogue by asking participants to jot down their aim points during argumentation.



The trends and patterns emerging from the data were captured and read through several times as raw data. Atlas ti was also used to capture the emerging patterns from the raw data and made into themes and families for easy interpretations which enabled the researcher to quantify the responses of participants into percentages. However, due to the small sample used, most of the data was also presented as Arabic numbers side by side the percentage. The participants who actually took part in both pre and post test questionnaires was 15 out of a total of 17 participants. The other two participants only wrote one test and missed the other without providing any explanations. Cohen, et al. (2007) argues that a small sample size may compromise the quality of research results. In this case multiple methods were used in order to triangulate different data to come to a plausible conclusion.

### 3.2.2 Quantitative research methods

In part B questions 1 to 5 were quantitative questions seeking participants' opinions, and perceptions about integrating science with indigenous knowledge and the nature of science and indigenous knowledge questions (NOSIKQ). The quantitative questions were in the form of ordinal data requesting participants to make choices ranking from; strongly agree, agree, uncertain (U) disagree (D) and strongly disagree (SD). It should be noted that these rankings did not give certainty on differences between values of intervals (Creswell, 2007).

## 3.3 Data collection

*Table 3 1: Course structure:*

| Research Question | Instruments | Rationale |
|---|---|---|
| Q1 | 1. Earth in space questionnaire<br>2. reflection assignments (1&2) | Measured students' ideas about NOS, NOIK including curriculum-integration<br>Identification of shifts if any in responses before and after the intervention |
| Q2 | 3. Part D & E of pre-post test Q; reflections<br>4. Learners' alternative conception (LAC) assessment activity including<br>Dialogue during modelling | To compare if there is any differences in after exposure to argumentation & SM activities<br>Participants' assessments of LAC |
| Q3 | 5. Audio recorded argumentation<br>6. Projects presentation- the solar system<br>7. Excepts of interviews | To assess the effectiveness of intervention through presentations, and excerpts from responses |

Instruments used including the question addressed.



### 3.3.1 Introduction

Bryman (2001) advocates that researchers use existing questions when collecting data. Doing so negates the need to pilot the questionnaire and also results from the previous study would be used in comparison with the current study. Although, this saves time, in the case of my study, I had to prepare my own instruments since the existing instruments did not sufficiently answer my research questions. However, I adapted a few items on integrating science and indigenous knowledge from previous studies these were from the nature of science and indigenous knowledge questionnaires (NOSIKQ), from the Science and Indigenous knowledge systems project (SIKSP), (Angaama, 2013, Diwu, 2012, Ogunniyi, 2006). The rest of the questions were prepared to address specific issues pertaining to this study

The data was collected from;

- a responses from the earth and its biosphere pre and post test questionnaire
- from two reflective assignments,
- Pre-service teachers' assessment of learners' alternative earth in space conception exercise,

- it also came from audio recordings of argumentation,
- Dialogue emanated from solar system models group presentations.
- Focus group interview

#### *3.3.1.1 The questionnaire*

There was a pre and post test earth in space questionnaire. However, only the pre-test questionnaire had Part A, the biographical section. Part B the assumptions about science and IK issues including the science-IK curriculum integration debate. Part C had questions about the earth in space conceptions. Part D concerned views about argumentation as a teaching strategy and Part E dealt with perceptions about spatial modelling. All these were within the context of earth in space conceptions. Tables 3.2 to 3.5 which follow below show how different parts of the questionnaire were addressed.

**Biographic information**

Personal data of participants helps in keeping track of individual participants. It also helps in this type of study which deals with individual perceptions to identify any significance between the social cultural environments of individual participants and how they perceive the earth in space. Below is a table showing the biographical data of participants.

3.3.1.1.1 Biographic information of the sample

| | | | | | |
|---|---|---|---|---|---|
| Age Range | 21 to 28 | | | | |
| Gender | | | | | |
| Male | 7 | Female | 10 | | |
| **Place of birth** | | | | | |
| **Rural** | 3 | Urban | 14 | | |
| **Province** | | | | | |
| **Western Cape** | | 16 | Eastern Cape | 1 | |
| **Religion** | | | | | |
| **Christian** | | 10 | Islam | 6 | |
| **Mother Tongue** | | | | | |
| **English** | 8 | Afrikaans | 7 | Xhosa | 1 |

The biographic data of the pilot study was almost similar to that of the study. There were 17 participants altogether. There were 8 females and 9 males, all aged between 22 and 29 years old. I participant was from KwaZulu Natal, 1 from Gauteng, 2 from the Eastern Cape and 13 were from the Western Cape Provinces.

**Part B: Assumptions about science and IK**

Part B had closed questions that used ordinal data. Refer to table 3.2 below showing how responses were classified. Questions 1 to 5 responses were ranked as follows:

**Strongly agree-** This is where views of a participant agree exactly with a given statement. The statement could be positive or negative.

**Agree-** a participant agrees to the views stated

**Uncertain-** this is when a participant is not sure so cannot take a stance.

**Disagree-**when a participant opposes the statement given

**Strongly disagree-** a participant opposes strongly the view stated. These responses were ranked 5-1 as given in a Likert scale. However, I should mention that questions 1 and 5 were negative questions and therefore, ranked inversely. This meant SD would be ranked as 5, D=4 and so on and so forth. In my study I opted to use all the 5 ranks so that participants were not forced into agreeing or disagreeing if they were not sure. X stands for a stance chosen by participant.

Questions 6 to 9 dealt with issues about science-IK integration issues in the curriculum. The ***Key*** for the abbreviations given for questions 6 to 9 are: **SO-** scientific orientation; **IKO**-shows indigenous knowledge orientation; **SISIK**-supports integration of science and IK and **NISIK** stands for No integration of science and indigenous knowledge.

Table 3.2: ***Classification of claims made by participants***



| Item | Science & IK assumptions | **SA** | **A** | **U** | **D** | **SD** |
|---|---|---|---|---|---|---|
| 1 | Sci & IK are different | | | | X | |
| 2 | Scientific processes involve aspects of IK | X | | | | |
| 3 | There are benefits in integrating scie & IK | | | X | | |
| 4 | Basic assumptions of sci & IK are similar | | X | | | |
| 5 | IK is all about witchcraft and superstitions | | | | | X |
| | | **SO** | **IKO** | **SISIK** | **NISIK** | |
| 6 | Expressed claim & evidence for sci-IK integration | | | X | | |
| 7 | Made claim/s to show foresight in what Sci-IK entails | | | | X | |
| 8 | Claim made to take stance | | | X | | |
| 9 | Claim made to take stance on challenges foreseen | | | X | | |

### Part C: The earth and its biospheres

In this section participants were required to make claims about their prior knowledge about the earth and its biospheres. They were expected to state sources of the prior knowledge. Furthermore, participants were required to state sources of the prior knowledge and current scientific knowledge. All this was from science and indigenous knowledge questions about the earth (SIKQE). See *Table 3.3*, below with different categories in which participants' responses were classified. Participants were expected to justify their stances about claims made.

Here is the key to Table 3.3:

Questions 1 to 2 and 4b required participants to make claims and identify what influenced their claims. The following sources were given for participants to choose;

Family; Religion (relig); Culture (cul); Books (bks); Media (med); School (sch); Other - specify (o-sp). In table 3.3, the abbreviations are preferred over the full names.

From questions 3 to 4a up to 15, participants were required to express their views about causes of day and night. Participants were also required to name what they viewed as better methods for teaching earth's rotation with the aim of making learners understand the concept. **PSU**-in Table 3.3 stands for Practical scientific understanding and TSU denotes, Theoretical scientific understanding

**Table 3.3:** ***Perceptions about the earth and its biosphere***

| Item | Statement | Family | Religi.. | Cul | Bks | Med | Sch | O(Sp) |
|---|---|---|---|---|---|---|---|---|
| 1a | Prior beliefs about causes of day and night | X | | X | | | | |
| b | Sources of indigenous knowledge | X | | X | | | | |
| c | sources of scientific knowledge | | | | X | X | X | |
| 2a | Expressed own claims about earth's shape | X | | X | | | | |
| b | Made claims about sources | X | X | X | | | | |
| 4b | Has provided evidence to explain revolutions | | | | X | X | X | |
| 3a | Expressed claims about teaching spinning of earth | PSU | TSU | | | | | |
| b | Expressed further with claims about day/night | PSU | TSU | | | | | |
| c | Gave further evidence about Day/night causes | PSU | TSU | | | | | |
| 4a | Has clear claims about earth's revolution | PSU | TSU | | | | | |
| 5a | Made a claim, with further evidence | UIKP | LUIKP | | | | | |
| b | Made a claim, with further evidence | UIKP | LUIKP | | | | | |
| c | Made a claim, with further evidence | UIKP | LUIKP | | | | | |
| 6 | Made a claim, about myths and taboos | UIKP | LUIKP | | | | | |
| 7 | Provides claims about lightning | UIKP | LUIKP | | | | | |
| 8 | Provides further evidence about claim | UIKP | LUIKP | | | | | |
| 9a | Has a claim about IK and conservation | UIKP | LUIKP | | | | | |
| b | Made further claims about IK and conservation | UIKP | LUIKP | | | | | |
| 10a | Has a claim about Scie and conservation | DSR | LSR | | | | | |
| 11a | Made a claim about a part of biosphere | DSR | LSR | | | | | |
| b | Provided further evidence for claim | DSR | LSR | | | | | |
| 12 | Provided data for causes of cold fronts | IKUW | LIKUW | | | | | |
| 13 | Claim shows evidence of knowing signs of weather | IKUW | LIKUW | | | | | |
| 14 | Claim shows evidence of knowing signs of weather | IKUW | LIKUW | | | | | |
| 15a | Can make further claims about weather predictions | IKUW | LIKUW | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| b | Further claim of weather prediction given | IKUW | LIKUW | | | | | |

Key:

Religion (relig); Culture (cul); Books (bks); Media (med); School (sch) and other-specify (o-sp)

PSU-Practical scientific understanding; TSU -Theoretical scientific understanding

UIKP-Understands indigenous knowledge perceptions

LUIKP-Lacks understanding of indigenous knowledge perceptions

DSR-displays scientific reasoning, LSR-lacks scientific reasoning

IKUW-indigenous knowledge understanding of weather and LIKUW denotes lacks indigenous knowledge understanding of weather.

**Part D: Argumentation as a teaching strategy**

Participants were required to respond to questions concerning their familiarity i.e. practical or theoretical experience with argumentation. The table 3.4 below illustrates what questions required.

*Table 3.4:* ***Perceptions about argumentation as a teaching strategy***

| Item | Question seeking to understand if; | PUA | TUA | NFA |
|---|---|---|---|---|
| 1 | Can make a statement about argumentation | | X | |
| 2a | Can provide further data about claim | X | | |
| b | Can rebut or support argumentation as a strategy | | X | |
| 3a | Claims to have used argumentation | | X | |
| b | Provides evidence for claim | X | | |
| 4a | Provided further evidence for above claim | X | | |
| b | Is conversant with challenges/success | | X | |

Key: PUA-practical understanding of argumentation teaching strategy; TUA stands for theoretical understanding of argumentation; NFA-means not familiar with argumentation

**Part E**: Spatial modelling and teaching/learning.

Table 3.5: ***Conceptions of spatial modelling***

| Item | Item seeking to understand | PUSM | TUSM | DFSM | LFSM |
|---|---|---|---|---|---|
| 1a | Participant made a claim | X | X | | |
| b | Participant provided data | X | X | X | |
| 2 | Participant made a claim about SM | | X | | |
| 3a | Participant is able to give further data | X | X | | |
| 3b | Data provided | | X | | |
| 4 | Evidence provided | | X | | |

| | | | | | |
|---|---|---|---|---|---|
| 5a | Provided further evidence to support claim | | X | | |
| b | More evidence to support claim | | X | | |
| 6a | Can make claim about choice of teaching strategy | | X | | |
| b | Supports claim with reasons | | X | | X |
| 7a | Shows equipollency in use of SM | | X | X | |
| 7b | Provides evidence to support claim | X | X | X | |
| 8a | Makes a claim on use of 3Ds in a lesson | X | X | X | |
| b | Provided evidence to support claim | X | X | X | |
| 9 | Has Provided data on SM uses in science lessons | | X | | |

Key: **PUSM**-practical understanding of spatial modelling (SM); TUSM-theoretical understanding of spatial modelling; DFSM-displays familiarity in spatial modelling, LFSM-lacks familiarity in spatial modelling

Similar to earlier parts this section required participants to state their perceptions about SM with regards to the earth in space conceptions. Most of the questions were open ended needing participants to state their views with regards to earth in space conceptions.

This questionnaire was administered at the first contact with pre-service teachers and also at the end of the 8th week intervention period.

#### *3.3.1.2 The reflection assignment/s*



Two assignments were given on the 2nd week of contact and the last one was at the 7th week. Pre-service teachers were required to reflect on how they viewed their roles as future teachers and what makes different if so from other subject teachers. Reflections had to be in the form of assignments because the intervention also formed part of their module.

#### *3.3.1.3 The learners' alternative conception assignment*

This assignment entailed participants assessing learners' responses with regards to the earth in space conceptions. They were to identify the misconceptions as presented in answers from learners. After identifying misconceptions pre-service teachers were to suggest how to help the learners with misconceptions. This included suggesting teaching strategies to use.

#### *3.3.1.4 The audio recordings*

These were recordings of dialogue which happened in argumentation. The participants were divided into two groups whereby a civil law suit took place. This was based on the residence against the South Durban Petrochemical Industries for polluting the environment with sulphur dioxide. Residence took these industries to court so as to force them to reduce the amount of sulphur dioxide in the atmosphere. So there were two groups, one representing industry and the other of representatives of residence with their lawyers. The dialogue was to be assessed in terms of contiguity argumentation theory (CAT). Participants were encouraged to appoint a secretary who wrote down the main points as contingency in case the recordings were inaudible. Samples of this data will be appended.

#### *3.3.1.5 The solar system models group presentations*

Pre-service teachers were given a project to design solar system models in groups of 4 to 5 participants. In their presentations of the models, they would highlight the rationale for the choice of model and its purpose. This project was given in the first week of the intervention. All this data forms part of the collected data. See appendix 11for details of project instructions and the projects made by prospective teachers following the instructions.

## 3.4 Validity and reliability

Validity and reliability are important facets in research. They measure the suitability and trustworthiness of a piece of research.



Validity is therefore defined as the extent to which an instrument measures and performs what it is intended to measure and to achieve. It also involves among other things the appropriateness of the instruments. On the other hand, validation entails the processes a researcher engages from collecting data to its analysis (Biddix, 2009; Denzin & Lincoln, 2005).

There are three ways of validating research instruments, the face validity which refers to how relevant a test is to a sample used in research. To achieve face validity, the research instruments I used were put under scrutiny by subject specialists in the area. This entailed me sending my instrument to members of SIKSP for them to check whether it was up to standard. The process involved a to and fro, flow of suggestions and adaptations from group members which I made. The SIKSP members were checking among others, the construct validity of the instrument. This refers to whether the same construct could be used to make inferences on similar cases. Mainly the SIKSP members were concerned with content validity. Content validity refers to the relevance of the content to the sample and topic under study (Denzin & Lincoln 2005). However, there are some qualitative researchers who view reality as unique to individuals. Therefore, they put emphasis on trustworthiness in research by using triangulation (Lincoln & Guba, 1985). Triangulation entails the use of different tools for data collection. For example, in this research triangulation was achieved by use of the earth in space questionnaire, the reflection assignments, learners' alternative perception exercise, audio recordings and focus group interviews. Denzin & Lincoln (2005) argue that triangulation brings out meanings as well as different views by which different people perceive phenomenon.

**How instrument reliability was observed in this research**

In this research I had to design most of my own instruments so that they could answer to my research questions. However, Part B; the Assumptions about science and IK questions 1 to 5, were adapted from the science and indigenous knowledge systems questionnaire (SIKSQ) from the Science and indigenous systems Project (SIKSP). Apart from that, all the other parts C, D and E were set by this researcher.

In designing the questionnaire, there were many movements of questionnaire from the specialist researchers. When it was finally deemed ready, the same questionnaire was emailed to four scholars to rate it from 5 to 1. 5 represented very good, while items rated1 and 2 were removed. In the end, part B had 9 items, part C had 24 items, part D-7 items and part E had 10 items. All in all, the questionnaire had 50 items in the end.



**Trustworthiness**

In qualitative research projects, the issues of trustworthiness is achieved by making sure the findings are credible, transferrable, dependable and confirmable (Linclon & Guba, 1985; Shenton, 2004). As mentioned in the paragraphs above, these characteristics were made possible through the use of multiple methods of data collection. The researcher also shared the research problem with seasoned academics in the SIKS Project. In doing so this lead to objectivity since the researcher got input from non participants. The sharing also inspired some prospective post graduate teachers to design their own teaching and learning models. This was focused at trying to understand learning using world view theories.

### 3.5 Ethical issues

Cohen, Manion & Morrison (2007) insist on researchers' insurance in protecting sensitive personal information of respondents in collecting data. As such, a researcher is compelled to inform participants about their rights to privacy and to participate. In this study, I also took heed and informed participants beforehand about my study, their rights as participants and how I was going to maintain their anonymity by use of codes. In this research, the participants who were the undergraduate pre-service science teachers signed consent forms after the researcher addressed them about ethical issues. Contingencies such as the use of coding were to be used to protect participants' identities. However, the study was part of their module in the Methods of general science which made it mandatory for them to participate, but still they had options of not consenting if they did not want to be part of the study. Thus 2 out of the 17 pre-service teachers only wrote one test and decided not to do the other. All the 17 participants signed consent forms including the 2 of them who were absent on days of writing pre and post tests.

The participants' rights, values and beliefs as well as their identities were to be respected and protected through coding. As mentioned earlier on, all the participants participated in the intervention because it was part of their course and the intervention happened during their scheduled timetable, therefore, the intervention was in a modular form.



However, though there is emphasis on the protection of rights and values of participants Creswell (2007) and Cohen et al. (2007, p. 318) attribute the success of a questionnaire to the co-operation and understanding reached between the researcher and participants when consenting. With this in mind, the researcher discussed with participants and informed them of the following rights:

- Rights to withdraw at any stage of research and not to complete aspects of the questionnaire if they feel it is too invasive.
- To the fact that the information they provide will not be used to harm them.

The researcher discussed beforehand about how they would benefit by participating in the research. Therefore, the use of pseudonyms was adopted as a measure to ascertain them of confidentiality, anonymity and non-traceability in the research by in order to protect their identities and beliefs. With these measures in place, it was envisaged that participants would feel free to express their views without being coerced or judged by the researcher.

### 3.6 Data collection

#### 3.6.1 Introduction

The process of collecting data was done over a period of eight weeks. The first and last week were reserved for writing of pre and post-test questionnaires.

**The 1st introductory meeting- prior to commencing the study**

The 1st meeting took place on the 12th of August and it was a 30 minute meeting just to debrief the group about myself and the project I was undertaking. The pre-service teachers were given ample time to ask any questions and concerns which they had. They also introduced themselves to me as I also did the same.

**The Pre-Post test questionnaire**

The researcher addressed the participants about consenting and importance of signing consent forms. Pre-service teachers were allayed about fears that signing of consent forms did not mean their right would be violated. After that participants signed consent forms and they answered the pre-test questionnaire. Most of the questions were open ended questions meaning pre-service teachers had to answer according to their understanding. A few questions e.g. Part B, questions 1-5, had agree, strongly disagree type of questions. One participant was absent on that day, and I excluded him in the study since there was no communication given regarding his absence.

The questionnaire had 5 sections altogether numbered from parts A-E. Part A was for biographical information of participants, Part B, Assumptions about science and IK, Part C, the earth and its biosphere, Part D, Argumentation as teaching strategy and Part E, Spatial modelling and teaching and learning. See Appendix 2 for details of what the questionnaire entailed. For the scoring of participants' responses to the questionnaire, I refer you to the whole of part 3.3.1.1

#### 3.6.2 The intervention

As mentioned in the introduction above, the actual intervention was done over a period of six weeks. I met the group every Monday for two and half hours once a week from the 26th of August to the 7th of October for a total of 20hrs. The 14th of October was for writing of the post-test. The

Intervention module was prepared and given to a specialist in the area of study to scrutinise and validate beforehand. Cohen et al. (2007) opine for a lengthy period of time to be spend on a project as one measure of ensuring validity and reliability of a qualitative research project. A total of 12hours was spent during the 6 weeks intervention period.

**Week 1**- 26 (2.5hrs) August-Intervention 1

The first meeting, was geared towards participants as prospective science and math teachers. Activities involved:

- Watching a 6 minute video entitled *"Miss Connie's last day,"* from "*A teacher affects eternity*" a maxim attributed to Henry Adam from; http://www.youtube.com/watch?v=AnQVDqlT48U.
- The 1st reflective assignment by participants about their perception about teaching science in particular.
- In groups look at the South African National Curriculum Statement (NCS) and the Curriculum and Assessment Policy Statement (CAPS). Focus on assessment and the earth and beyond strand from grades 4 to 8. Assigned to read Krathwohl's (2002). A revision of Bloom's Taxonomy: An overview. Group assignment is given out



**Week 2- 9th September**

- Introduction to models and modelling in science teaching and learning using available globes.
- Individual modelling of the earth's shape using newspapers and the Mercator maps.
- Presentations, peer assessments and discussions about model making including challenges
- Reflection on modelling activity

**Groups to read**

- Onerk (2008). Models in science education...
- Vosniadou & Brewer (1992). Mental models...
- Sneider & Ohadi (1998). Misconceptions about the earth's shape...

- Sanders (2006). What teachers should know...?

It must be noted that for validation and reliability of this part of the module, two experts validated the part. One of them even liked the concepts and trialled them on another group of post graduate prospective teachers.

**Week 3-16th September**

- Report back about literature read and discussions
- Alternative perceptions or alternative conceptions/misconceptions about the earth's structure.
- Discussions about good models based on Ur's (2001) characteristics of a good model.
- More information about group models and how to present them
- An exercise about learners' alternative perceptions given for individuals to assess and suggest teaching methods to help learners who present alternative conceptions.

**Week 4- 23th September**

- Introduction to the nature of science and indigenous knowledge (NOSAIK) from the NOS and NOIK module (Ogunniyi, 2008).
- Introduction to argumentation, both the TAP and CAT and how the two theories work.
- Sharing with participants who already used argumentation in their teaching as revealed in pre-test questionnaire results. Most of them expressed the challenges of learners' tendencies of being confrontational which made them quite cautious about the use of argumentation as a teaching strategy.
- Introduction to the spatial modelling in argumentation model (SMAM).The construct of this model is underpinned by worldview theories. See figure 3 for the SMAM model.

For validity and reliability, the course module was sent to an expert who verified and gave a go ahead of the content. Also of importance is the fact that the NOSAIK was taken from modules 1 and 2 of NOS modules. These are being used for training pre-service and in-service teachers at a teacher training institution.

**Week 5-30th September (2.5hrs)**

Dialogical argumentation: The South Durban Community against the Petrochemical companies. The part used for argumentation purposes was ranked by 4 experts. The excerpt use was ranked with the questionnaire and got a ranking of between 4 and 5. 5 meant very good and 4 was good.

This is based on real life scenarios which are affecting the communities around the South Durban industrial hub in South Africa which has 120 industries. Human settlements were built in close proximity to the industrial hub to provide cheap labour force as well as cutting down on transport costs of the workers.

This topic was seen as vital because all over the world the environmental effects of industrial development and technology has been concentrating on maximising profits without really considering the effects on the environment at large. This exposed participants to being environmental stewards who look beyond the socio- economic benefits but also consider values and morals in the science, industry and technology development.

The participants were divided into two groups; group 1 was made up of South Durban communities who were exposed to unsafe environment due to pollution of the atmosphere by sulphur dioxide. The communities were suing the petrochemical industries for justice against the pollution which has ruined the health of many. Group two, consisted of the industrialists who are the respondents as well.



**Individual activity**: (10 minutes) familiarising with the caption about the Petrochemical pollution in the Durban South and writing grievances.

This culminates into peer assessment and a discussion of the exercise by whole class.

Participants go into two groups, 5 were the industry representatives and their lawyer/s and 11 were residents' representatives and their lawyer/s. 1 participant is chosen to be the judge. Participants had to choose a secretary to jot their important points and also some people from the group as witnesses, including their lawyer.

**Group 1**

It consisted of the South Durban residents' association members and lawyers representing them. They were suing major companies that included 'Petroden' a [pseudonym] and others for environmental pollution. The community representatives with their lawyer wanted Petroden and its associates to commit to reducing the levels of sulphur dioxide emissions released into the atmosphere. They also listed subsequent challenges which included diseases caused by the dirty air that they are exposed to daily causing increases in asthma sufferers, many complaints of people with chest pains, and cancers. They wanted an increase in the medical health insurance contributions by the companies to employees and reduction in sulphur dioxide emissions.

**1$^{st}$ member's claim:** *I was recently diagnosed with asthma due to polluted air which is poisoning me and my community. In my family there is no history of asthma. It only started when I came to Durban to work.*

**Evidence given**: No history of asthma in his family; diagnosed with asthma after finding work in Durban.

**2$^{nd}$ member's claim:** *My children had breathing problems from infancy which get worse in winter and this is due to pollution which is rampant in this environment.*



**Evidence**: She backed her claim by citing a report done by the Health Protection Agency on sulphur dioxide which attributes the aforesaid problems to exposure (HPA, 2010). This acted as warrants.

**3$^{rd}$ member**: *I was diagnosed with emphysema. I do not smoke and all my family members do not smoke.*

**Group 2**

**Respondents:** It consisted of major companies' representatives namely 'Petroden' and their lawyers.

**Their counter-claims [Company's spokesperson] were:** *Our companies are providing employment and cheap accommodation to the surrounding communities in Durban. In order for business to be viable, we need to grow industry through producing more. We demand you the community to applaud us for our contribution to this area.*

Secondly, *there is no adequate proof that our industries are polluting the environment, the problem is that the employees are bringing all their clans to live in the houses which they provide for next to nothing which causes overcrowding.*

*Thirdly we are also paying high medical costs for you employees and your families, which many companies do not do...*

This led to argumentation which was based on present-day issues about industrial development and pollution in comparison to human settlement and the environment.

### 3.6.3 Discussion of argumentation activity

The two groups forwarded their grievances through their lawyers or do so as witnesses to claims made. After that, the respondents Petroden would argue against or seek clarification.

The two groups would regroup, discuss again the arguments put forward to them and engage again. Using Dialogical argumentation framework i.e. the Toulmin's (1958) argumentation pattern TAP and Ogunniyi's (2004) contiguity theory (CAT) were used to analyse the dialogue. However, for the purpose discussing argumentation discourse in the study, Osborne et al.'s (2004) analytical framework for scientific argumentation was adopted. This framework has 5 levels. See figure 4 below in the appendix.

- Level 1=claim + counter claim or claim + claim {C+CC, or C+C}
- Level 2=claim + data + warrants [backing], {C+D+W(R)
- Level 3= claim/counter claim + data, warrants or backing + a rebuttal (a weak)
- Level 4= a claim and strong rebuttal [may have several counter claims]
- Level 5= higher argumentation than level 4, with more than one rebuttal



These will be used in analysing the argument discourse.

## 3.7 Data Analysis

Samples of selected data from various activities done by participants will be analysed to answer the research questions. Data was categorised into patterns found in participants' responses and dialogues before and after the intervention to determine the trends and patterns of growth or no growth. For example, Part B questions 1-5 with ordinal data; namely, questions 1 and 2 were reverse coded. This meant that when a respondent SA or A, with the statements, s/he assumed that science and IK were very different. See appendix 12 for the results obtained from the assumptions about science and IK, Part B questions 1-5.

For Parts C, D and E, Atlas.ti was used to classify participants' raw data into identifiable patterns. The researcher then used the tables 3.3; 3.4 and table 3.5 discussed earlier on. These tables were used to get statistical figures. Statistical figures were generated from patterns identified through Analysis using Atlas ti. Atlas ti was chosen over other methods because of the nature of my research which was mostly qualitative. The codes

TAP and CAT were used as frameworks to describe the extent to which participants could express their views about earth in space and teaching. A framework by Osborne et al.'s (2004) dialogical argumentation analysis was used in analysing data. It must be mentioned that there are many other researchers who drew analytical frameworks before the one by Osborne et al. Ogunniyi's (2007a) contiguity argumentation Theory (CAT) was also used for tracking the participants' discourse from before and after the intervention. See figure 3.3, used for TAP in the appendix.

## 3.8 Challenges and remedies met in carrying out this research

The pilot study provided some insights into the actual study. For example, the problem of reluctance in doing assigned work was addressed in the actual study by assigning parts to individuals for presentation the following week. There was a perception that they were wasting time rather than doing real science. One participant actually said that she was bored because she was not doing real science but modelling like a child and reading articles. For example a participant was constantly complaining that she was doing geography which she avoided in high school. However, in the end she was quite grateful that she participated because she got an opportunity to engage with some parts of the curriculum. The following were put in place in order to motivate the participants:

- Brought in fruits which were eaten on breaks so the meetings were workshops (This was made possible because the researcher got funding from the NRF).
- Most readings were done in class and divided into small paragraphs per person so that they would share ideas
- Managing time was problematic at first but the researcher had to put measures in place such as time out and the group which would be legging behind lost points. This improved a lot resulting in keeping to the time on a task.

In the next chapter I am going to show and discuss the result

# Chapter 4

## Results and discussion

### 4.0 Introduction

In this chapter the emerging themes obtained from the qualitative results of pre- and post-test perceptions of pre-service Natural Science teachers, focus group interviews and reflections are presented. The emerging themes are discussed in reference to the existing literature.

### 4.1 Research Question 1

**What indigenous and scientific conceptions of the earth in space did the pre-service teachers hold before and after being exposed to an argumentation/spatial modelling?**

To answer this question the pre-service teachers' responses to questions 1-9 of NOS and NOIK questionnaire (see appendix 12 for raw data) from part B numbers 1 to 5. In both questions 1 and 5, part B, the rankings were reversed such that a strongly disagree (SD) response would be ranked 5 and a strongly agree (SA) was ranked 1. Questions 5, 6, 7, 8 and 9 from part C were also used. An analysis of the pre-post-test data on questions 1-5 reveals that 6 [40%] out of fifteen participants agreed that there are distinctive differences between the indigenous and scientific conceptions of earth in space.



In the post-test, however, only 1[7%] perceived them to be different and one participant did not answer the question. On the same notion 8[53%] disagreed whilst one was unsure in the pre- test. After the intervention 14[93%] participants disagreed and only one participant agreed in the post test. There was a shift of perceptions from participants after the intervention of which the number of participants who perceived IK and science to be distinctly different dropped by 27% from 40% at pre-test to 13% in post-test.

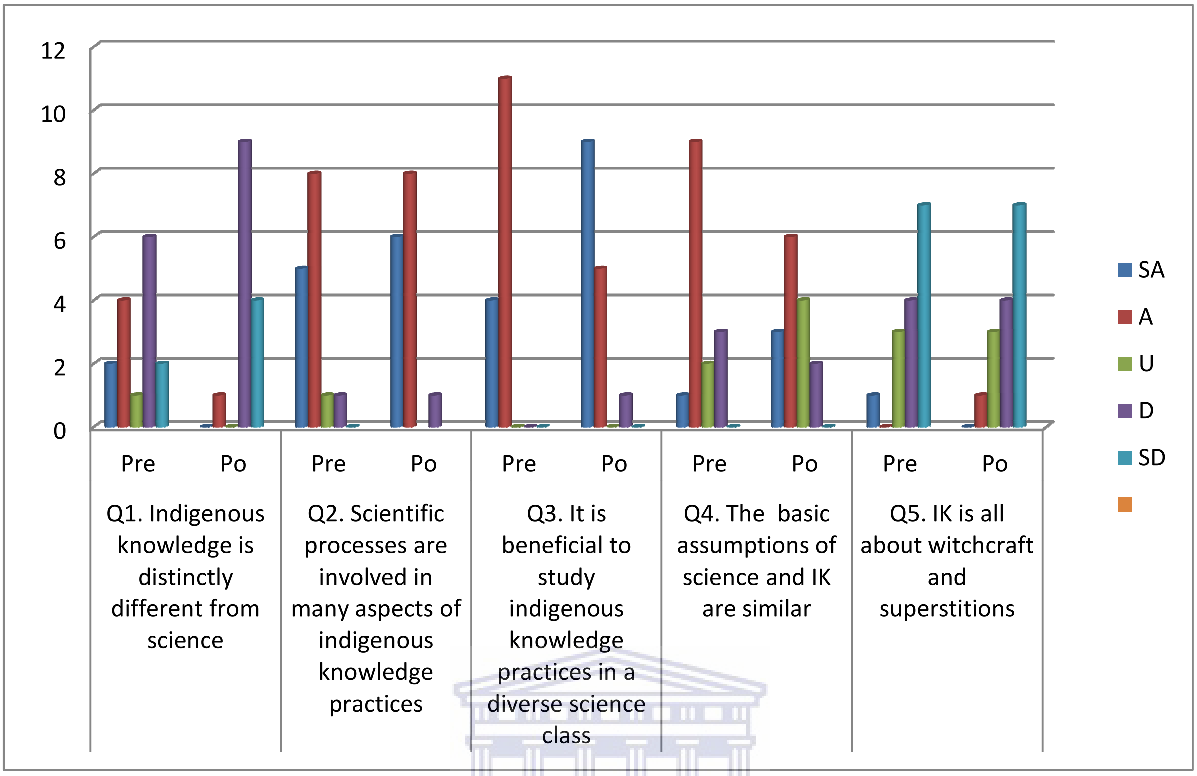


Figure 4.1 Pre-service teachers' indigenous and scientific conceptions about the earth in space

In the second statement 13/87% of the participants in the pre-test agreed with the assertion that scientific research is involved in studying many IK practices. Of the remaining two participants, one was uncertain and the other disagreed. In the post-test 14/93% of the participants viewed scientific processes as involved in most indigenous practices. Only one participant disagreed with the notion.

The assertion in statement 3 about benefits of including some IK practices in science lessons which have diverse learners yielded the following responses from participants- all fifteen in the pre- and 14[93%] in post-test agreed respectively, whilst one participant in the post test disagreed. The participant who disagreed about inclusion of IK in a diverse class is the same one who agreed that science and IK are distinctly different. This participant's perceptions are predominantly scientific on worldviews issues.

In statement 4, participants' responses were as follows; in the pre-test, the majority of the respondents, two fifths or 10/67% of them agreed in the pre-test. However 3[20%] disagreed and 2[13%] were undecided. In the post-test an overall of 9/15[60%] agreed and 4[27%] were undecided whilst two disagreed. There was a decrease in the number of participants who agreed by 7%, where 40% in total were either disagreeing or undecided. In statement 5, participants' views on the notion that IK is all about witchcraft and superstitions did not show any major changes between pre-test and post test results. The only shift was of one participant changing from agreeing strongly to agree in pre-post test respectively.

### 4.1.1 Discussion

The stance taken by the participants regarding science and IK was that the two worldviews have different epistemologies although they both interpret phenomena. The extant literature concerning the exposure of prospective and in-service teachers to history of science and nature of science courses is not conclusive. In other words it is not clear whether or not such courses influence teachers in their practice (Abd-El-Khalick & Lederman, 2000, Lederman, 1999). However, these findings do not rule out the importance of exposing prospective science teachers to such courses. It is argued that by exposing prospective teachers to NOS courses, their understanding of how scientific knowledge is acquired improves and this may also contribute towards the way they teach science positively (Brickhouse, 1990; Bryan & Atwater, 2002). Lederman (1992) infers that a teacher's conception about the nature of science affects the way s/he relates to learners. Also, despite the differences between science and IK there is a general consensus among scholars that the two worldviews are ultimately concerned with interpreting human experience with nature.



To get more insight pertaining to science and IK, some scenarios were created for prospective teachers' views using open ended questions. These were based on widely perceived notion of IK being laden with superstition and witchcraft of which the majority of participants had agreed to in question 5. The scenarios related to taboos and beliefs that lightning can be manipulated by certain people and used to harm others. The responses are from question 5 and 8 from part C of the questionnaire. Table 4.2 below shows some excerpts from some of the given responses. Results from question 5 in the pre-tests indicate a general view from participants that taboos and myths are good when used to protect the environment giving the view that some myths are good and some are bad. However, in the post-test responses two participants were of the view that myths and taboos are irrational hence referred to them as 'scare tactics' which need to be neutralized.

Concerning the belief that lightning can be manipulated by evil people who consult the 'Sangomas' *a Zulu name for a traditional healer/diviner or shaman* whose purpose is mainly to cure people of physical or spiritual illnesses. The belief that Sangomas are able to manipulate lightning so to strike people is wide spread in Africa. Many Africans believe that lightning strikes are a form of punishment of the victims. This belief is common in areas that are prone to thunder and lightning. According to the South African Weather Services, South Africa is ranked among the countries which experiences high incidences of lightning strikes. However, the Western Cape Province where this study took place has the least lightning incidents per year. This therefore means that perceptions about lightning would mostly be the scientifically agreed view. Question 6 in the table below shows some of the responses given. Liz dismisses any thought of manipulating a natural weather phenomenon such as lightning to cause bodily harm. She was born and grew up in the Western Cape in the urban area where lightning is a rear phenomenon. In contrast, to Ludwe who was born and grew up in the Eastern Cape Province in an area which is quite prone to lightning strikes. His perception was in agreement with the scientific conception of causes of lightning. However he does not rule out the view that lightning can be manipulated by certain people to cause harm. Two participants perceived lightning strikes on people as an act of God or as an unlucky occurrence to the victims. The excerpts in Table 4.1 below are representation:

**Table 4.1** Pre-service teachers' pre-post-test views about myths and lightning strikes



| **Scenario** | Participants' responses |
|---|---|
| **5.** A chief and elders are using taboos and myths to stop the hunting of pangolins by the community. | *Pre: The pangolins are creatures which need to be protected; they will not be hunted so they have an opportunity to reproduce before dying.*<br><br>*Post: Nature conservation practice, preventing hunting is a practice in modern science as well. Ray* |
| | *In the pre test, Joe- Ann said: I disagree. People will say dramatic things to scare people of even though it's not true.*<br><br>*Then in post test later said: I disagree; it is a scare tactic that has a quick effect on people.* |
| | *In pre test Mildred said: It cannot be judged that what they are experiencing is wrong since we do not live in their community and culture.*<br><br>*And later she said: Pangolins are rare so that might make them think they are* |

| | |
|---|---|
| | *near extinction* |
| **8.** In certain cultures people believe that lightning can be manipulated or used by sangomas to strike others. What are your views about causes of lightning strikes? | *In pre test Liz said: Lightning strikes are natural phenomena. I don't believe in the whole sangoma thing or that it can be manipulated. It is a natural occurrence and there is a scientific explanation for it.*<br><br>*Post: Lightning is an act of nature. Doesn't matter what people believe, it has a scientific explanation.* |
| | *Ludwe's response: Firstly, the lightning is an independent factor, base on my understanding lightning is cause by the heat reaction, or heat friction, and its depends [it depends] on the force or energy that took place there.*<br><br>*Post test: My views are that lightning is independent factor and it depends on the charges of electricity based on scientific textbooks but in beliefs that it is because of sangomas.* |

The responses in Table 4.1 suggest that the participants are aware that some myths and taboos which are synonymous with IK practices are good especially those which are aimed at conserving nature and also some are bad. In the same vein they agree that science and technological development have good and bad effects on both humans and the environment. The extant literature has attested to the fact that many indigenous communities do possess a commendable knowledge about the management of their local environment as well as knowledge of herbal medicine (DOE, 2002; DST, 2004; Ogunniyi, 2004, 2007a & b, 2008). However, from an outsider's viewpoint, some IK practices may not make sense since IK tends to be very contextual in nature, apprentice-based and not well documented (Aikenhead, 2001, van Wyk, 2011).

Myths and taboos form part and parcel of traditional culture and practices especially in connection with the management and conservation of the biosphere. The traditional leaders and elders are the enforcers of the norms (Agrawal, 1995, Chingwenya & Mutasa 2007). In general, most of the participants in this study who answered questions 5 and 8 perceived some myths to be good and some to be bad. Those who view such myths as bad tend to compare what they deem as the irrational aspects of such myths with logical and rational nature of science. My own view is that indigenous knowledge practices concerning interpreting of nature should be viewed in that context and not be measured with scientific lenses. It must be borne in mind that indigenous knowledge practices are specific to a community as a result of the observation and interactions between that community and the environment (Bisht & Sharma, 2010). In comparison scientific knowledge is documented and a result of studying nature in patterns that are agreed upon thereby making it universal.

However, it is apposite to state that myths in many an indigenous community often play important symbolic roles which cannot easily be adequately understood or appreciated simply by using a logical or scientific yardstick so to speak. For instance, environmental conservation has been successfully managed over time by the indigenous communities because of the attached mythical or symbols referents e.g. the sacred trees, forests, rivers, mountains and other biotic reserves which must not be burnt or used for recreational or hunting purposes.

Furthermore, for scientific knowledge to be accessed by all learners, the literature also underscores the need for teachers to gain some knowledge of the cultural beliefs and practices of learner groups in their classes so that they can relate to each other at personal levels into more activity based science interactions (Bruna, Chamberlin, Lewis, et al., 2007). To a certain level conceptions which participants hold pertaining to science and IK practices can determine their choice of teaching strategies in science to a certain level (Lederman, 1992 & 1999).



### 4.1.2 Perceptions about science-IK infusion

The perceptions of participants with regards to integrating science and indigenous knowledge in general and with reference to the earth in space conceptions were solicited from questions 6 to 9 in pre and post open ended questions.

Using Atlas Ti to find the patterns in the responses of participants, Table 4.2 below shows the themes emerging from participants' conceptions about Science-IK infusion. 14/15 [93%] pre-test stated that an integrated science-IK curriculum contextualizes scientific concepts leading to understanding science knowledge. 1[7%] participant saw no reason in teaching science using IK since in her view it is phasing away. In the post-test, all 15(100) participants stated various reasons why they think an integrated curriculum would benefit the learning of science. Although the majority of the participants viewed science and IK integration as beneficial, the majority of pre-service teachers in the study argued that IK was not easily accessible. They also indicated the difficulties of how to teach using two worldviews which use different epistemologies.

**Table 4.2** Assumptions about science and IK

| | Six Arguments for integration of science and IK | Pre- | TAP | Post | TAP |
|---|---|---|---|---|---|
| | | test | CAT | test | CAT |
| Yes | SISIK - but had no valid reasons for claim | 13% | 0 | 13% | 0 |
| Yes | SISIK - with a reason-appreciation of culture | 33% | 1 | 33% | 1 |
| Yes | SISIK-will give the learners an investigative attitude towards science | 7% | 3 | 40% | 2 |
| Yes | SISIK-with claims and counter claims | 33% | 2 | 13% | 3 |
| | NISIK-IK outdated, OBE-downgraded education | 13% | 2 | | |
| | **Seven Perceived limitations in integrating science and IK** | | | | |
| | NISIK with insight of challenges | 33% | 0 | 13% | 0 |
| | NISIK insight to challenges and claims | 40% | 1 | 40% | 1 |
| | NISIK , identifies challenges and counter-claim | 20% | 2 | 33% | 2 |
| | SISIK, with both SO and IKO | 7% | 3 | 13% | 3 |
| | **Eight Perceived advantages of integrating science and IK** | | | | |
| | SISIK | 27% | 0 | 20% | 0 |
| | SISIK | 13% | 1 | 47% | 1 |
| | SISIK | 53% | 2 | 20% | 2 |
| | SISIK | 7% | 3 | 13% | 3 |
| | | | | | |
| | **Nine Perceived challenges regarding bringing Indigenous astronomy into science** | | | | |
| | | **Pre-test** | | Post test | |
| | Prejudice of teachers and some learners about IK | 13% | 0 | 20% | 0 |
| | IAP of learners do not link with scientific ones | 13% | 1 | 0% | 0 |
| | Teachers lack IA knowledge enough to teach it | 27% | 1 | 13% | 1 |
| | Difference in epistemology makes it difficult to integrate | 20% | 2 | 40% | 2 |
| | Fear of creating controversies between science and IK | 13% | 1 | 0% | 0 |
| | No answer | 7% | 0 | 7% | 0 |
| | No challenges foreseen | 7% | 0 | 20% | 0 |

**N=15**

***Key:*** For the acronyms used: **SO**- scientific orientation; **IKO**-shows indigenous knowledge orientation; **SISIK**-supports integration of science and IK and **NISIK** stands for No integration of science and indigenous knowledge. CAT- stands for the contiguity argumentation theory

### 4.1.3 Discussion on the pre-service teachers' views about a science and IK integrated curriculum

To interrogate pre-service further, they were asked about their views about integrating science and IK within the school science curriculum. Table 4.2 above shows the results from qualitative data from pre-post-test arguments. 13% of pre-service teachers oppose the infusion of science with IK.

Tahini argued that "*IK is in my opinion phasing out and therefore I don't see the need, however teachers should not discourge [discard] IK*." Tahini in the assumptions agreed that IK was all about myths and witchcraft but then in the post test strongly disagreed. On the other hand, Ludwe who had strongly disagreed that IK was all about myths before the intervention became unsure in the post-test. His response to the question on integration does not seem to answer the question. He argued against the introduction of OBE into South African education. His argument about the OBE has got nothing to do with introduction of IK into school science, therefore making his argument out of context. This is so, because the OBE was abandoned by the Department of basic Education (DBE) for the current curriculum, the NCS (DBE, 2004). It has been noted that most of the participants were stating unsupported claims as shown in table 4.2 above. Also to note is the use of the phrase '**where possible**' implying that participants were aware that integration is not possible in all science concepts. Below are some of the participants' claims with counter claims about science and IK emanating from open ended questions 6 and 8;

Question 6 Ashar: Pre; *I think this is a brilliant idea, the learners would study knowledge that have come with them for so long already, and it is great to know where you come from. This will give the learners an investigative attitude towards science, seen that science is a very boring subject and that they can actually relate to it in this matter.*

Post***;*** *I think it is an excellent idea integrating science with IK. This will make learners appreciate where science come from. And they will see the world in a different light.*

**Question 8** Aadam*:* Pre; *When learners can relate to issues in the classroom then they find it easier to learn and understand. If we use IK in our teaching strategies we as teachers can have a* *higher success rate when it comes to he [the] learners understanding new theories and topics.* Post; *Learners will know that they need science on a daily basis as they link it with their ways of life*.

To sum up participants highlighted many views about what they thought science and IK integration would benefit from each other. Some of their views include appreciation of one's culture and feeling of worthiness. Science-IK integration was also presumed to lead to contextualisation of learning which translates to meaningful learning and interest in scientific research using indigenous practices. These arguments support claims by many worldview theorists. They advocate for multicultural science approaches in school science with a view that every culture has its own science (Aikenhead, 2001, Ogawa, 2002). Science scholars further argue that the nature of school science is too foreign and riddled with a lot of difficult language instead of being in contexts familiar to learners (Brickhouse, 1990; Bryan & Atwater, 2002; Abd-El-Khalick & Ledderman, 2000).

The pre-service teachers were also aware of the challenges which an infused curriculum presents to their teaching practice. Though great success stories have come out of Canada, Australia, and New Zealand, in the South African school context, an integrated science-IK curriculum is still in the pipeline (Botha, 2011; Odora-Hoppers, 2004; Ogunniyi, 2008). The perceived challenges include some of the highlighted ones below by Ray and Liz. These include the fear of being isolated from the global technological race to isolation of some learners and then the notion that IK ontology cannot qualify as science, then other scholars argue that indigenous knowledge systems (IKS) of which IK is part should be studied on its own merit (Dei, 2000; Hountondji, 2002; Shava, 2013).

Ray*:* Pre; *Limitations include the educator not having specific knowledge of all the cultures to which learners belong as well as a difference in opinion could cause conflict within the class resulting in a disorderly class which would not promote learning.*

Post***;*** *The class could have conflicting views and this could cause problems should the discussion not be guided appropriately.*

*Rafidah: One of these limitations is that educators are prejudice when it comes to ingenious knowledge and the lack of understanding of the subject.*

*Post: It may create some conflict in the learners' beliefs or views but the teacher should not disregard their beliefs on a certain topic/ concept but portray science as a fact however use science to create a different paradigm*

Other challenges perceived by the pre-service teachers as deterrents in adopting an integrated science-IK teaching strategy included prejudice from teachers and other learners of IK cited by Rafidah and Aadam. The other challenge from Ludwe, Farizah, and Ashar's perceptions were about how to link IK to flow with specific topics in science within the allocated lessons durations. Two participants did not see any challenge pertaining to teaching the earth in space from learners' prior knowledge and 1 participant did not answer question 9. Consistent with the participants' views, (Horsthemke, 2008, Banks, 1999) amongst other researchers on science education opine for a revamp in school science curriculum so that it becomes more interactive and contextualised, similar to how scientists go about discovering how phenomena works.

### 4.1.4 Some emerging themes from the Earth in Space questionnaire

**Table 4.3** Themes from questionnaire data

| Question assessing | Emerging trends drawn from raw data |
|---|---|
| Part C<br>1a. Prior beliefs about causes of day & night | ✓ Prior conceptions are derived from observation of phenomena,<br>✓ They are also culturally or religiously acquired (47%).<br>✓ Observing perceptions does not involve sophisticated technology but accompanied by myths.<br>✓ Prior conceptions form mental models, thus they are difficult to model |
| 1c. Scientific explanation of causes of day and night | ✓ These are acquired mainly through school, media and books, 67% responses<br>✓ Scientific explanation can be represented as conceptual models.<br>✓ Scientific conceptions can be tested and modelled. |
| Part E<br>1. Best methods to illustrate earth's structure | ✓ Scientific methods: 3D models, videos, the internet and or diagrams showing relative distances.<br>✓ Books for high school learners. |
| Benefits of describing the earth's structure using 3D models(spatial | ✓ Better understanding leading to long-term cognition<br>✓ Ray said, "*Kinaesthetic learners learn better and visual* |

| | |
|---|---|
| modelling) | *learners learn better*."<br>✓ Visual and activity based leading to better understanding |
| Part B<br>9. Perceptions about integrated science-IK to teach the earth's structure | ✓ Difficult to integrate the two due to different belief systems<br>✓ Scientific astronomy is too advanced/abstract because it uses technology to probe into space<br>✓ Integration may cause controversy if the teacher is not well informed in both worldviews.<br>✓ The two can be integrated- 2/13% (No clarification) |
| Part C<br>4a. Explanations to answer claims that:<br>1.The earth is a sphere and it is always revolving<br>2. How come we don't fall off a spinning and orbiting earth? | ✓ Using a model to demonstrate-7%<br>✓ Use an example of a ship approaching the harbour and explain how it is viewed from far until it gets near<br>✓ Explain using seasonal changes to prove that the earth spins<br>✓ Giving examples of travelling by car, bus, train or plain and how one does not feel the movement when travelling smoothly 13% responses.<br>✓ By use of Newton's laws of gravity-80% responses |
| Part D<br>Advantages of discussing a difficult issue with others | ✓ Argumentation allows communication of personal views<br>✓ It provides opportunities for different views to be aired<br>✓ Provides opportunities to become rational thinkers<br>✓ Creates cognitive conflict leading to adjustment of schemes of thought and recreation of new ideas-learning. |



**N=15**

**Discussion**

Table 4.3 above shows some emerging themes which were drawn from the Earth in space questionnaire using Atlas ti. The results from open ended questionnaires on conceptions of the earth in space are discussed below. In Question 1, pre-service teachers pre-school beliefs about causes of day and night, the results had five of the participants stating that they believed God or Allah or the Divine Creator caused day and night to happen. Seven of the participants' beliefs were influenced by their interaction with phenomena, their beliefs about the causes of day and night were perceived as experienced. This is to say that they interpreted the causes of day and night according to what they saw. That is the sun being visible during the day and the moon being visible during the night, or the sun going down ‘because it wants to rest’ or the sun ‘hiding behind the mountains.’ However, only two participants believed that day and night where somehow caused by the earth’s rotation. Their beliefs were influenced by their families, culture, their daily experiences with phenomena or based on religion. This brings in the importance of perception or prior perception with regards to science teaching.  Whether a teacher recognises the prior knowledge of learners or not in a science lesson may in a way contribute to the learners’ understanding of the concept being taught, bearing in mind that children will be having their own perceptions of the concept as discussed in question one (Lederman, 2000).

The disclosures above are consistent with results from other studies done about children’s pre-school beliefs about the causes of day and night (Lemmer et al., 2003, Trumper, 2000, Troadec, et al., 2009, Vosniadou & Brewer, 1994). Their findings show that most pre-school children have naive beliefs about how day and night happens. The beliefs are experientially interpreted as such the sun is perceived to also get tired and to need rest in the same way humans behave. Then a belief in divine creation as perceived by other five participants as reasons for the day and night phenomenon is not conclusive because it depends on personal faith of which is out of the realm of science. These kinds of beliefs are referred to as organismic. This entails the nature of an entity as perceived by ancient Greek philosophers namely Aristotle where by the world is perceived to have characteristics of an organism (Jaki, 1992, Schaefer, 2010).  On the contrary two participants thought that the earth rotates ‘somehow’ causing day and night. Their view though scientifically correct was not supported with evidence. These views are synonymous with the stages of cognitive development of children and how they perceive the world around them as proposed by Jean Piaget.



Part C: Emerging trends from the participants are that prior knowledge was acquired through either social interaction with environment itself, social cultural and religiously acquired. For these some participants perceive the integration of indigenous astronomy with scientific astronomy may offend learners with strong cultural/religious beliefs. Their sentiments are valid but it also depends upon the method used to bring out these different world views.

The patterns further reveal that the conceptions about the earth in space differ greatly between science and IK. These differences were attributed to the differences in the way knowledge is acquired. In indigenous astronomy, people observe phenomena using their eyes and making links with their environment.

In contrast scientific astronomy use advanced technology to probe beyond the eye's rich (Troadec, 2009). Due to these differences, teachers who are aware should adopt teaching strategies which allow engagements, so that learners can interact with scientific data. In doing so, learners are accorded chances to link what they know with new knowledge. Furthermore, participants view argumentation as one such strategy which may help in achieving cognitive adjustments when it comes to different worldviews if handled well.

### 4.1.5 Summary

In conclusion it seems safe to state that the pre-service teachers construe the indigenous and scientific views about the earth in space as being distinctly different worldviews. They regard science as being well documented and easily accessible while they regard IK as being local and only accessible at a local level orally and in practice. This finding is not surprising considering the impact of colonial western science on the education system. It must be realised that right from the elementary school these pre-service teachers have been told again and again that the IK that shape their worldview is no more than a bunch of superstitions or worse still, a form of witchcraft (Ogunniyi, 1988, 2004, 2007a & b; 2013). Therefore, in order to infuse science and IK in a meaningful way, there is need for the teacher training institutions to take leading roles in equipping teachers with pre-requisite knowledge. This might also mean, schools working together with knowledge holders who are usually elders in the communities as specialists in IK. Participants were aware of the differences between science and IK.

## 4.2 Research Question 2

**To what extent did spatial modelling and dialogical argumentation instructional model enhance the pre-service teachers' conceptions of the earth in space?**

### 4.2.0 Introduction

There are some emerging themes coming through from parts C, D and E of the earth in space questionnaire [i.e. the earth and the biosphere, argumentation as a teaching strategy and spatial modelling and teaching/learning] respectively. From part C the earth and the biosphere, pre-service teachers' perceptions about the earth's shape are discussed. Part D- Argumentation as a teaching strategy presents pre-service teachers' perceptions about the use of argumentation before and after the intervention. Lastly, from part E- spatial modelling and teaching and learning, the participants' perceptions are discussed using data from pre- and post-test results. Below is the presentation of data followed by discussions. [Also refer to appendix 2 for the earth in space questionnaire and respective parts of it].

### 4.2.1 Emerging themes from the pre-service teachers' pre-post-test perceptions about the earth's shape (Part C)

**Table 4.4 Emerging themes from the pre-service teachers' pre-post-test perceptions about the earth's shape**

| Item | Question seeking | Emerging themes | Pre test | Post test |
|---|---|---|---|---|
| 1 | Beliefs about the earth's shape | It is round/spherical as stated by scientists in books | 14 | 12 |
| | | The proof of spherical earth is evidenced by horizon and ship approaching harbour | 0 | 2 |
| 2 | Sources of belief about earth's shape | Media, school, books | 13 | 11 |
| | | Family, religion, culture | 2 | 4 |
| 3 | Best teaching aid to explain to a primary school learner about the spherical earth concept | Using models, videos, the internet | 8 | 14 |
| | | Diagrams showing relative sizes of the earth and sun | 6 | 1 |
| 3b | Perceptions about rotation and revolution | Simple book explanations | 11 | 10 |
| | | Substantiated with warrants | 4 | 5 |
| 4 | How to contextualise the explanation | Use observable explanation e.g. a | 1 | 3 |

| | | | | |
|---|---|---|---|---|
| | about rotation and gravitational pull concept | ship approaching harbor, models | | |
| | | Using Newton's laws, internet, | 14 | 12 |

**Discussion**

Table 4.4 above shows the summarised results of the themes that were extracted from the participants' pre-post conceptions about the shape of the earth (refer also to Appendix 6 for detailed themes). The first item was about perceptions held by the pre-service teachers about the earth's shape. They all claimed that they perceived the earth to be spherical in shape. In the pre-test, 14 participants who answered the question believed the earth was spherical. In the post-test 12 participants also maintained the same stance as in the pre-test but two participants gave detailed data or evidence to support their stance about the earth being spherical in shape. One participant did not answer this question in both the pre- and post-tests.

The majority of the participants in the pre-test and post-test claimed that the scientific knowledge about the spherical shape concept was school-based knowledge. Thus 13 out of 15 pre-service teachers attested that the spherical earth worldview emanated from school, books and media in pre-test. In the post-test, the number dropped to eleven of them still maintaining the same views as in the pre-test. Only 2 participants in the pre-test claimed that the family, culture or religion informed their perception. In the post-test, four participants claimed that their scientific knowledge was from family, culture and religion. From the data presented, the emerging theme is that scientific knowledge is mostly acquired from school with only four participants claiming that their scientific knowledge were socially acquired through family, religion and culture. This notion brings in the arguments of worldview theorists. They assert that the differences between scientific and IK calls for teachers who act as cultural brokers between the scientific culture and the IK culture in order to ease participants' [learners] access to scientific knowledge (Aikenhead & Jegede,1999).

In item three, eight and 14 participants respectively in both pre-test and post identified models, the internet and videos as best teaching aids for teaching the earth's shape. There was an increase of six participants post intervention. In item 3b, the pre-service teachers' explanations of how rotation and orbit happens were just simple short answers with no warrants at all. Eleven participants in the pre-test and ten in post-test gave simple answers respectively. However four and five in both the pre-post-tests gave warrants to support their claims.

In item 4, participants were required to explain to a learner why people do not fall off the spinning earth. Most of the pre-service teachers stated that they would use Newton's laws to explain. One participant in the pre-test stated that the use of observable models would aid learning. Meanwhile in post-test, three participants argue for the use of models.

Below are some excerpts from some participants about earth in space perceptions before and after the intervention. The excerpts are a representation of some of the responses from pre-service teachers regarding the earth in space conceptions.

#### *4.2.1.1 Excerpts from participants about their views after the spatial modelling activity*

Ashar; Pre-test: *I understand that the earth is spherical because this has been proven so many times already. And I can explain by the means of the horizon that all of us has.*



Post-test: *I understand that the earth is spherical, through our horizons one could see where the bend comes in. It is the watching a boat coming up the sea, and it doesn't appear all of a sudden.*

Ashar's response in the pre-test emphasis is about scientists having proven it as fact. He also tries to give his own understanding but not very clear. In the post test he emphatically explained supported with evidence that he had actually observed the horizon while watching ships came back to dock. According to her when a ship approaches a harbour, one sees the tip of a mast then slowly the body of the ship.

Hassan's response on the other hand had erroneous statements although there was evidence that he knew what he was describing in both pre and post-test.

In question1, Hassan said that his preschool perceptions of day and night causes were religious. He however has redeveloped the scientific viewpoint about the shape of the earth. In explaining further, the scientific view that the earth spins on its axis as it orbits the sun his explanation was correct but then some facts were flawed. Below are some of his arguments:

Hassan's evidence in the pre-test was as follows: "*The earth moves around, or orbits the sun. It takes 24 hours for the earth to complete a full orbit around the sun, which is why there are 24 hours in a day*." In the post test, again he said: "*The earth orbits the sun, it takes 24hrs for the earth to complete a full orbit around the sun, which is why there are 24hrs in a day.*"

For Hassan's responses in both pre- and post-test were basically unchanged. This is noteworthy because the post-test was written seven weeks after the pre-test. I can extrapolate that such flaws may have been caused by interference of the meanings derived from his mother tongue. Scientific language is very different from everyday language. I think Hassan's use of the word orbit interchangeably to mean spin is very common within the indigenous languages. In other words, one word can be used to mean more than one thing. This to me shows that in integrating science and IK, the other challenge would be the disparity between the language of instruction and the home language of the learner. Indigenous languages are not that well advanced in the description of scientific terminologies. In fact, Fakudze in her 2004 study also highlighted the challenges emanating from learners directly translating from their home language in discussing scientific concepts (Fakudze, 2004).

This may be a case of language barrier, because his mother tongue is Afrikaans. Language plays a greater role as a means of communication and such cases are common hindrances faced by learners whose mother tongue is not his/her language of instruction.

Due to this anomaly, I had a telephonic interview with Hassan just to find out what his experiences at school were like in science and what he thinks about science teaching. He also believes that it is important to know scientific facts in high school. He also noted that teachers are under pressure to produce good results from learners in science therefore a lot of revisions and drills into what was to be assessed were done towards exam periods. Referring to an exercise of identifying learners' misconceptions about the earth's shape, Hassan argued that the teacher's role was to teach at the end of the day leaving no time for diagnosis. His reasons were that the curriculum had to be covered and therefore teachers must teach.

Hassan believed that getting correct answers as a learner was very important. Sometimes if you ask too much, the teacher may see you as rude or a problem learner. If a teacher believes in a learner's potential, s/he will take time to explain concepts but sometimes due to pressure it is not done to everyone. He understood why in some cases teachers had to drill scientific facts of what was to be assessed in order to get a learner to university. Referring to himself, Hassan believed that it was the practice and revisions that helped him to get to where he was and though most of the scientific data did not make sense some of the time, he now understands most of what he learnt in high school.

From the conversation with Hassan he conceded that memorising facts helps especially during exam times to which I partially concurred. I shall clarify this later. However, it is difficult to tell whether Hassan was playing what Larson in (Aikenhead, 1996, p17) termed "Fatima's rule" which is a game of getting correct answers without engaging in scientific discourse and without making scientific meaning. If Hassan's responses in both pre and post- test were responses from his understanding of the earth and sun relationship, yet there is no sign of effects even after engagement during the seven weeks of intervention, I can extrapolate that he still maintains his view by the way he articulates his evidence in writing. When I spoke to him he explained the sun earth relationship correctly.

Memorising is not bad if the data is correctly taken in for internalisation purposes and if it leads to mastery or understanding of concepts (Duong & Nguyen, 2006). However advocates for interactive learning argue that learning should engage the learner in sense making as opposed to memorising facts (Aikenhead, 1999, Cobern, 1995, Hutchison & Hammer, 2009). In the event that data is wrongly memorised, this may be detrimental to a learner who may not get a chance to revisit and refine the data, if no cognitive engagement exists between stored data and concept at hand.

Despite the variance between the pre-test and the post-test for Hassan, his involvement in modelling and argumentation activities on his perception of the earth in space has helped him a lot in finding evidence that enables him to become more aware that the earth is not a perfect sphere as he previously thought. Below is what he says in his final reflection:

> **Hassan**: *I learnt that the earth is not a perfect sphere when I realized that I had to re-shape my ball to a more irregular shape so that the map could fit on it. More such evidence was provided in the activity where I was required to construct the surface*

*dimensions of the earth. I learnt that the diameter at the poles were not the same as the diameter at the equator, proving to me that the earth is not a perfect sphere.*

Furthermore, Hassan alluded to the fact that; "…an interesting fact I learnt is that the International Date Line is not a straight line at all. I always thought that it is exactly on the Greenwich Meridian, but the activity on lines of latitude, longitude and time zones taught me that I was wrong. Furthermore, I learnt that modelling a three-dimensional representation of the earth provides a more realistic interpretation of the earth because it makes us aware of the earth's shape in space. Also, I learnt that the earth is composed of 71% water (hydrosphere) and 29% land (biosphere). The different time zones mean that it is a different time of day in different parts of the world. Thus, I now value time and the different parts of the earth."

There is sufficient evidence from Hassan's final reflections to show that his involvement in argumentation and spatial modelling equipped him with practical evidence to back up the theory about the earth's shape. Hassan believed that kinesthetic learning promoted retention of learnt concepts in own language (Palvio, 1986). By engaging in modelling, Hassan also engaged in intrapersonal argumentation when he revisited his prior conceptions about the International Date Line (IDL) which prompted him to reflect as well. For Hassan, modelling activities led him to revision of his pre-conceptions of earth in space which led him to a better understanding. On the other hand Liz had this to say about the earth and sun's relationship in the pre- post test;

Liz: *The Earth moves in its own axis, and it is placed in the solar system.* Post- test: *No, the earth moves around the sun in its orbit.*

Liz revealed some similarities with findings in Lemmer et al.'s study where some of the students' responses gave an organistic worldview like the 'sun stays there' or 'it is placed in the solar system' (2003, p574-575). Unlike the findings of Lemmer and associates suggesting that African students generally held organismic worldviews, the pre-service teachers involved in this study had only one participant who regarded himself as African and whose mother tongue was IsiXhosa, thirteen regarded themselves as Coloured and one as White. Nine participants out of the fifteen's mother tongue was English, one Isixhosa and five claimed that Afrikaans was their mother tongue. But despite their cultural backgrounds, most of them held conceptions of the earth in space which was not strictly speaking scientific.

Regarding personal benefits through participating in modelling Ray's views after the intervention said,

> *From a personal point of view my knowledge of the biosphere was improved, skills of creating and designing things were improved and my value of respect towards other members of the classroom improved. Knowledge of the solar system and the earth.*

Again, there is evidence that there was sharing of ideas between participants when pre-service teachers were making individual models. Most of them claimed that modelling the earth was very difficult because they wanted to come up with perfect spheres which could fit into the Mercator map. Although the participants in theory agreed that the earth is not a perfect sphere, in practice they tried to make their sphere perfect which did not work. However, most of them produced good models though at the poles it proved to be quite challenging. Step by step guidelines were given but most of the participants were not following them, instead they were looking at what their colleagues were doing.

Mildred's response is also quite interesting in that she gives some kind of crisscrossing or that the sun intersects with the earth at times as she stated in that;



Pre-test: *"The sun has its own axis as well and rotates slowly around the earth in the solar system."* Post test: Mildred drew a diagram which she believes would explain the rotation and revolution of the earth and sun relationship

The misconception of the sun that slowly rotates around the earth with the earth rotates around it as alluded to by Mildred was also echoed by some graduates at an American university (Schneps & Sadler's, 1989) 'a Private universe.' Schneps and Sadler to some extent reveal that most people use their preconceptions to complete theories learnt in science if there are gaps in the new knowledge [science]. I can infer that pre-service students also have their own conceptions about the earth and sun relationship as Mildred and Hassan. The abstractness of astronomy makes students substantiate the astronomical explanations with their own preconceptions when there are gaps in the theories that they are taught at school (Sneider & Ohadi). The kind of engagement which usually takes place in a science class between a teacher and learners may not deal with such issues. This is because in most cases the teacher is the main source of knowledge.

In her final reflection regarding the spherical earth she said that she confirmed that the earth is not a perfect sphere through "drawing the earth with its dimensions showed that the earth is not a perfect sphere, and also looking at different globes we had."

Besides the fact "that the earth is not a perfect sphere, through modelling, touching the earth, looking outside and reading more." This was when Mildred through touching the globe she felt that it was bumpy. She was also able to distinguish for the first time that not all globes which are sold are not good models to illustrate that the earth is not flat. She and other participants thought all earth globe models are good models.

> *That water covers most of the earth's surface, with global warming our living space will become smaller and smaller. That we should appreciate our biosphere and how it interacts with the other spheres. I think through hands-on activities you develop a deeper understanding on what was learnt. It made me think and share with my friend as we modelled the earth. However in a classroom situation, I have to design a strategy to maintain order in learners.*

Mildred was also able to reflect about herself as a prospective teacher on what and how she needs to involve learners in scientific processes through practical lessons and maintain order in her class. In science it is important to expose learners to scientific processes which scientists engage in besides equipping learners which scientific and technological knowledge it is essential for learners to do science as well (Lederman, 2000).

### 4.2.2 Emerging themes from spatial modelling before and after the intervention [Part E of the earth in space questionnaire]

There was dialogue between some participants during individual modelling activities of the earth's shape. Some meaningful engagement took place between participants which helped them to come up with better spatial models of the earth. For example, one participant stated that she did not do geography and she does not like it either. At first she asked me why she was expected to do geography in science. Though other participants did not comment about their knowledge of geography, Talah may have represented a few of her colleagues with the same challenge.

Several studies done in South Africa on astronomy teaching have shown in certain cases some teachers did not teach this particular topic. The reason as stated before was that some of the teachers did not have the content knowledge required in that area. Another reason was attributed to the fact that astronomy used to be in geography and since its transfer to the Natural Sciences some teachers like Talah were facing challenges on the astronomy learning area. This might be the reason why in some cases the topic was not being taught (Lelliott, 2010, Mosoloane, 2012, Sanders, 2006, Lemmer et al., 2003).

Ryan (2012) concurs that the teacher's own awareness plays a major role in her/his choice of teaching strategies. Whereas many studies including Diakidoy & Kendeou's, (2001) opine that learners who are exposed to interactivity about their pre-conceptions and involvement in experiential learning understand astronomical conceptions better than those who are taught from the text books only. The challenges which teachers are faced with in their teaching careers influence to a great deal their pedagogy (Lederman, 2000). This will have a ripple effect on learners as they encounter new knowledge, upon which they may memorise scientific facts for exam purposes only of which these facts stored and retrieved when the need arise (Aikenhead, 2001).

### 4.2.3 How participants benefited from spatial modelling activities and argumentation

Charles' involvement in modelling and argumentation was an eye opener as he reflects that; "Personally there were very little new topics I learnt as I had known many of the topics covered. Yet it amazed me at how the lack of knowledge some of the other students had about common things such as the continents and so on. Skills wise, it was nice to see the students and myself push our creative limits a bit with some of the activities. Values, I learnt that people grow closer when working together, if the work isn't too difficult. I also received some insight into other students' cultures and beliefs."

From his reflection, Charles was involved in sharing his geographical knowledge with his knowledge. Considering that he is a licensed pilot he is quite knowledgeable in geography. I have to mention that these preservice teachers were in their fourth year yet according to Charles they did not know much about each other, but through hands on activities Charles learnt about his colleagues and they learnt from him too.

Concerning hands-on activities in teaching and learning, Charles says; "*Well rote learning and tests got me to where I am, so it must work to some level.... Yet I think hands-on activities have a MAJOR part in any field of education and must be promoted to be used in classes more."*

There is no doubt that rote learning works to some extend but not for all learners, especially to learners whose language of instruction is foreign to them. As mentioned earlier Palvio, argues that modelling surmounts the language barriers and maximise memory retention of concepts learnt. In a nutshell Charles shared his knowledge with colleagues who lacked knowledge about continents. Apart from that he also learnt the culture and beliefs of his colleagues besides his struggling to construct an earth model by crumbling newspapers to be enclosed with a Mercator projection map.

In question 4, the results from 13 prospective teachers' responses were scientifically correct in the pre test and post test respectively. One responded by explaining effects of the moon on tides in pre test and he also did not complete his explanation in the post test. One participant used gravity to explain why we do not fall off the spinning and orbiting earth, he however misconstrued the speed at which the earth spins on its axis to be very slow. Here is what he said in the pre-test:

Aadam: *The earth moves extremely slowly and because of gravity we are "stuck" to the earth therefore we don't feel the rotation.*

He repeats the same in the post test by emphasising how slowly the earth rotates when he says: *The earth rotates very, very slowly so you won't feel the rotation and gravity keeps us stuck to the earth.*



He must have arrived at this reasoning after imagining what happens when one puts an object on a ball and spins it; the object might not fall if the ball is spinning very slowly. School text books do not usually cover the speed at which the earth spins except stating that it rotates/spins. As calculated, the speed is calculated dividing the circumference of the equator 40 075 kilometres by the 23.93 hours which is the time it takes for one spin of the earth on its axis, and dividing 40 075/23.93 would give the speed of 1675km/h. If this is to be compared to the maximum speed allowed in South African roads, this is unimaginably fast.

In view of pre-service natural science teachers' perceptions about the earth in space with regards to its shape, causes of day and night, rotation-revolution of the earth and its gravitational force, there is a general understanding of the scientifically accepted conceptions as revealed by their responses. However, a few who had misconceptions like Aadam and Hassan retained them even after the intervention in writing. This can be attributed to mother tongue interference, whereas scientific language is very prescriptive, whereas everyday language and especially indigenous languages tend to have multi-purpose terms (Fakudze, 2004).

During the discussion after individual modelling of the earth's shape using Mercator map projections, participants reflected that modelling activities would not fit well within the time allocated per lesson at school level. Here are some excerpts of how participants felt about the practical of modelling the earth using recycled paper then covering it with the two dimensional Mercator projection.

Seven out of the 15 participants felt that modelling the earth with recycled papers was a challenging activity to do. Their main challenge was that of not following step by step instructions given. Instead, they wanted the researcher to tell them how to do make it step by step. This led us to discussing about the nature of science and scientific processes. It was during discussions when they were able to connect the assertions that the earth is not a perfect round with the models which they were struggling to fit a Mercator map round.

Although several participants followed instructions, some of them despite having the worksheet still sought help from their colleagues. Mildred, in her final reflection, acknowledges that she was too lazy to follow instructions which made an activity which was quite straight forward a bit tricky for her. Her remark came after she asked why she was not doing real science. The labelling of the map also proved challenging to those who did not do geography (Mosoloane, 2012), hence a suggestion that more world maps were needed. That was when participants discovered that they had a pilot amongst them.

Table 4.4: Pre-service teachers' conceptual understanding of argumentation (Part D)

| **Item No.** | **Questions seeking**: | **Pre- test frequency** | | **Post test frequency** | |
|---|---|---|---|---|---|
| | | PU | CU | PU | CU |
| 1. | Participants' understanding of argumentation as an interactive teaching strategy | 4/15 | 11/15 | 3/15 | 12/15 |

| | | | | | |
|---|---|---|---|---|---|
| | | 27% | 73% | 20% | 80% |
| 2. | If participants are aware of some advantages and disadvantages of using argumentations teaching strategy | 6/15 40% | 9/15 60% | 2/15 13% | 13/15 87% |
| 3. | Participants can explain any experiential argumentation lesson | . | 6/15 40% | . | 9/15 60% |
| 4 | Participants can identify successes if any in using argumentation | . | 6/15 40% | . | 6/15 40% |



Key: PU =practical understanding; CU = conceptual understanding

In question 1 of Table 4.4 above, the participants explained what they understand by argumentations as a teaching strategy. Since they are still training, I assumed that some of them might not have used it in teaching practice. From their explanations, the prospective teachers were aware of what argumentation is as shown by their responses. There are two views being portrayed here;

Petros had this to say at the pre-test about what argumentation entails: *To explain (unpack) an idea to someone who have [has] a different opinion of the idea itself.*

Then at the post-test he said: *When two people have different opinions and do not accept or understand each other's views.*

At the pre-test Joe-Ann said*: When people give their opinions and some disagree on certain topics or subject being discussed.*

At the post-test she viewed argumentation as*: When two or more people come in disagreement about something*

Those who view argumentation in a negative perception said the following;

Then Ludwe had this to say: *Is the discussion that has the contradictive or absurdum ideas, that does not bring the solutions.*

At the post-test he said: *Argumentation is when individuals argue to each other. For example the use of IK with science is not much considered and people are discovering adding new knowledge*

Ashar said in pre post: *Something that does not have enough evidence and were you include your views on a certain topic.*

Post test: *When two people come in disagreement with one another.*

All of the above definitions portray that argumentation happens only interpersonally yet it also happens within an individual or intrapersonal.

Summary



There were several issues arising from the participants' perception of argumentation. Participants perceive argumentation as unscientific from the citations above. Then the issue of not substantiating one's responses to questions was very common. When asked to explain, some participants just agreed without substantiating. In this regard, Khun (1999) bemoans the characteristics of a science lesson whereby a teacher aims at doing a lesson thus, short correct answers are preferred. Responses of one word were given in some cases for example: Is the earth moving around the sun or the sun around the earth, a few participants' responses were just 'Yes' without further expalnation.

Most of the participants in their reflections were complaining about the Mercator projection not being to scale, however they did not seem to link the theory about the earth not being a perfect round to the practical they did. Most of them wanted to make their models perfect spheres however; Charles found the activity quite easy. Talah expressed her dislike of geography, in the practical and asked me why she had to do geography; such are examples where teachers end up not teaching the 'Earth and beyond strand' as identified reasons why some teachers do not teach some sections (Mosoloane, 2012, Sanders, 2006).

Two participants, Aadam and Hassan retained their misconceptions about the speed by which the earth spins, referring to it as very slow, then the earth and sun's relationship were not conceptualized correctly with regards to spinning of earth in 24 hours causing day and night. There was a lot of sharing of ideas especially in modelling, thus a benefit of co-operative work.

## 4.3 What cognitive shifts did pre-service teachers exhibit in their attempt to use an argumentation/spatial modelling instructional model to implement an integrated science-IK curriculum?

### 4. 3.0 Introduction

To answer the question above, the study adopted the spatial modelling and dialogical argumentation strategy (SMDAS). The dialogue began in form of brain-storming as each pre-service teacher made attempts to solve the cognitive assigned to individuals. The dialogue continued at the small-group-level and finally ended at the whole-group level. As indicated earlier, SMDAS is an adaptation of the Ogunniyi's (2007a) dialogical argumentation instructional model (DAIM)- an instructional model which in turn is informed by the contiguity argumentation theory (CAT). CAT construes argumentation as starting at the individual level (intra-argumentation, then in small groups (inter-argumentation and finally at the whole-group level (trans-argumentation) where collaborative consensus is normally reached (Ogunniyi, 2007a). The cognitive tasks in the worksheets were designed in conformity with these levels of dialogical argumentation. In the same vein, the pre-service teachers were involved in a series of dialogues about their imagined roles as science teachers. These dialogues commenced at the individual level, then in small groups of four or five members before it was finally carried out in the whole group. The purpose was to link their views with what is envisaged of a science teacher in the NCS. The commonly perceived roles by all participants were in developing learners who are critical thinkers in their adoption of scientific approaches to solving socioscientific challenges.

### 4.3.1 Perceptions of the roles of a science teacher (Individual task-5minutes)

Question; You will be joining the teaching profession soon. What are your perceptions as a science teacher in South Africa?

*Petros:* I will cultivate within learners a culture to think critically, develop a scientific mind-set.

*Liz;* I would like to share my love for science with the learners so that they can go out in to the community and share. I want to build good relationships and have a positive impact.

*Joe-Ann*: A science teacher must make science more practical and applicable to use in everyday life.

*Tahini*: My perceptions are that learners tend to perceive science as a difficult subject and I intend to disapprove this myth.

*Charles*: To make science be identifiable for students. Have the students feel like they can make science their own.

*Ludwe*: I would construct the science knowledge. I would tell the learners how to be able to know science, understand and apply science into indigenous knowledge, relate to nowadays technological science.

*Rafidah*: My role as a science teacher is to change the mindset of learners, by encouraging and showing them what science is. I would encourage them to look at things e.g. environment in a scientific way.

*Chad*: There are many misconceptions with regards to what science is in communities hence as a science teacher, it is vital to educate and equip learners with skills e.g. understanding what science is being able to do investigations, solving problems, asking questions etc.

*Tarub*: My role as a science teacher is to give the children a good perspective and understanding about the world and themselves. And make things clear about what they partially know already.

### 4.3.2 Discussion

Different views about their roles as would-be science teachers were expressed by the pre-service teachers. The view that eventually emerged among these prospective teachers is that science is as a difficult subject to teach or learn. They therefore believed that the way to change this negative perception was to find a way to change learners' mind-set e.g. by getting them involved in arguments, dialogues and debates on controversial subjects or issues considered relevant to their sociocultural environment. It was hoped that if teachers are able to create their learners' awareness about their environment or other issues relevant to their life world experiences through argumentation/spatial modelling activities they are likely to replace their negative perception about science with a more positive one. Most of the sentiments expressed by the prospective teachers suggest the need for an inclusive and multi-cultural science curriculum-i.e. a curriculum that touches the sensibilities of the learners by the fact that is it addresses matters of their learners' immediate concern (Aikenhead, 2001, Kuhn, 1999, Cobern, 2000).

After the individual reflections participants shared their views with peers in groups and then presented to the whole class. The intention of this discussion was to draw attention to a science teacher's role in a classroom when considering that science may be viewed as a culture which differs from that of the learners. This is done in order for teachers to create enabling environments for learning science. The teacher's awareness will in turn inform her/him of using inquiry based teaching methods (Bryan & Atwater, 2002, Meyer & Crawford, 2011, Meyer, 1991).

### 4.3.3 Group dialogue (15 minutes)

Ludwe's group's which had four members namely Rafidah, Mildred and Petros viewed themselves as advocates of inspiration to learners. They envisaged learners who not only saw science as a school subject but learners who think in terms of applying scientific knowledge at home as well. During whole group discussion all participants agreed that science should be relevant to learners. Consensus was reached that teachers can involve learners in the scientific discourse thus adopting strategies that engage them as interacting partners in the teaching-learning process. However, this is only possible if teachers are aware of the misconceptions/alternative conceptions which learners are likely to hold and if teachers are willing to accept the role of facilitators rather than transmitters of readymade knowledge (Diwu & Ogunniyi, 2012; Lederman, 2000, Shulman, 1986).



The pre-service teachers involved in the study also viewed themselves as being responsible for creating a viable environment for the co-construction of scientific knowledge with learners by using asking thought-provoking questions, testing, observing, hypothesising plausible scenarios, etc. However, teachers have the tendency to tell learners what science is all about instead of involving them in the discovery and construction of scientific knowledge. This has been the difference between scientists doing science and science teachers teaching science as put forward by many researchers (Clark, 2012, Erduran, 2008, Lederman, 1999). Lastly, the group perceived their roles as that of demonstrating textbook information such as testing for the presence of chlorophyll in leaves in the laboratories or other concepts. My personal observation of this group of pre-service teachers is that like most practising teachers they also view their roles as that of telling learners what they need to know and as such they maintained a teacher-dominated lesson in that they do not give the learners sufficient time or space to make their own contributions.

Hassan's group had five members, namely Ray, Talah, Tahini and Tarub. Their views as prospective science teachers were largely to "*educate, motivate, inspire, encourage, support and give them higher expectations to encourage them to aim higher*." They also perceive their role mainly to "*create opportunities to integrate scientific knowledge into previous beliefs and life styles*" of learners. Furthermore, as science educators they attested to the fact: "T*hey are required to influence learners' lifestyles as opposed to just academically influencing learners*."
The group also had a view that science teachers are different from other teachers but similar to Mathematics teachers because they have similar mind-sets. As noted from the previous group, with the exception that Hassan's group talked about integrating scientific knowledge with pre-conceived beliefs and life styles of learners. Again there is a perception being put forward of learners receiving and teachers giving yet research has proven that when faced with new information, it is referenced to what an individual already knows upon which there will be interfacing realignment or the new information will be stored in separately, therefore for effective science learning, it is important to actively involve learners. So as we interacted during whole group discussion I referred participants to some readings on worldview and conceptual change theory, including the nature of science and multicultural science.



Charles' group members had five members as well namely Aadam, Liz, Ashar and Joe-Ann. They viewed themselves as critical thinkers who in turn would advocate for critical thinking among their learners. They also saw their responsibility as affording learners the opportunity to make science applicable in everyday life as well as eliminating misconceptions in science.

Their response on how to make science applicable at home was met with uncertainty on how they will encourage scientific knowledge in everyday living. Anyway, Rafidah intervened by talking about involving learners in doing investigations at home. Science teachers claim that learners will get a better understanding of how nature works through doing science (Hodson, 1993). However, it is difficult to ascertain that learners understand their world better after being exposed to western science if all they are exposed to is textbook knowledge which is not in the context of the learners' world.

### 4.3.4 Discussion

Researcher paused this question; "*From whose perspective and worldview will you teach in order for learners to get a better understanding of nature?*

Ludwe, argued that science makes use of hypothesis which can be tested and observed resulting in scientific theories. The group had to go back into defining what the study of science is all about. Consensus was then reached that "nature is all around us so it is possible to contextualise the scientific concepts where possible," and to accord learners opportunities to reconstruct their knowledge into scientific knowledge.

Charles' group highlighted one of their roles as "to eliminate misconceptions in science" for example the earth and sun's relationship was given as an example. Chad, also mentioned that attribute, but when I asked how they intend on eliminating the preconceived conception, Liz said; "*Through demonstrating to them the spinning of the earth.*"

Cobern (1996) underscores the conceptual change theory regarding teaching science explicitly to non-western learners as ineffective if learners do not engage actively in the learning process. He argues that learners should be actively involved in learning through interaction with their peers and with the teacher in a way that affords them the opportunity to re-align their world views. Social constructivists argue that knowledge is not transferable from a knower to the learner but through social interaction between the knower and the apprentice. Mark (2012) argues that the lack of knowledge of the NOS by teachers is an impediment to teachers teaching science effectively. Thus the increase in calls for NOS courses during teacher training so that they can teach science effectively. Effective teaching of science can be improved if it involves learners in the empirical processes just like scientists but under the teachers' guidance (Abd-El-Khalick & Lederman, 1999, Erduran, 2012, Lederman, 2007).

It emerged that, the prospective teachers already have their views about their roles as science teachers. These views are guided by their perception of NOS and consequently the way they approach teaching. Interestingly they all mentioned that they are critical thinkers yet it does not look like the same critiquing right is accorded to their learners.

Here are the excerpts from the three groups;

"*Science teachers are required to be critical thinkers and should promote critical thinking in their classroom,*" Charles' group.

On the same notion Hassan's group said, "To *develop critical thinking with regard to a scientific approach to solving issues within the world*."

And Ludwe's group also said, "*To cultivate within the learners a culture to think critically with a scientific mind set.*"

There is the universalistic worldview being portrayed by participants when they say they will be promoting critical thinking in learners. The challenges arise when one is asked to think critically from a world view which is foreign to her/him, thus the need of spatial modelling to mirror the participant's views and through conceptual models be assisted to reconstruct mental models of earth in space. Their views of the NOS do not have a learner in mind, it is science which is the subject and learners are just recipients of scientific knowledge which teachers view would benefit learners. The prospective teachers are likely to adopt the same teaching techniques which they witnessed from their teachers during their school days. In fact, Charles remarked that, "It was through rote learning that he got to an institution of higher learning."

There are various push factors at play, whilst the discourse about the importance of changing the way school science is presented to learners at school levels to be more of a human enterprise, there is very little change happening on the ground with regards to implementation and assessment. In the meantime school science learning is largely about learners amassing scientific data for evaluation purposes and examination and very little for their personal benefit as scientifically literate citizens (Asante & Miike, 2013). And for prospective teachers the main focus is to get through the syllabus whereby the teachers asks questions, learners respond and the teacher evaluates the lesson (Lemke, 1990). This is further worsened by the extensiveness of assessment and evaluation which teachers are expected to perform (Diwu, 2010).

Change in cognition is a process which happens after being exposed to similar situations for a period of time. I will trace Ludwe's perceptions from start to finish. On nature of science (NOS), Ludwe's initial perceptions on NOSIK questions were equipollent. He disagreed that science and IK are distinctly different. He was also of the perception that science uses some IK practice processes in producing scientific data. In the post test after the interventions for the similar questions Ludwe's views remained in the equipollent category although he viewed IK and science as different. He became uncertain about the notion that IK is all about witchcraft and witchcraft.

From Ludwe's responses he thinks the education is lowering the standards of education by awarding learners with low marks certificates.

To sum up what these prospective teachers perceived of their roles, Shuman defines clearly what teachers should understand of their roles as teachers who can influence learners to re-organise their pre-conceived beliefs on certain phenomena. In his assertion Shulman underscores this by stating that:

> The teacher need not only understand that something is so; the teacher must further understand why it is so, on what grounds its warrant can be asserted, and under what circumstances our belief in its justification can be weakened and even denied. (Shulman, 1986, p. 9).

Thus Shulman not only stresses the importance of teachers' content knowledge but also the importance of deeper understanding of it. Therefore, from the pre-service teachers' views about their roles, in the dialogue, it is imperative to state that teachers ought to contextualise the content for learners to access scientific knowledge.



### 4.3.5 How did pre-service teachers use IKS-based spatial models in explaining the earth's structure?

Cognitive shifts observed in assumptions about science and IK

Table 4.5 shows the perceptions of pre-service teachers on the Nature of Science, and the Nature of IKS. As explained in chapter 2,

Table 4.5: Frequency of pre-service teachers' pre-post-test perceptions about NOS and NOIK (Part B of the earth in space questionnaire; refer to appendix 2)

| Statement | Agree Pre | Agree Post | Unsure Pre | Unsure Post | Disagree Pre | Disagree Post |
|---|---|---|---|---|---|---|
| 1. Indigenous knowledge is distinctly different from science | 5 | 2 | 1 | 0 | 9 | 13 |
| 2. Science is involved in many aspects of indigenous knowledge practices. | 13 | 14 | 1 | 0 | 1 | 1 |
| 3. It is beneficial to study indigenous knowledge in a science class. | 15 | 13 | 0 | 0 | 0 | 2 |
| 4. The fundamental assumptions of IK and science about nature are similar. | 10 | 8 | 2 | 5 | 3 | 2 |
| 5. IK is all about witchcraft and superstitious beliefs. | 1 | 1 | 3 | 3 | 11 | 11 |



In discussing the results shown in the table 4.5 above, Ogunniyi's (2013) contiguity argumentation theory was used to explore the responses given. Contiguity Argumentation Theory has five categories which are: dominant; suppressed; assimilated; emergent; and equipollent. The 15 participants' views were analysed in terms of these five categories. For example, in item 1, in the pre-test, a small majority (9) of participants disagreed with the notion of indigenous knowledge being distinctly different from science; in other words, they believed the two knowledge bodies to be similar. Thus these participants had equipollent views about science and IKS.

However, in item 2, the majority (13) of these same participants believed that IKS embeds aspects of science. In this case too, the participants can be said to hold equipollent views.

Both these views were reinforced by the intervention activities because the numbers of participants holding these views increased in the post test. This demonstrates the emergence of the equipollent view, from previously Dominant, Assimilated and Suppressed categories. Using these contiguity argumentation categories, table 4.5 can be summarised as in table 4.5b below. Table 4.5b will be used to discuss the responses to items 1-5 in the pre and post tests.

In item 1: The emerging views from pre to post tests in this item showed that three out of the 5 participants who initially agreed with the statement changed their stances. Also one participant who initially was unsure changed the stance to disagreeing. In the post test four participants who initially agreed with statement had emergent views regarding the notion that IK and science are distinctly different.

**Item 2: Science is involved in many aspects of indigenous knowledge practices.**

13 participants in pre-test and 14 in the post-test agreed with the above declaration. 13 participants in both pre and post test maintained the equipollent views about item 2. One participant who was unsure in the pre-test changed stance to emergent by agreeing with the majority of participants that their science related studies in IK practices. Most of the participants cited the research in herbal medicine usage. See test item 2 in table 4.5b below.

**Item 3: It is beneficial to study indigenous knowledge in a science class with diverse learners.**



In the pre-test, all 15 participants have equipollent views about IK and science integration. In the post test, 13 participants had equipollent views about integration. Their views were not altered by the intervention. However, two participants who shifted their stances in the post test changed their stances from agreeing with the statement to disagreeing. 15 participants at the post-test whose stance was equipollent namely that science and IK could co-exist had shifted to a suppressed view about integrating the two knowledge corpuses. One strongly disagreed that any benefits could come out of integrating science and IK. This participant's view could be described to have developed an emergent stance. The shift in stances might be as a result of continuous reflections on the NOS and NOIK.

Table 4.5b: Categories of participants’ pre and post test beliefs in Science and IKS. .

| **Test Item** | **Test** | **Dominance** | **Suppressed** | **Assimilated** | **Emergent** | **Equipollent** | **Comment** |
|---|---|---|---|---|---|---|---|
| 1. Indigenous knowledge is distinctly different from science | Pre | 5 | 1 | 0 | | 9 | The emergent views result from one suppressed and three Dominant views being transformed into equipollent views |
| | Post | 2 | 0 | 0 | 4 | 9 | |
| 2. Science is involved in many aspects of indigenous knowledge practices | Pre | 1 | 1 | 0 | 0 | 13 | The emergent view results from one suppressed view being transformed to the equipollent view.<br><br>Note that the dominant view of one participant was not affected by the intervention of classroom activity |
| | Post | 1 | 0 | 0 | 1 | 13 | |
| 3. It is beneficial to study indigenous knowledge in a science class | Pre | 0 | 0 | 0 | 0 | 15 | In this case, there was a reverse shift from equipollence to dominants.<br><br>One could therefore conclude that the class activities given to the participants tended to affirm the dominance of science rather than its equipollence |
| | Post | 0 | 0 | 0 | 2 | 13 | |
| The fundamental assumptions about IK and Science about nature are similar | Pre | 3 | 2 | | | 10 | It appears as if there was a shift from both equipollent views and dominant views towards suppression of beliefs. This could have been due to the fact that the students were unsure of the underlying assumptions for both IK and science, especially after participating in the class activities. |
| | Post | 2 | 5 | | | 8 | |
| IK is all about witchcraft and superstitious beliefs | Pre | 12 | 3 | | | | There was a clear cut dichotomy of views which were both categorically expressed in the belief that IKS is all about witchcraft and superstitious beliefs. However even after the classroom activities, these views remained strongly ingrained. |
| | Post | 12 | 3 | | | | |

**Item 4: The basic assumptions of IK and science about nature are similar**

In the pre-test ten participants held a view that the philosophy of IK holders are similar to science ones. However, the number of pre-service teachers with equipollent views about IK and science dropped to eight after intervention. In the pre-test three participants had initially disagreed with the above notion. Yet in the post test, five participants disagreed with the notion of similarities in beliefs about nature between science and IK. From the table, two participants had suppressed views, in the pre-test. The number of pre-service teachers whose stances about IK and science were suppressed in the post test was five. Analysing the results in item 4 further, I noticed a lot of shifts in perceptions of pre-service teachers between pre and post test responses. This might have arisen due to the nature of the statement; especially the phrase basic assumptions, may have invoked uncertainty in participants for them to maintain the same stance. Another reason could be that the pre-service teachers became more cautious in committing to one perception after the intervention giving rise to the number of participants who were uncertain.

**5. IK is all about witchcraft and superstitious beliefs.**

There were no shifts in the stances of pre-service teachers' views about IK being riddled with witchcraft and myths in the pre and post test. The results showed dominant positions being retained by participants in agreeing with the statement and three participants who were unsure in the pre-test retained the same perception in the post test after the intervention. Refer to tables 4.5 and 4.5b above.  It seems like my intervention was not convincing enough to effect any changes in the pre-service teachers' views about the belief that IK is all about witchcraft. This could also be due to the perceptions about participants regarding IK. In my view, it must also be conceded that the fact that IK has been kept out of the schooling system for many years, this may have contributed to the way pre-service teachers took their stances about the superstitious nature of IK.

#### *4.3.5.1 Summary*

I can extrapolate that there were significant cognitive shifts in perceptions about assumptions of science and IK of pre-service teachers from pre- test to post test. In item 1, there was an increase of shifts in pre-service teachers' responses rejecting the notion that IK and science are distinctly different, nine out of fifteen equipollently perceived IK and science as similar compared to 13 out 15 participants' responses in the post test. It is also worth mentioning that the dominant worldview about IK being riddled with superstitions remained unchanged in both pre-test and post test (12/15 disagreeing with the notion and three out of 15 participants maintaining the uncertainty stances. In item 4, participants' perceptions shifted a lot from pre-test to post test. This led to the number of participants whose perceptions were suppressed increasing from three in pre-test to five in post test. The responses of participants with equipollent perceptions of the worldview about basic assumptions of IK and science also dropped in numbers in the pre-post test from 10 participants to eight respectively. In a way I attribute the variations in perceptions of pre-service teachers to either the consciousness brought about by the exposure of pre-service teachers to the nature of science and indigenous knowledge (NOSIK). This consciousness would have barred them from maintaining positional stances.

## 4.4 Focus group interview

### 4.4.1 Introduction

The excerpts of interviews below were randomly extracted to display issues about the pre-service teacher's perceptions concerning the infusion of science with IK. It covers the participants' views about similarities or differences thereof between science and IK. Most of the participants targeted had shifted their stances regarding IK and science integration. Some had given flawed explanations to some concepts.

*Interviewer:* What are your views about bringing indigenous knowledge into a science classroom?

*Ludwe*: I believe so personally because in modern science use technology like in astronomy, whereas in our culture we use our senses and beliefs, science has developed some technologies which see where the eyes cannot see, think of Robert Hooke and the cell, it happened centuries ago, when he developed a microscope, so that's why. However, I agree that science developed from indigenous knowledge because the early scientists used perceptions and investigated further to find reasons why things happened the way they did.

So if indigenous knowledge is brought in science, I think they will develop as science when learners go home and search for answers as to why things happen the way they do. Now we look down on it because it is not talked about at school.

*Interviewer*: Do you think there is a similarity between science and IK?

*Charles*: IK is not known because it is not written down like science that is why there is suspicion about what it does.



*Ludwe*: Both science and IK are similar because they are all about science. They are different ways on how humans try to understand their world, in IK the people's environment and what they get is combined with their culture yah in science at school, culture is removed. Like when you dissect a rat to study it you just do it, but in IK you may do some ritual may be because they believe that they did not create the rat so you cannot just cut it.

*Hassan*: I strongly disagree that IK is all about witchcraft and superstitions because like the pangolins and rhinos, these taboos worked because it scared people away and people respected it. Now because there are no fears rhinos are being poached and trees are cut. The need for money also made it worse miss; because people no longer share the resources, the *ubuntu* spirit has vanished. I think bringing in IK can also put science in context. So I support it. Now they put the laws to protect rhinos but people will still poach because they don't have anything, no land, food and money, yah that's what I think.

#### 4.4.1.1 Discussion

The interviewees seemed to have grasped some understanding of science and IK from the nature of science (NOS) and nature of indigenous knowledge intervention. The interviewees' responses further elaborate on their views.  Ray made an interesting remark that the fear of the unknown brings uncertainty.

*Interviewer: Do you see yourself empowered enough to teach the concepts of the Earth and beyond from what we did and what you experienced in teaching practice?*

*Joe-Ann: Well, I never thought of I can make my own spatial model and it taught me to appreciate the earth and the resources that it provides. It is a good activity to use coz it helps by making learning more practical, it accommodates for more than one learner in the class. Learners find it exciting to do practical activities than tests.*

*Talah*: *For me it was difficult also my geography knowledge is not good so I found it hard to grasp some concepts. I found the model the most difficult. I think that I will be better equipped to teach earth and Beyond but I still need to read more so that I can be better.*

*Ashar: For me personally, spatial modelling my knowledge of the biosphere was improved, skills of creating and designing things were improved and my value of respect towards other members of the classroom improved. Therefore I think this activity can bring meaningful learning in a science classroom for learners when properly planned for.*



*Ludwe: For me personally, all I can say is that it astronomy is difficult and many teachers leave it because they lack the skills and knowledge to teach it. Now I can use the skills I learnt to do activities in class. I didn't know about the sizes of the lithosphere as compared to other spheres which I didn't know as well. My science teachers didn't do the earth and beyond with us. Well, well! Miss, if I go to Eastern Cape, I can make change like in astronomy, I didn't know about the spheres of the earth until we did it now, because the teachers thought it's too difficult so they leave it. But with the problem of nepotism I won't get a teaching job there, that's why the Eastern Cape will remain with low pass rates.*

#### 4.4.1.2 Discussion

Issues being highlighted included amongst others the fact that spatial modelling as an activity creates social-cultural learning environments. There is also a feeling of empowerment as alluded to by Joe-Ann. Emerging from the interviews are views which were discussed earlier own in this chapter. The issue of lacking the geography content knowledge is also crucial. Natural sciences forms a foundation for science subjects to be studied later, therefore, this is a cause for concern. It however seemed like only one pre-service teacher did not study geography in high school but it is worth noting. Another point of abstractness of astronomy has been raised again. In chapter two this researcher discussed briefly the differences between indigenous astronomy and scientific astronomy, due to this reason, meaningful engagement may help when teaching.

*Interviewer: Do you ever wonder why it looks like there are no scientific discoveries from Africans in the books you read?*

*Ray: Because of colonialism miss, Africans especially were not allowed to do science. They were taught subjects so that they serve their masters. So I think there could be some discoveries which were from our people which were not acknowledged. Now here in South Africa, science can be done by anyone but the thing of "maths lit" (Mathematical Literacy) will prevent many from achieving their goals. Teachers decide who does what at school and don't care about your dreams.*

*Ludwe; I think it's because of colonisation miss. But there are discoveries now especially in South Africa of Africans doing well just like Hooke (Sandile Ngcobo's) newly discovered LCD digital laser, read all about him and I'm excited. Now there will be an increase of African innovations because we are free.*

*Rafidah: I think there are discoveries but because people are poor, they sell their discoveries and get quick money.*

#### 4.4.1.3 Discussion



This seemed like an out of place question but I brought it out to find out the views of pre-service teachers to reflect about why it looked like very few or there were no well known scientists of African descent at all. Those who responded were very well informed, the other reason was that there was only one pre-service teacher of African descent majoring in science and mathematics amongst the participants.

**Interviewer***:* So do you think one must be smart in order to do science as you mentioned earlier on?

*Talah*: I think science can be done with anyone who is interested, especially when the teachers can give enough support. I will be different to my learners; I won't embarrass learners in class and I was trying to expose them to spatial modelling and lead by example.

*Charles*: Sometimes Rafidah pressure of work and size of class make teachers demonstrate in class. Also fear of class control, especially when you have big class. It becomes risky to keep everyone in check

*Tahini*: It also depends on the activity; it saves time to show a YouTube video than doing a practical. At high school where learners move classes, they come late and you can't do a practical

*Joe*-Ann: What about in rural areas where there is no electricity and internet? You sometimes have to do a practical I think.

*Interviewer*: Of cause people say the same, in fact in the questionnaire some of you said argumentation causes a lot of noise, what do you think now?

*Hassan:* When you can control the class it's good because it's when learners can develop the conceptual ideas on science. I used it once and it worked, but I had planned a lot, so it's when you have not planned what learners do that you lose control.

*Petros:* Time is always a limiting factor, but it is a good strategy when learners know what to argue about.

#### 4.4.1.3 Discussion

Ludwe believes that he does not need to use modelling if he is teaching bright students. He likes using big scientific words when conversing in science; and he uses them correctly most of the time. Born in the Eastern Cape Ludwe, does not want to go back to the Eastern Cape to teach in his province. According to him the schools in his province not well managed due to corruption, meaning therefore that good teachers get frustrated and leave.

Participants here had mixed feelings about the use of argumentation as a teaching strategy. These issues were raised in the questionnaire but the dialogical argumentation strategy can be used successfully as long as the teacher knows the strategy and has prepared well.

**Conclusion**

From the interviews, the pre-service teachers view spatial modelling and argumentation as be beneficial to learners. There is a consensus on preparation time needed and then fear of loss of class control is the limiting factors. I would like to reiterate that every lesson needs planning but do agree that with the dialogical argumentation one has to plan the lesson well and be good at class management. When I planned for dialogical argumentation with the group, I planned extensively and it went well.

Spatial modelling on the other hand provides the data from which participants can discuss. Therefore, spatial modelling activities in a dialogical argumentation strategy can enhance meaningful learning if the teacher is prepared to make proper planning.

# Chapter 5

# Conclusion, implications and recommendations

## 5.1 Introduction

The study was aimed at investigating the pre-service Natural sciences teachers' perceptions of the earth in space using spatial modeling and argumentation. Qualitative data collection methods were used. These included a pre-post test questionnaire, journal reflections, an assessment assignment, spatial modeling of the earth and the solar system in groups and as individuals. Spatial modeling was an activity used to enrich argumentation. This chapter provides a summary of the study, including the main findings, implications and recommendations for further development. The next section discusses the finding, using the research question as the subheading. It is hoped that this approach will make more explicit the finding of the research.

## 5.2 Findings

The research findings below, generally underline the view that construction of new knowledge depends upon connections between existing knowledge and the new knowledge (Butler & dale Tunnicliffe, 2007). Specifically, these findings were that most of the pre-service teachers' experienced shifts in perceptions about the nature of science and the nature of IKS, as well as the integration of the two corpuses of knowledge, after being exposed to spatial modeling and argumentation.



### 5.2.1 Research Question 1

*What are the pre-service teachers' indigenous and scientific perceptions about the earth in space before and after they have been exposed to argumentation and spatial modelling activities?*

The participants registered a net shift from either IKS dominated or Science dominated worldviews to equipollent world views. The IKS-Dominant worldview participants believed that God or the divine creator controls everything and causes day and night. The participants recognized this knowledge as having been acquired through family, religion, culture and interaction with the environment. This view was therefore tagged, the "indigenous perception".

On the other hand, participants held largely accurate scientific perceptions that the earth is a spherical planet in the solar system. It rotates on its axis causing day and night, and at the same time it orbits the sun. 1 orbit of the earth around the sun is equal to 365¼ earth days. Seasons occur when one of the earth's poles is tilted towards the sun so the pole or hemisphere that points towards the sun is in summer. The participants held that these views arose from school.

After exposure to the intervention activities, the participants agreed that both worldviews were equally important. As a result, there was an accompanying shift in the teachers' perceptions on integration of science and IKS. Before the intervention, only 2 participants were against integration. After the intervention, all participants viewed integration of science and IK as beneficial for learners. At the same time participants were aware that it would not be an easy task to integrate in astronomy before and after. Before the intervention, only one participant could substantiate assertions about the spherical earth. After the spatial modelling activities, more than half of the participants gave reasons as to why the earth is perceived to be spherical.

### 5.2.2 Question 2

*How does the involvement of pre-service teachers in spatial modelling and argumentation help them to understand the earth in space conceptions better?*

Argumentation enabled the participants to demonstrate cognitive shifts in their understanding of the concept of the earth in space. For example, there were significant changes in the way some pre-service teachers contextualised some of the sub-concepts relating shape of the earth as being spherical. Whereas in the pre-test the participants made unsupported claims about the shape of the earth but after the intervention they made attempts to support their claims. A few went further to describe the condition or context in which a particular conception was valid or otherwise. For example some of them expressed the scientific view about the shape of the ship approaching a harbour in terms of first seeing the mast and other parts before finally seeing the whole body of the ship as it gets to dock. As for the application of argumentation in teaching and learning, many saw argumentation as a good strategy for linking prior knowledge with scientific knowledge.

The use of spatial modelling also enhanced the visualisation of a 3-D earth. Before the intervention, the pre-service teachers tended to describe the earth in terms of 2-D because they referred to charts and pictures of the earth. However, after the intervention there was a significant improvement in their valuing of the use of 3D models to describe the shape of the earth in space. The pre-service teachers were even able to discuss the limitations of the types of models that they chose for specific purposes. For example, the use of: geode shape to illustrate a bulging earth; the earth models to illustrate relief structures such as mountain ranges; and perfectly spherical spheres to illustrate relative sizes of the planets.

### 5.2.3 Research question 3

*What cognitive shifts did the pre-service teachers exhibit in their attempt to use an argumentation/spatial modelling instructional model to implement an integrated science-IK curriculum? How did pre-service teachers use IKS-based spatial models in explaining the earth's structure?*

The participants developed an awareness of supporting their stances with reasons. They also became cautious about the use of generalizations when taking stances especially when dealing with different worldviews. They attributed this in terms of their exposure to the NOSIK. As a result there were shifts in perceptions about similarities and differences between the IK worldview of the earth and that of science. As a result some participants became reluctant to take specific stances. Despite this several participants were very confident in using the models which they made to describe the shape of the earth in space. In terms of TAP they seemed to have a lot of data to back up the choice of materials and design for their models. They also had outlines of the topics for the model. After they had acquired the skills, they were able to design spatial models to suit their teaching needs. For example, they were able to differentiate the sizes and distances between the sun and the earth as vast hence they could not model them to scale. Materials which are readily available such as clay were used. This means that such activities could also be transferred to learners to do so that they can engage their current knowledge with the new knowledge. However, participants invoked caution in using spatial modeling and argumentation, arguing that the classes tended to be noisy and the teacher ran the risk of losing control.

## 5.3 Implication of findings

Involving the participants in doing science through activities in itself invokes dialoguing amongst participants. The participants derived multiple benefits from activity-based learning provided in the study. These included the sharing of content knowledge and learning about each other's culture and beliefs. For example, one of the participants in the study had to help some of his colleagues in naming continents when he realized that they did not know the names of such continents.

On the whole the integration of IK and science through the use of spatial modeling and dialogical argumentation helped the participants to contextualize the scientific and the indigenous descriptions of the shape of the earth in space. Several of the participants also became aware what description (i.e. scientific or indigenous description) was relevant for a given context (Gunstone & White, 2000). The use of these tools, once learned, could also be applied across the curriculum. However, the main drawback as already reflected in the limitations of the study is the fact that our curriculum is heavily assessment - orientated. The current curriculum states the need to integrate science with IKS in its aims, yet it goes silent in the assessment. The implications are captured by the behavior and attitudes of the two participants reported in chapter 3 who declined to participate in the pre- and post test because they were not for formal assessment purposes. Although one of these participants later conceded to have acquired useful skills through the module, the initial attitude is reminiscent of the behavior of other teachers in the field, who are working towards assessment deadlines.



If any major changes are to take place from a teacher centered to a child centered approach, then there should be a revolution in the teaching of science and in the content. Otherwise the IK will continue to be used to introduce concepts as was shown in pre-service TE lesson plans (Angaama, 2012, Diwu, 2010, Ogunniyi & Hewson, 2008).

Argumentation as a teaching strategy puts a learner at the centre of learning and makes science a human enterprise. The use of dialogical argumentation enables learners to use logical reasoning to deduce relationships, much as scientists do. However, for this to happen, teachers will need to be empowered to use argumentation, through training during their pre and in-service professional development. Scholars like Diwu (2010) and Lederman, (2000) have consistently argued that teachers will only use teaching strategies which they are familiar with, so the question to ask is, are teachers familiar with argumentation teaching strategy?

## 5.4 Limitations

The time available for contact with the participants was fixed to two-hour sessions per week for six weeks because there was a syllabus to be covered for the completion of the course. I would have liked to increase this contact time by following the students on teaching practice. However, this was impossible since the teaching practice sessions were carried out before this particular course commenced.

Ethics in research requires a researcher to disclose to participants what the research is about and its purpose. Also I had to explain to them their rights with regards to their participation. Although they all participated, at times there was lack of commitment especially when the participants knew that they would not be assessed. For example for any task given, the pre-service teachers wanted to know if they would be assessed or not. There were assessments done since the intervention was an eight week long module. I was able to persuade all the students to take the pre and post tests in the first and eighth weeks.



The use of pre-post tests introduces instances whereby participants might remember their earlier responses to test items and thus introduce perceptual errors in interpreting cognitive shifts in their understanding. One participant in the group returned the same erroneous response to both the pre and post tests pertaining to the rotation and revolution of the earth. However during the interview sessions, I asked the participant, the same question and he answered the questions correctly. One way to limit this type of error will be to move around the questions in the pre and post-tests so that they do not look obviously identical.

The sample size of 17 participants was too small to provide generalised conclusions about teachers' perceptions on the inclusion of IKS in the teaching of the *Earth in Space* component of the *Earth and beyond* curriculum, although the findings were authentic.

## 5.5 Conclusion

Argumentation as a teaching strategy is a complex teaching strategy. It takes time to master it and to plan it. The teacher needs sound content knowledge on that particular topic and learners need supervision as well to make sure they are all participating. Assigning tasks can limit some of the challenges. Notwithstanding these trivial issues which can be corrected by teacher training institutions, the benefits of using inquiry methods such as argumentation and spatial modelling are empowering for the teacher and learners. Contextualizing school science to include indigenous knowledge practices will be even more liberating for a learner who knows what to learn and how to learn it with the teacher's guidance (Kuhn, 1999).

Spatial modelling was seen as a conceptual model which is physical which can be used for baseline, formative and summative assessment. When used, both the teacher and learners are connected in that they speak on the same topic because of the model. The mere availability of models invokes argumentation intra and inter-argumentation for the participants.

There is so much emphasis on assessment such that if there is no assessment students do not feel the need to work. The research needs to be done and also taken into the classroom to give a clear picture of effectiveness of spatial modelling and argumentation in a classroom situation.

### 5.6 Recommendations

Although the findings were based on a small sample they have shed some light into how two different worldviews can be harmonized in school science to offer learners an education which is relevant and functional to them.

One of the lessons learnt from the study, especially when presenting a scientific topic in a multicultural classroom context, is that conceptual models e.g. the globe can be used to facilitate the learners' understanding of the earth in space or other subject matter. In this regard the conceptual model serves as a bridge to link the learners' conceptions with that of science or IK whichever is appropriate for that given context (e.g. Gunstone & White, 2000; Ogunniyi, 1988, 2004, 2007a & b). The use of spatial models supersedes language barriers and has many advantages if appropriately used. An integrated science curriculum acknowledges that science is a human enterprise which is shaped by humans to better their lives. The integration of science and IKS with spatial modeling assisted the participating pre-service teachers to better understand the cognitive demands of teaching the unit *Earth and Beyond*. The use of the Dialogical Argumentation Instructional Model enhanced the participants' engagement with content that would have been otherwise unfamiliar to them. The shifts in perceptions recorded in sections 4.3, and 4.4 illustrate these benefits.

The findings of this study certainly raise assessment issues. Prospective teachers were concerned that although the new curriculum expects them to integrate IK with science very little attention is paid to assessment of the former. For this reason most teachers do not see the point of including IK in their science lessons when teaching. Although the teachers' complaints are valid a topic should not be taught simply for the purpose of passing examinations. There are other valuable sides to acquiring knowledge (including IK) in terms of the development of essential life skills and cultural values. In most discussions this researcher held with prospective teachers during intervention most of them feel that as long as the curriculum remains assessment based, it will be difficult to teach topics that are not assessed. It is for the same reason that most teachers tend to drill their learners for examination purposes.

My view based on the findings of this study is that teaching and topic taught e.g. the concept of earth in space should go beyond learners passing examinations. For example within the indigenous communities the earth is not just an object to be studied for exploitive purposes as has unfortunately being the case for science, but a place where all living things must find conducive for their survival and therefore worthy of being treated with respect and care. I shall like to conclude this thought which resonates with the indigenous view of the earth. Ogunniyi (1998), drawing inspiration from Bredemeir and Getis' view about our attitudes towards the environment we live in, contends that:

> With the ever increasing danger of exhausting the earth's non-renewable resources and our utter dependence on a balanced eco-system, the whole of humanity faces an uncertain future. Already the most needy individuals and nations are at the verge of being completely cut off from participating fully in the exploitation of the natural resources for the common good of all. In the final analysis we are faced with a bleak prospect (despite our technological prowess) for mindlessly depleting the very resources essential for our continued existence. (p.9)



The perspectives above are certainly worthy of closer attention in future studies dealing with an indigenized science curriculum as briefly considered in this study.

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**Appendices**

**Appendix 1 Consent form**

I ………………………………………… consent to participate in the study being carried out at the University of the Western Cape. The details of what is involved have been explained to my understanding. I do therefore understand my rights in the study.

Signed…………………………………………….

Date………………………………………………..

**Appendix 2**

**The questionnaire**

**Earth and its Biospheres Questionnaire**

The aim of this investigation is to find out how you use indigenous knowledge in teaching the earth's biosphere

**Part A**: Biographical data

| | |
|---|---|
| Name | |
| Surname | |
| Gender | |
| Age | |
| Place of birth(include province) | |
| Home language | |
| Place I grew up (rural/urban ) | |
| Place I did my primary education (include Province) | |
| Place I did my secondary education (include Province) | |
| Religion | |
| Teaching practice school | |
| Location of school | |
| Grade/s taught (include class size/s | |



To make science relevant to learners' home background, Specific Aim 3 of the National Curriculum Statement (NCS) wants science teachers to link what they teach with the indigenous knowledge used in the learners' socio-cultural environment.

**Please complete this questionnaire as candidly as possible.** All the data collected will be treated as confidential your name will not be disclosed to anyone.

**Please answer each question as honestly and as fully as you can**

**Part B: Integration of science and indigenous knowledge**

*(**Indigenous knowledge (IK) the knowledge, practices and beliefs that people in traditional communities use to interpret their experiences through interacting with their local environment)***

For each statement below, **place X** to indicate your view

**Strongly Agree (SA)=5; Agree (A)=4; Uncertain (U)=3; Disagree (D)=2; Strongly Disagree (SD)=1**

| Part B: Perceptions about Science & IK | | | | | |
|---|---|---|---|---|---|
| **Statement** | **SA** | **A** | **U** | **A** | **SD** |
| 1. Indigenous knowledge is distinctly different from science | | | | | |
| 2. Scientific processes are involved in many aspects of indigenous knowledge | | | | | |
| 3. It is beneficial to study indigenous knowledge in a science class | | | | | |
| 4. The basic assumptions of science and IK are similar | | | | | |
| 5. IK is all about witchcraft and superstitions | | | | | |

6. What is your view about the National Curriculum Statement (NCS)'s aim 3 asking teachers to integrate science with IK in teaching?

7. What limitation(s) do you foresee in integrating IK with science if any?

8. State one benefit that you think IK may add to the teaching and learning of science?

9. What challenges do you foresee in integrating science with IK when teaching about the earth and its biosphere?

**Part C**: **The earth and its biospheres**

1. In most languages day and night are expressed as the sun moving from East and setting in the West. a). What were your beliefs about causes of day and night before you learnt the scientific explanation?



1b). What are the sources of your indigenous beliefs about the earth and its biosphere? Place X in the appropriate boxes: Family ☐ Religion ☐ Culture ☐ Others (specify) ☐

1c). What influences your scientific beliefs about the shape of the earth? *Place X in the appropriate boxes*:

Books ☐ Media ☐ School ☐ Family ☐ cultural ☐ Religion ☐ Others (specify) ☐

2). There is a general scientific belief that the earth is spherical although some people also believe that the earth is flat.

***a.*** What is your own understanding of the earth's shape?

***2b).*** What influences your beliefs about the shape of the earth? *Place **X** in appropriate boxes*

Books ☐ Media ☐ School☐ Culture ☐ Religion ☐ Others (specify) ☐

3a). Day and night is caused by the earth spinning on its axis. This concept is very abstract for learners. Rather than rely on 2D text book's explanations, what can you use to help learners to understand the concept?

3b). Is the sun moving around the earth? Yes ( ) No ( )

Explain:

______________________________________________________________________

3c) Is the earth moving around the sun? Yes ( ) No ( )

Explain: ______________________________________________________

***You can use a well labelled diagram for questions 2a to 2c to answer the questions.***

4. A learner asked her teacher the following question, "Excuse me Miss, You say the earth is a sphere and it is always revolving around the sun, how come we don't fall off as it is revolves?"

a). You are the teacher in question, how would you answer this learner's question?

4b).What informs your answer? *Place X to show what applies to you*:

Books ☐ Media ☐ School ☐ Family ☐ cultural ☐ Religion ☐

5). A community realises that pangolins in their area are getting to near extinction. (***See the picture of a pangolin below***) Together with their chief, villagers agree to set up a taboo banning the hunting of pangolins in the area. (*A pangolin is a scaly anteater. They are found in the tropics. Though very rare, in South Africa in Tswalu game Reserve near Kimberly, they have about one hundred pangolins.*).

**What is your view concerning the responses about some myths given by different people?**

Place X on either agree or disagree in a, b and c whichever best reflect what you think and give a reason(s) for your answer

a). It is just one of the myths which characterise indigenous practices.

I Agree ☐ I disagree ☐

Reason:

http://www.wildlifesafari.info/pangolin.html

b). I think this makes sense because the ban will allow the pangolins to repopulate again.

I Agree ☐ I Disagree ☐

Reason:


c). This is similar to setting up banning protocols as usually done in nature conservation programmes for endangered species such as the black rhinos.

I agree ☐ I disagree ☐

Reason:

http://www.naturephoto-cz.com/white-rhinoceros-photo-1337.html

6). What is your view about certain cultural myths, taboos or practices (*e.g. taboo on the use of certain wild fruit trees as firewood, taboo that prohibit the hunting of pangolins etc*) that are used for environmental conservation?

*In 1998 a visiting football team was struck by a lightning bolt killing all the 11 players in the Eastern Democratic Republic of Congo (DRC) leaving the other team unhurt. 30 other people received minor burns. Reports say the teams were at a 1-1 draw when disaster struck.*

http://news.bbc.co.uk/2/hi/africa/203137.stm

7). The picture above shows a soccer player struck by lightning. In certain cultures people believe that lightning can be manipulated or used by sangomas to strike others. What are your views about causes of lightning strikes?

8). Explain causes of lightning strikes to help a learner(s) who agree(s) with the above statement to understand the scientific explanations to causes lightning.

9). Identify one good example and one bad example of some indigenous and scientific practices that you know of; which make the earth sustainable and unsustainable (*making the earth more suitable for human dwelling*)

a). A good indigenous practice that makes the earth sustainable is;

______________________________________________________

b). A bad indigenous practice that makes the earth unsustainable is;

______________________________________________________

10a). A good scientific practice that sustains the earth that I know is;

______________________________________________________



b). A bad scientific practice that makes the earth unsustainable is;

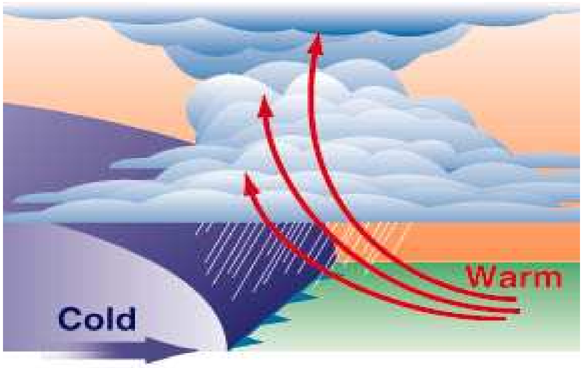
______________________________________________________

11). The biosphere is essential for the survival of all living things.

a) Name one part of the biosphere: ______________________________

b). What is its function?

12). Winter weather in the Western Cape is characterised by cold fronts and rainfall. Use the picture below to explain how rainfall immediately occurs after a cold front.




**Nature can also tell us about the weather. What kind of weather is anticipated with?**

13).The occurrence of dew on the grass in the morning suggests?

14. A cloudy sky combined with restless dogs or cows suggests?

15. List two other weather predictions that you know.

a).



b).

**Part D**: **Argumentation as a teaching strategy in science**

*In Parts B to C, you have been supporting or opposing a particular view about the earth and its biosphere. You have been "arguing" [taking a stance (claim)] and supporting that stance (claim) with reasons (evidence).To express your views or maintain a position requires the use of argumentation in your mind or with others*.

The following section is concerned with finding out how familiar you are with the use of argumentation.

1). In your own words define argumentation?

2a). What is the advantage of argumentation in thinking or discussing an issue with others?

2b). What is the disadvantage of argumentation in thinking or discussing an issue with others?

3). Have you used argumentation during teaching practice? Yes ( )  No ( )

b). Explain:

4a). If your answer to <u>question 3 is yes,</u> what was one success in your argumentation lesson?

4b). State one difficulty you experienced in your argumentation lesson if you answered 4a

**Part E: Spatial modelling and teaching/learning**

***Spatial modelling (SM) here means using 3D shape a model or globe to describe the earth's shape. It also describes the size & space occupied by an object in relation to other objects e.g. the earth in relation to other planets in the solar system.***

*Figure 1*


*Figure 2*

- ***Look at the two examples of images/pictures above and answer the questions that follow***
- **<u>Figure 1</u> above is a 3D globe map of the world/earth, and <u>Figure 2</u> is a 2D flat map of the earth or world.**

1. Based on figures 1 and 2 above, do you understand the picture of the earth's physical features better on a 2D diagram/ flat map or 3D/ spherical globe?

____________________________________________________________

b). Explain;

2. Have you used spatial modelling before? Yes ( ) No ( )

3. List two benefits of describing the earth's structure through spatial modelling if your answer in 2 is yes.

i.
ii.

4. Name a model you have used or made and what its purpose was.

5. Did you achieve your goal? Yes ( ) No ( )

5b. Explain

6. In one of your lessons you want the learners to make a 3D model of the structure of the earth. In this practical, your role is to guide and supervise learners in the construction of the model so that it represents reality as much as possible. **Do you agree?** I Agree ( ) I Disagree ( ).

b. Explain

7. Do you agree or disagree that spatial modelling may act as a useful bridge or link which enables learners to cross from their everyday experiences into the scientific way of seeing the world.

Agree ( ) or Disagree ( )

b. What is your reason or evidence to support your claim?

8. Using a 3D model to teach an abstract concept makes understanding easier.

Agree ( ) or Disagree ( )

b. Give <u>one</u> reason or evidence to support your claim.

9. What do you think are the benefits of spatial modelling in science teaching and learning?

List two;

## Appendix 3  Effects of industrial development on the Biosphere

**The Petrochemical pollution in South Durban:** A case of the South Durban communities' struggles against the exposure to hazardous environmental and sulphur dioxide pollution.

Environmental justice struggles in contemporary South Africa are a legacy of the Apartheid era which is reflected in how spatial planning of the time. South Durban is an industrial capital of KwaZulu-Natal. South Durban has two largest oil refineries in the country. It is home to the largest concentration of petrochemical industries making 60% of SA's petroleum.

The South Durban industrial area also has numerous toxic waste landfills, waste water treatment works, an airport, etc. In total there are 120 industries, hence the area is nicknamed "the Durban poison."

The same area is residence to low income communities of Merebank, Wentworth and Bluff who inhale the toxic fumes. In total there is a population of about 285 000 within the proximity of these toxic industries.

***Large-scale pollution:*** *South African refineries produce approximately 82 tons of sulphur dioxide gas daily. [Retrieved from: http://www.umich.edu/~snre492/brian.html*

*Mail & Guardian, April 28, 2000]*



Use the above information to answer the questions that follow individually:

1. List any 2 likely illnesses to be suffered by residents around the South Durban

2. In what form is sulphur dioxide found?

3. What is the chemical symbol of sulphur dioxide?

    ______________________________________________________________

4. List any two characteristics of sulphur dioxide

    ______________________________________________________________

    ______________________________________________________________

5.
6. Sulphur dioxide is naturally and industrially emitted into the atmosphere.

    Natural emitter ________________________________________________

    Industrial emitter ______________________________________________

7. You are a resident of one of the affected suburbs around the South Durban, in which season would you suffer more as a result of air pollution?
8. Why do you say so?
9. Sulphur dioxide has different useful functions. List any two:

    ______________________________________________________________

    ______________________________________________________________

9. Besides air being polluted, what else is polluted by the industries?

10. Scientists claim that some of the causes of global warming are related to human activities which pollute the environment. Do you agree or disagree?

11. Why do you say so?



## Appendix 4 The analytical framework of TAP

**The analytical Framework table used to assess the quality of argumentation**

**Level 1 argumentation**: consists of arguments that are a simple claim v a counter claim or a claim v claim

**Level 2 argumentation:** consisting of claims with, data, warrants or backings but do not contain any rebuttals.

**Level 3argumentation**: consists of a series of claims or counter claims with either, data, warrants or backings with the occasional weak rebuttal.

**Level 4 argumentation**: have a claim with a clearly identifiable rebuttal. Such an argument may have several claims and counter claims as well but this is not necessary.

**Level 5 argumentation**: displays an extended argument with more than one rebuttal

*Adapted from Osborne, Erduran & Simon (2004)*

## Appendix 5 The instrumentation

| Research Question | Instrument | Rationale |
|---|---|---|
| Q1 | Pre test and post test Questionnaires; 1st reflections | Measured students' ideas about NOS, NOIK including curriculum-integration |
| Q2 | Observation of modelling activities; Part D & E of pre-post test Q; reflections | Measures whether there was any change in perceptions about teaching astronomy through argumentation & SM activities |
| Q3 | Projects presentation-assessment; Argumentation; interviews | To assess the effectiveness of intervention through 1.presentations, 2. Argumentation and 3. final reflections |

*Table 3 1: Instrumentation used in the project*

## Appendix 6 Preservice teachers' conceptions about the earth in space (raw data)

| Question seeking to understand the participants' conceptions about the earth in space | Emerging themes | Pre-test | Post test |
|---|---|---|---|
| 2a. What is your own belief about the earth's shape? | The earth is round that's what I was taught | 1 | 0 |
| | Scientists proved that the earth is a sphere | 2 | 1 |
| | The earth is spherical | 11 | 0 |
| | Satellite images, the horizon and how ships are viewed as they approach the harbour are evidence of a spherical earth | 0 | 2 |
| | My understanding is that the earth is spherical | 0 | 9 |
| | It is round according to the books I used | 0 | 2 |
| 2b. Sources of conception | Media, school and books | 12 | 8 |
| | Culture/family/religion | 2 | 0 |
| | School | 1 | 1 |
| | Books, media, school and family, culture and religion | 0 | 4 |
| | Books and school | 0 | 2 |
| 3a. Rather than rely on 2D text book illustrations and explanations, how can you help learners to understand the day and night | Using models | 8 | 6 |
| | Use models, video, | 0 | 4 |
| | Use the internet | 6 | 4 |
| | Use diagrams showing relative distances | 0 | 1 |

| | | | |
|---|---|---|---|
| concept? | Did not provide answer to question | 1 | 0 |
| 3c. Is the sun revolving around the earth or the earth around the sun? | The earth rotates/spins on its axis and at the same time revolves/orbits around the sun, use a model or video to prove | 6 | 6 |
| | The earth is a place in a specific position to the sun, the sun never moves. The planets in the solar system rotate around the sun. | 1 | 0 |
| | The earth has plates and poles and rotates | 1 | 2 |
| | Gravitational force causes the earth to rotate around the sun | 2 | |
| | The earth moves around the sun due to the change of seasons as well as the position of the stars in the sky as evidence | 4 | 2 |
| | The earth moves around, or orbits the sun. It takes 24 hours for the earth to complete a full orbit around the sun, which is why there are 24 hours in a day [error] | 1 | |
| | Drew diagrams which demonstrates the rotation revolution | 0 | 3 |
| | Blank | 0 | 2 |
| 4a. A learner asked her teacher the following question, "Excuse me Miss, You say the earth is a sphere and it is always revolving around the sun, how come we | Use Newton's laws of gravity theory | 12 | 12 |
| | Use a model to demonstrate | 2 | |
| | Elliptical orbits of the moon round the earth and earth around the sun has a substantial effect on the sea tides | 1 | 0 |
| | Use an example of a ship approaching the harbour, about how it appears from far, and he horizon for inland learners, then discuss about how we have different seasons- for orbiting of the earth and used an example of a journey by bus whereby you do not feel that you are moving when the bus is travelling smoothly | 0 | 2 |

| | | | |
|---|---|---|---|
| don't fall off as it revolves?"<br><br>You are the teacher in question, how would you answer the learner's question? | The earth is round and making use of the earth globe and rope to demonstrate | 0 | 1 |
| **4b.** What informs your answer? | School | 3 | 1 |
| | Books | 2 | 1 |
| | Media | 2 | 1 |
| | School and books/media | 2 | 1 |
| | School, books and media, | 5 | 5 |
| | School, books and media, family and culture/religion | 0 | 6 |
| | Culture | 1 | 0 |

## Appendix 7 Dialogue- The roles of a science teacher

1. What are your roles as future science teacher in South Africa?

Follow-up questions

2. What are your views about bringing indigenous knowledge into a science classroom?

3. Do you think there is a similarity between science and IK?

4. Are you confident enough to teach the concepts about the Earth and beyond from what you have done so far?

5. Do you ever wonder why it looks like there are no scientific discoveries from Africans in books you read?

6. Previously some of you said argumentation causes a lot of noise, what do you think now?

Individual Interviews

1. You agreed that indigenous knowledge is distinctly different from science in your pre-test; do you still think the same?

2. Do you see yourself empowered enough to teach the concepts about the Earth and beyond from what we covered?

3. Do you still think one must be smart in order to do science as you say the teachers do?

## Appendix 8 1st Spatial Modelling of the earth's shape

Reflect on problems relating the construction of a paper sphere.
Was it easy or difficult to accommodate the 2-dimensional Mercator projection?
Which parts were the most difficult to find on the map
Did you learn where places you had heard about were located on the globe?
Which parts were the most difficult to find on the map
What have you learnt from the activities 1.2 to 1.3?
Have you any suggestions for improving or streamlining the activity.

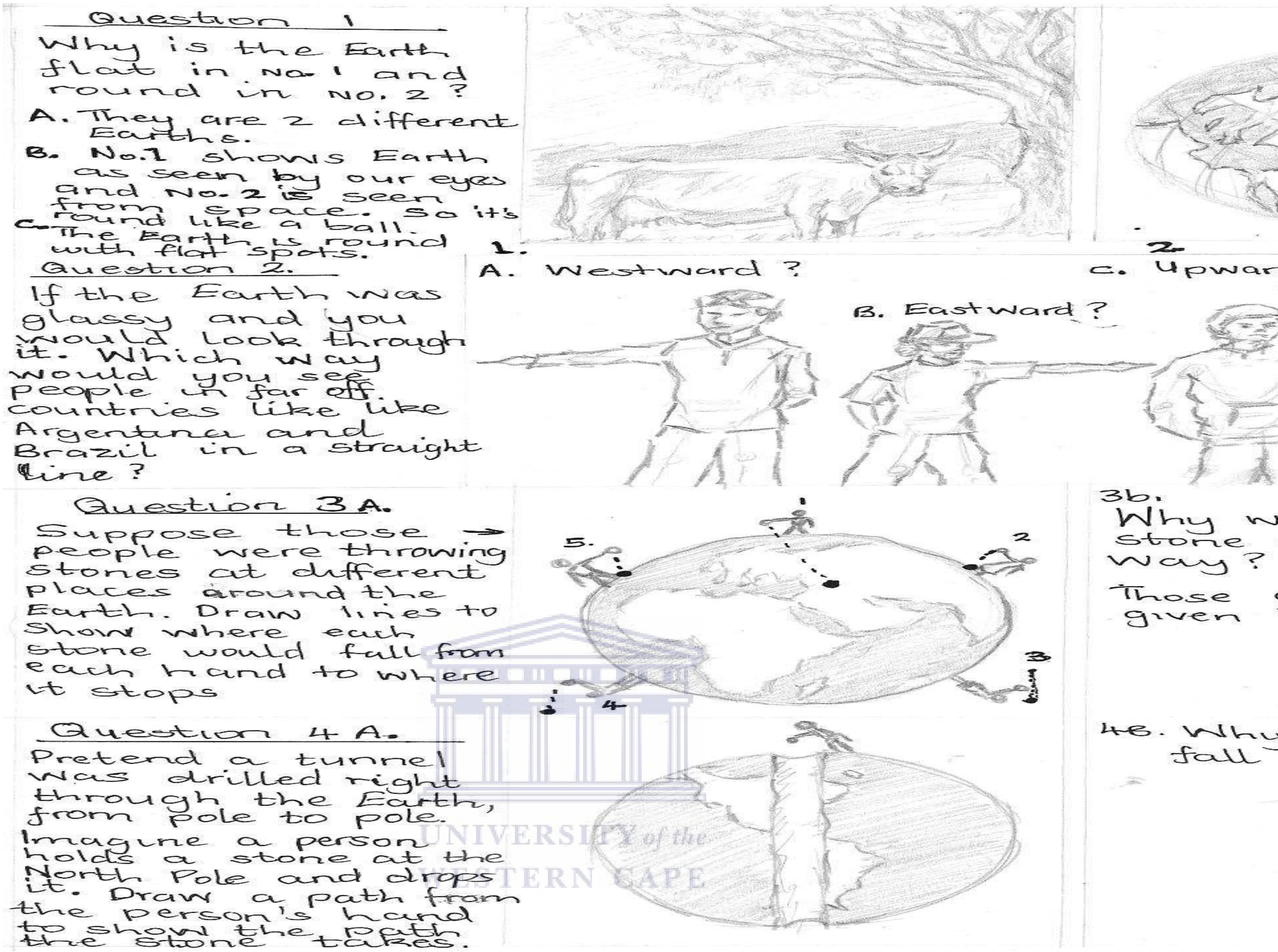
## Appendix 9 Final reflections

These questions are to guide you in reflecting

Reflect on how this course has helped you by looking at:

1. The use of modelling in teaching science topics?
2. What are your views about the use of argumentation as a teaching strategy?
3. What have you personally learnt with regard to teaching astronomy?
4. How do you compare rote learning and learning through hands-on activities?

**Appendix 10 Learners' alternative conceptions about the earth's shape**



## Appendix 11 Pre-service natural science teacher's solar system models

**The solar system model**

**Characteristics of a good model**

1. A good model is reasonable; it should be a true representation of what is known.
2. It should be as simple as possible and expresses itself using very few words, figures or ideas.
3. It is as explicit and clearly communicates what it represents.
4. It is user friendly and it enables people to construct and reconstruct knowledge from it.
5. A good model must be as comprehensive/detailed but simple with all important data to help the understanding of what it represents, usually the abstract data it represents.

Adapted from Ur (2001)

**The Project:**

1. Use the above information in your group to make a model of either;

a. The solar system

b. The earth, moon and sun relationship

**NB**: Try to make your model as representative as possible in sizes of planets, colour, and must be in 3 dimensions. Also try to use recyclable materials.

Your model must have the characteristics listed above. (20)

It must be well labelled (5)

You must explain its uses and grade level/s it can be used (5)

List any activities that you can assign learners to do (which aim/s are applicable and why?) (10)



2. Choose a grade and plan a detailed lesson plan where you will use the model. The lesson plan should have the following sub headings:

**Subject:**

**Topic:**

**Grade:**

**Number of learners:**

**Duration of lesson:**

**Date:**

**Resources:**

**Lesson objective/s [Use measurable verbs e.g. demonstrate, identify etc]**

**Procedure; Step by step activities including time on task**

**Assessment**

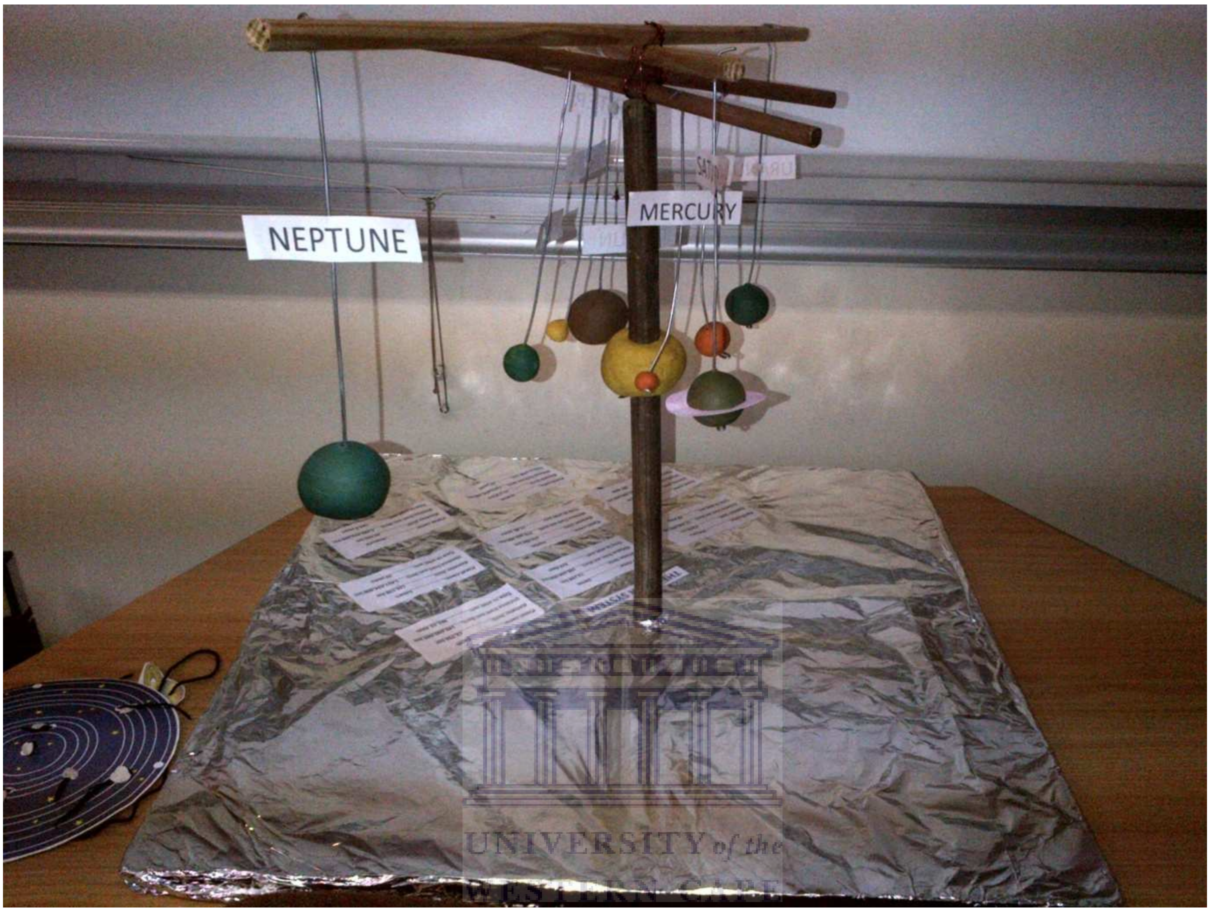
Notes **(Out of 20)**

**Rubric for Model**

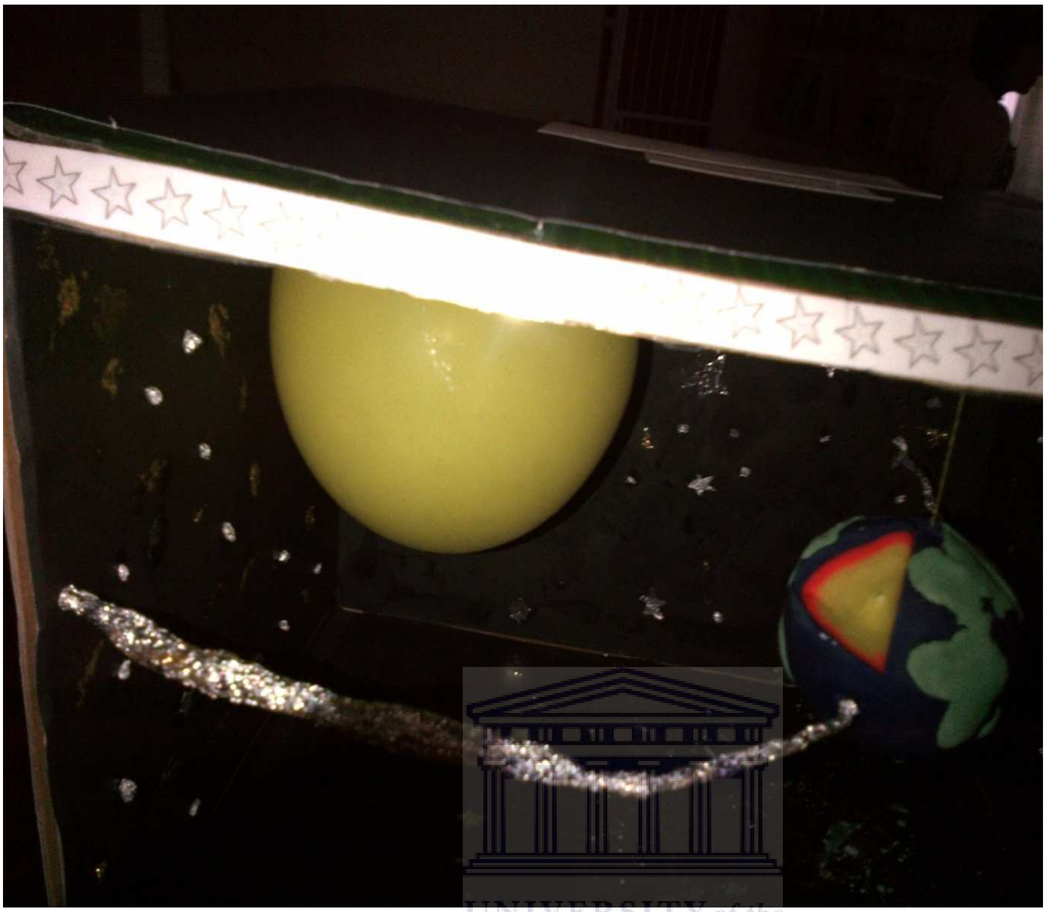
**Names of Students:**

| **Criteria** | **Excellent 5** | **Very Good 4** | **Good 3** | **Fair 2** | **Comments or suggestions** |
|---|---|---|---|---|---|
| **Originality** | | | | | |
| **Size** | | | | | |
| **Simplicity** | | | | | |
| **Labelling** | | | | | |
| **Out of 20** | | | | | |

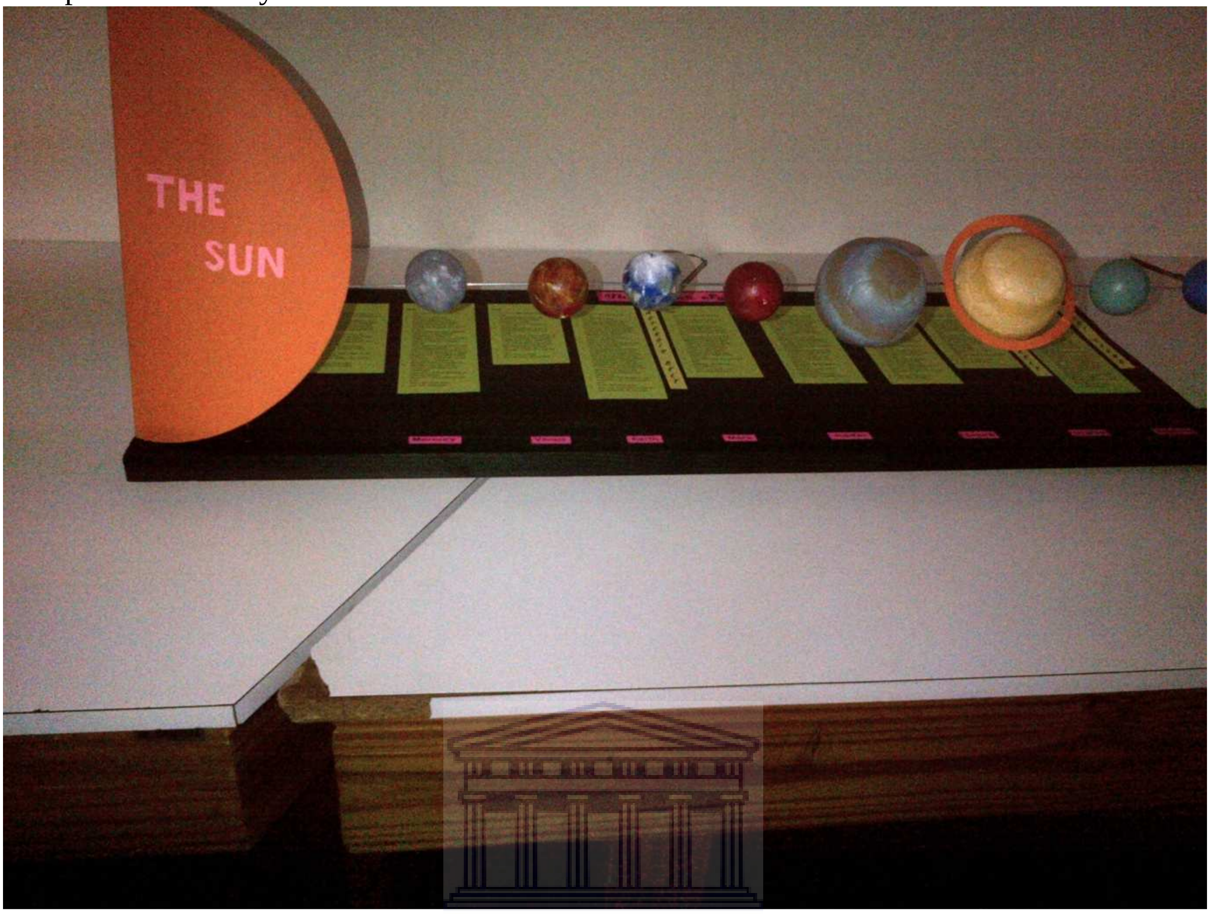
Group A-Solar system Model



**Group B- Earth, moon sun system**



Group C The solar system model



**Appendix 12 Pre-service teachers 'assumptions about science and IK raw data table used for graph in chapter 4 Research question 1**

| Ppts | PRE Q1 | PRE Q2 | PRE Q3 | PRE Q4 | PRE Q5 | POST Q1 | POST Q2 | POST Q3 | POST Q4 | POST Q5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Fariza | 2 | 5 | 5 | 4 | 1 | 2 | 4 | 5 | 4 | 1 |
| Aadam | 1 | 5 | 5 | 4 | 5 | 2 | 5 | 5 | 5 | 5 |
| Mildred | 2 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 3 |
| Liz | 2 | 5 | 5 | 4 | 3 | 5 | 5 | 5 | 5 | 3 |
| Ludwe | 4 | 4 | 4 | 4 | 1 | 2 | 5 | 4 | 4 | 3 |
| Charles | 4 | 4 | 5 | 3 | 5 | 4 | 4 | 4 | 2 | 4 |
| Rafidah | 1 | 2 | 4 | 4 | 1 | 5 | 5 | 4 | 4 | 1 |
| Hassan | 2 | 4 | 4 | 4 | 2 | 5 | 4 | 5 | 3 | 1 |
| Ray | 4 | 5 | 4 | 2 | 4 | 4 | 4 | 5 | 4 | 4 |
| Ashar | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 3 | 5 |
| Tarub | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Petros | 1 | 4 | 2 | 1 | 5 | 2 | 4 | 1 | 3 | 1 |
| Joe-An | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 4 |
| Tahini | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 5 | 3 | 1 |
| Talah | 3 | 4 | 4 | 2 | 3 | 4 | 4 | 5 | 3 | 4 |