THE RELATIVE IMPACT OF AN ARGUMENTATION-BASED INSTRUCTIONAL INTERVENTION PROGRAMME ON GRADE 10 LEARNERS' CONCEPTIONS OF LIGHTNING AND THUNDER

BY

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ABSTRACT

The basic premise of this study was that when a learner is confronted with two contradictory explanations of the same phenomenon, there is cognitive dissonance in the learner as the learner tries to determine which of the two explanations is correct. An argumentation-based instructional intervention programme (ABIIP) was created for and used on and by the Grade 10 learners in order to attempt to ameliorate this cognitive conflict. The purpose of this study was to determine the relative impact of that intervention programme on Grade 10 learners' conceptions of lightning and thunder. The programme was designed to help learners to develop argumentative skills and use the acquired skills to negotiate and harmonise divergent and conflicting explanations of the nature of lightning and thunder that are propounded by different worldviews (Science and indigenous knowledge).

The research design was primarily a case study of 16 Grade 10 learners of the Xhosa ethnic group at a high school in the Eastern Cape Province of South Africa. The Xhosa people are a typical example of a people whose cultural values were undermined and whose voice was silenced by the colonisers and whose local knowledge has been repressed and replaced by forms of Western privileged knowledge and understandings but who remain, deeply and resolutely, steeped in their cultural values and practices, making them a classic example of a people who would battle to harmonise the indigenous and the scientific explanations of natural phenomena. The research instruments used were questionnaires which were administered to learners, educators, community leaders, indigenous knowledge holders and experts to solicit information on causes, dangers and prevention of lightning; individual and group activities as learners went through the lessons on both argumentation and on lightning; follow up interviews and discussions with learners individually or in groups to seek further clarification of the ideas the learners would have raised in their earlier responses to questionnaires or group discussions; guided and reflective essays by the learners to determine the learners' levels of understanding of the major tenets of the two thought systems and the relationship between the two worldviews and to determine the qualitative gain, if any, that the learners got from the intervention programme; observation schedules used by the researcher during participant observation of group discussions and during the lessons on lightning; an achievement test on lightning; field notes used by the researcher for memoing observations and reflections as the research process proceeded; informal and serendipitous sources of information.

The collected data were analysed, mostly, qualitatively. Frequencies, percentages and t-test values were used to express and analyse quantitative data. Aspects of several analytical frameworks that included Toulmin's Argumentation Pattern (TAP) [and its modified versions such as that of Leitao (2000) and that of Osborne et al (2004)] and Contiguity Argumentation Theory (CAT) were used to attach meaning to the collected data and to address the research questions.

The major findings of this study were that while an argumentation-based instructional intervention programme has its challenges, it can help learners to develop satisfactory argumentative skills and to use these newly acquired skills to navigate and synchronise different and sometimes contradictory explanations of the nature of lightning and thunder. The results of the study showed that an ABIIP can broaden, deepen and strengthen the learners' understanding of lightning. Specifically, the research showed the following:

- Initially, the learners equated argumentation with yelling and quarrelling in order to win the argument. They did not bother or were unable to offer adequate or appropriate evidence to support their knowledge claims or to refute their opponents' argumentation. They were preoccupied with their own views, paying little, if any, attention to their opponents' opinions. With more debating activities their views gradually got transformed to the extent that they began to support their claims with valid evidence. Further, they challenged their opponents' arguments as well as required them to justify their claims. In the process, they started to collaborate with each other to build stronger arguments and to shift from one stance or claim to another in light of available evidence.
- At the beginning of the intervention programme, the learners seemed to hero worship science; seeing it as the only legitimate way of explaining natural phenomena and as the panacea of humankind problems. At that time, indigenous knowledge was relegated by them to a belief system that did not have any meaningful role to play in today's modern life. However, the intervention programme seemed to help them to re-examine that earlier position. Besides, the learners developed a deeper and clearer understanding of the two worldviews as well as began to appreciate the importance and complimentary roles of these thought systems in explaining natural phenomena such as the nature of lightning and in their everyday lives.

- At the start of the intervention programme, learners did not think that indigenous explanations of the causes of lightning were valid and useful in any context. All their explanations of the causes of lightning although not always clear or scientifically valid, were nevertheless based on the scientific worldview. Finally, the majority of the learners seemed to accept that the nature of lightning could have more than one possible explanation and that these explanations could come from both the scientific worldview and the indigenous knowledge worldview.

In view of the positive results emanating from the study there is need to support the implementation of the policy of integrating school science with indigenous knowledge using argumentation as an instructional tool.

The study identified several challenges such as the learners' and educators' attitudes towards and expertise in IK and the required resources and support systems that the Department of Education must address or overcome if this policy on integration is to be implemented fully and effectively. Future research could explore the possible impact of an argumentation-based instructional intervention programme in other learning areas outside science education.

KEYWORDS:

Argumentation, argumentation instructional programme, grade 10 learners, school science, western modern science, indigenous knowledge, Toulmin's argumentation pattern, contiguity argumentation theory, conceptions of lightning and thunder, science-indigenous knowledge curriculum

DECLARATION

I, Partson Virira Moyo, declare that **THE RELATIVE IMPACT OF AN ARGUMENTATION-BASED INSTRUCTIONAL PROGRAMME ON GRADE 10 LEARNERS' CONCEPTIONS OF LIGHTNING AND THUNDER** is my own original work that has not been submitted for any degree or examination in any other university and that all the sources I have used or quoted here have been indicated and acknowledged in the reference list.

Signed ----------------------------------- Date --

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First and foremost, my heartfelt gratitude and indebtedness goes to Professor Meshach Ogunniyi, my supervisor, whose constructive input and suggestions stimulated and guided me throughout the course of this research, making it possible for me to do and complete this piece of work. Professor Ogunniyi also made his personal journal articles and other journal articles, spanning over many decades, accessible to me. Not only were these articles helpful in themselves, they also directed me to other extremely useful reading resources. These articles stimulated my interest in indigenous knowledge and this stimulation kept me going. My supervisor also made it possible for me to attend the third international conference on the integration of Western science and indigenous knowledge in October 2011, the first Systematic Review of South African-Mozambican Published Research on Indigenous Knowledge Systems Conference in October 2012 and several workshops and seminars at the University of the Western Cape. I found these conferences/workshops/seminars intellectually very enriching and stimulating. Through these conferences and workshops, I was able to exchange useful ideas with several colleagues through networking.

Ms. De Wet and Ms. B. Mandubu, the Faculty of Education Librarians at the University of the Western Cape library and Mr. Matthew Moyo at the University of Fort Hare library were very supportive and cooperative in helping me access, electronically, the many relevant journal articles from their universities' databases.

I express my gratitude to the Department of Education of the Eastern Cape Province of South Africa, the school and the local community for allowing me to carry out this research with the Grade 10 learners. I also thank the community knowledge holders and other community leaders for their invaluable information on indigenous knowledge on lightning and thunder.

The value of the role played by the Grade 10 learners, who were involved in this research, is beyond descriptive words. Without them, this work would not have been possible. To them I say THANK YOU AND GOD BLESS YOU.

I owe further gratitude to my wife, Memory, and my colleagues and friends (Prof. Almon Shumba, Prof Vitalis Chikoko, Dr. Alfred Henry Makura, Ms. Snodia Magudu, Dr. Neo Paul Liphoto, Mr. Simasiku Siseho, Dr. Emilia Afonso Nhalevilo, and Dr. Emmanuel Mushayikwa) who read portions of this thesis and made valuable comments on how to improve this piece of work. The men and women who agreed to form part of my research team are thanked for the various useful roles that they played during this study.

Any errors, misinterpretation, misrepresentation, omission of information in this piece of work rest with the author of this thesis.

DEDICATION

To my grandchildren, may they be taught meaningful science that extends outwards from their own worldviews.

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CHAPTER ONE

THE PROBLEM AND ITS SETTING

1.0 Introduction

This chapter seeks to highlight the issues that prompted this research and the practical value to education in general and to science education in particular in South Africa and in all nations where science is taught to indigenous populations. The chapter also shows the major components of the whole research process and the research report.

1.1 The contextual background of the problem.

This section seeks to answer the question: What motivated this research? What prompted the study?

Lightning is a subtopic under the topic electrostatics or static electricity which is taught and learnt at Grade 10 level in South African High Schools (Department of Basic Education, National Curriculum Statement (NCS) and the Curriculum and Assessment Policy Statement (CAPS), FET level, Physical Sciences). The learners come from indigenous groups of people who hold very strong views on lightning and on thunder. These learners bring this knowledge into their science classrooms where they are taught another, different, explanation of these natural phenomena. The school explanation is given as the only legitimate way of explaining the phenomena (Ogunniyi, 2006, 2007a). School science will, however, not replace the indigenous knowledge. The learners will continue to have their indigenous knowledge in their hearts and minds (Ogunniyi, 1988). The learner then now has two contrasting worldviews on the same natural phenomena, the indigenous and scientific worldviews. Both are part of the student's quest to make meaning of their lives and of their experiences. If this is not handled carefully, there could easily be cognitive dissonance in the minds of the learners when they cannot choose between the two worlds. This research sought to find out ways of reducing or minimising this possible cognitive conflict.

Having been granted permission by the Tribal Council to do the research in the area, I made extensive observations and interviews with elders who were respected for their wisdom and knowledge. These observations and interviews revealed a rich body of indigenous knowledge and well defined ways of viewing the world. This interaction with the local people raised my awareness of not only the richness of the local lore on natural phenomena but also of its potential usefulness in school science and for scientific research and development. For example, the local people's lightning protective mechanisms could be explored further with a view of making maximum use of promising practices on a large scale in this geographical area that is prone to lightning. Also, could the ability of some of the community members to create lightning, as they claim, be used to generate electricity for use by local communities? Unfortunately, until about the last decade of the last century, due to the colonisation and global spread of Western knowledge systems and technologies, the majority of the world's indigenous knowledge systems were ignored, side-lined, marginalised and classified as 'primitive' or 'non-modern' or 'non knowledge' by the West (Naidoo, 2005). Indigenous knowledge has been largely ignored or marginalised, if not ridiculed, by the school curriculum as the curriculum tended to be biased towards Western forms of knowledge. Writing about the education of American Indians, Bang & Medin (2010, p. 1012) observed that

> Formal education in American Indian communities has systematically undermined the sovereignty and the cultural and intellectual vitality of Indigenous peoples. Formal education has been wielded on Indigenous communities as a tool of assimilation (into the Western culture).

The authors go on to state that, control over the education of indigenous children was systematically and intentionally manipulated as a way to perpetuate values and practices of the dominant culture (Western culture). To these authors, for American Indian community members, memories of school are devastating. The same can be said about the school education of most indigenous people the world over. This is because this side-lining of the learners' indigenous knowledge "has led to the production of science curriculum documents that are irrelevant to the students for whom they are written" (Ryan, 2008).

A mono-cultural, Euro-centric education system, which fails to make use of the learners' existing knowledge and experiences could cause confusion, despondency and disorientation in the learners and might even alienate them from the school. New approaches that respect the epistemological and pedagogical experiences of the learners should be found and used. One way of exploiting the positive virtues of both the indigenous knowledge systems (IKS) and science is to integrate the two systems on an equal, mutually respectful, supportive and cooperative basis (Ng'etich, 1996).

Fortunately, there is now a keen interest in indigenous knowledge systems from academia and political figures from both the West (Snively & Corsiglia, 2001) and amongst the indigenous peoples (Ogunniyi, 2011). Although the motives for the inclusion and acceptance of indigenous knowledge could be driven by economic interests such as in the field of medicinal science (Ogunniyi, 2011), there are those who feel that indigenous knowledge is a legitimate way of trying to understand the world we live in, alongside other knowledge systems as shown below.

Since the 1995 UNESCO World Conference on Higher Education, many institutions of higher education around the world have been called upon to produce teachers who can relate science to the worldviews prevalent in their communities (Ogunniyi & Ogawa, 2008) The authors further contend that with increased global concern about the deteriorating natural or physical environment due to the unwise action of man through the Western scientific and technological systems, educational institutions are being challenged to come up with alternative ways or strategies that could halt this onslaught on the environment and help to restore the damaged environment to a healthier state. One of those alternative ways is the IKS which has shown that man can live in harmony with nature (Mazzocchi, 2006).

In South Africa, the introduction of Curriculum 2005 in 1997 saw a directive that compelled schools to integrate school science and indigenous knowledge in their science lessons. Learning outcome 3 of Physical Sciences, for instance, focuses on the Nature of Science and its relationship with technology, society and the environment when it states that

> The learner is able to identify and critically evaluate scientific knowledge claims; recognizing, discussing and comparing the scientific value of knowledge claims in indigenous knowledge systems and explain the acceptance of different claims (Department of Education, 2003, p. 14).

It seems clear that the new directive is that indigenous knowledge should be integrated in science lessons in South African schools. Later versions of Curriculum 2005 (C2005) such as the National Curriculum Statement (NCS) which was first examined in 2008 at Grade 12 level and the Curriculum and Assessment Policy Statement (CAPS) which came into effect starting with Grade 10 in 2012 have continued to call for the inclusion of indigenous knowledge in science lessons.

Although the directive is not clear on whether the two systems should be accorded the same status or whether schools should borrow from IKS to teach science, the move acknowledged the importance of IKS and paved the way for its inclusion in mainstream science lessons.

Such an education system would require teachers who are knowledgeable about the main tenets of both the IKS and school science; who are skilled in integrating the two systems; who can help learners to converge the two worldviews; who are able to cognitively border cross between the two worldviews without being confused and who are able to help the learners to do the same (Aikenhead & Jegede, 1999; Department of Education, 2002).

From the above and as we shall see later, integrating the two systems appears to be difficult since it has a lot of potential challenges. It will require careful planning and effective strategies. One such strategy is argumentation which is a tool that can be useful in resolving or harmonising two contrasting worldviews (IKS and school science).

There is a growing feeling that argumentation is important in many spheres of life as demonstrated by the number of policy documents produced the world over (Erduran & Jime'nez-Aleixandre, 2008). According to these authors, citizens across the world need to deal with a vast set of information and be able to evaluate such information, arguing with evidence to deal with their choices. This requires the skill of argumentation. The authors go on to say that internationally, the phrasing of the national science curricula has begun to incorporate more of an emphasis on the need to teach students the skill of interpreting, evaluating and debating information. In short, science curricula are putting an emphasis on the skill of argumentation.

I now quote some of the science curricula referred to by Erduran & Jim'enez-Aleixandre (2008).

The Programme for International Mathematics and Science Study Assessment Framework (PISA) emphasise the role of argument when it states that

> An important aspect for young people is the capacity to draw appropriate and guarded conclusions from evidence and information given to them, to criticise claims made by others on the basis of the evidence put forward, and to distinguish opinion from evidence-based statements. Science has a particular role to play here since it is concerned with rationality in testing ideas and theories against evidence from the world around us (OECD, 2003, p.132 in Erduran & Jim'enez-Aleixandre, 2008, p.16).

> (PISA is an internationally standardised assessment that was jointly developed by participating countries and administered to 15 year olds in schools (Erduran & Jim'enez-Aleixandre, 2008, p. 16).

In the United States of America, in the upper secondary school, the Qualification and Curriculum Authority states that "*How science works*" focuses on the evidence to support or refute ideas and theories. The evidence comes from a collection and creative interpretation of data (QCA, 2007 in Erduran & Jim'enez-Aleixandre, 2008).

In Turkey, the national reform efforts have promoted informed citizenship where citizens make evidence-based judgements in their everyday lives. Some of the curricula goals are

> To encourage students' argumentation and evaluation of alternative ideas; to mediate debates and activities in a way so as to allow for the possibility of students' own construction of scientifically accepted ideas and mind sets; to encourage students' skills in generating hypotheses and alternative interpretations in explaining phenomena (MEB,2005, p. 15 in Erduran & Jim'enez-Aleixandre, 2008, p.18).

Aikenhead & Jegede (1999) contend that science learning amongst students in former colonies rests on two pillars which are the ability of the students to move between their everyday life-world and the world of school science, a phenomenon known as cultural border crossing and the ability of the students to deal with cognitive conflicts between the two worlds, a phenomenon known as collateral learning. The authors further say that success in science teaching and learning depends on the degree of cultural differences that students perceive between their life world and their science classroom; how effectively the students move between their life-world culture and the culture of the school science; and the assistance students receive in order to make those transitions easier.

This research came up with an intervention programme that was aimed at helping the students to acquire the skills of argumentation and then use those skills to integrate knowledge on lightning from two different worldviews.

This study investigated the relative impact of an argumentation-based instructional intervention programme on Grade 10 learners' conceptions of lightning and thunder as depicted by the two worldviews.

1.2 Purpose of the study

The aim of the study was to examine the possible effect of an argumentation-based instructional intervention programme on Grade 10 learners' acquisition and use of effective argumentation skills to deepen and broaden the learners' understanding of lightning and thunder by harmonising and integrating school science and indigenous knowledge explanations of the phenomena.

1.3 Statement of the research questions

To achieve the above aim, the following questions were addressed:

The overall or overarching research question was: What is the relative impact of an argumentation-based instructional intervention programme on Grade 10 learners' ability to construct an argument and their ability to use argumentation skills to deepen and broaden their level of understanding of the nature of science and indigenous knowledge and of lightning and thunder?

Specific research questions were:

1.3.1 What are the pre-post levels of the learners' ability to construct an argument?

1.3.2 What are the pre-post levels of the learners' knowledge about

1.3.2.1. the nature of science and indigenous knowledge;

1.3.2.2. lightning and thunder?

1.3.3 What challenges are experienced when using argumentation to integrate indigenous knowledge and school science on lightning and thunder?

1.3.4 What benefits are accrued when using argumentation to integrate indigenous knowledge and school science on lightning and thunder?

1.4 The assumptions of the study.

This research took the following for granted:

The learners who took part in the research have deep seated beliefs on the causes, dangers and prevention of lightning and thunder and that these beliefs are at variance with school science explanations of the same natural phenomena.

The integration of the two distinctly different worldviews, although difficult, is possible and would result in better understanding by the learners of the explanations, given by the two worldviews, of natural phenomena. This assumptions was based on Ogunniyi's (2011) view of an 'alloyed knowledge' which is an amalgamation of knowledge from different thought systems which the author claims is better rooted than knowledge from either worldview. The assumption is also based on the commonly accepted notion that no culture is superior or inferior to another and that no culture is adequate on its own. In education, this means that a multicultural curriculum would be better than a mono-cultural curriculum. The importance of this approach lies in the belief that it "deepens students' community-based ways of knowing and---supports the learning of Western modern scientific understandings" (Bang & Medin, 2010, p. 1009).

Another assumption made was that classroom interaction which is centred on students' active learning and which takes into account the students' prior knowledge and where the focus of the students' work and activities is on reasoning and reflecting on their own learning, constructing, reconstructing and evaluating their and other people's knowledge would lead to effective learning (Duschl & Osborne, 2002). It was also assumed that the intervention programme would teach the learners other important skills and values such as critical thinking and team work spirit and that they would be able to apply the knowledge and the skills they learnt in the science curriculum area to other areas within and outside the school curriculum (transfer of learning).

I anticipated that the general unwillingness of the learners to argue with their peers and especially with elders and those in authority, would wane with time as the learners came to realise that every idea, no matter its source, was taken seriously in this study and during the intervention programme activities. It was hoped that the students would become more active and willing to take part in this research and in school science once they realised that this research and school science were relevant and useful in their communities (Aikenhead, 2006 in Bang & Medin, 2010). It was further assumed that the indigenous explanations of lightning and thunder that I got from the learners and the community were genuine and accurate.

1.5 The scope and limitations of the study.

The following were considered potential weaknesses in the study. Ways of ameliorating them are suggested.

Indigenous knowledge about the causes, dangers and prevention of lightning and thunder was collected from the learners, educators, community leaders, community knowledge holders and relevant literature. It is difficult to ascertain the authenticity of the knowledge of some of these sources of information. For example, one harbours the fear that the long exposure to Western influence may have eroded the community's knowledge base on lightning and thunder. The community may also have felt uncomfortable to talk openly and truthfully about their culture to a foreigner and stranger who could not communicate very well in their language. Authentic knowledge on lightning and thunder was needed in order to design an appropriate instructional and learning programme.

After having stayed in the village with this community since 2008, one hoped they had begun to trust me and to take me as one of their own. At a Traditional Council meeting, the Chief of the community introduced me to all the community leaders in the area who accepted me as their ‘son’ and promised to work with me in my research. I also incorporated one of their own (a respected local man who was teaching History and Xhosa at the school where I was stationed) to help me in getting information from the community. The other non-controversial sources such as relevant literature were also used.

Related to the above limitation is the observation that

> It is difficult to fully capture the cultural imagery, meanings and nuances associated with a form of knowledge with which one has little or no direct experience. It is a well-known fact that the same words or statements in the same language may convey completely different meanings depending on the cultural context in which they are said (Ogunniyi, 2004, p. 290-291).

Ryan (2008, p. 667) talking about the same concept says “--- certain words in a narrative do not have the references of ordinary language. --- these words communicate that which ordinary language does not.”

The inclusion of a local linguist in the research team was meant to overcome this challenge. He would supply the hidden meaning. (For example at the Tribal Council meeting one elder said to me ‘*When it is raining, take shelter in us.’* Later I was made to understand that the elder was saying that I was well protected by them and that should I come across any problems such as xenophobic remarks or attacks I should seek their protection.)

Both integration, especially of controversial issues such as causes and prevention of lightning, and argumentation present a lot of challenges as indicated elsewhere in this thesis. The duration of this study may have been too short to bring about the desired transformation in the learners. In their study, Zoller et al. (2000, 2002) in Osborne, Erduran & Simon (2004) found that one semester was too short a period to develop high order cognitive thinking and that a systematic longitudinal persistence is necessary to achieve significant outcomes. It was hoped that the intensity and the quality of my intervention programme would compensate for the short duration of the intervention. ‘A short period’ is relative: I had 100 hours of activities with my research participants. Other researchers such as Zohar & Nemet (2002) claim that they found significant improvement after a relatively short intervention period on argumentation

In general, adults in this part of the world (Southern Africa) normally expect children to be seen and not heard, and obedience is usually manifested in unquestioning acceptance of the views of elders and superiors, and especially of teachers (Ogunniyi & Hewson, 2008). These learners may have been made to believe that some sources of information possess “epistemic authority" (Bricker & Bell, 2008, p. 487). Such sources include parents, teachers, older peers, people who have more schooling than themselves, books, the television etc. Any information from such sources is believable by the learners and rarely, if ever, questioned. The learners could even use such sources as evidence for their claims, if called upon to justify those claims (Bricker & Bell, 2008). Given this social background, it was feared that the learners would not quickly embrace argumentation, especially with those in authority. To minimise the impact of this problem, most of these discussions were between the learners themselves, who had the same educational background, so that the influence of the educator and other factors were minimised. Here I was informed and guided by Naylor, Keogh & Downing (2007) who found that "argumentation appeared to be more productive in the absence of the teacher with teacher presence (not necessarily intervention) having an inhibiting effect" (p. 37). As a result, I was as inconspicuous as I could possibly be, only coming in when the need really arose.

Bricker & Bell (2008) quote Kuhn (1992) who claims that she found that higher educational attainment levels increased one's ability to argue effectively. One wonders if Grade 10 learners can be said to have these high educational attainment levels. I was, however, encouraged by the work of a colleague working on the Science Indigenous Knowledge Systems Project (SIKSP) at UWC in the Western Cape and by Naylor, Keogh & Downing (2007) who claims to have had very fruitful argumentation sessions with nine year olds.

Bricker & Bell (2008) further observe that young people associate the concept of argument with social dispute "where yelling and fighting" are legitimate ways of winning an argument (p.494). The authors ask of these young people: "If they are now asked to 'argue' scientifically, what impact do their meanings attached to the word 'argument' have for successful engagement with that endeavour?" Throughout this study, I emphasised to the research participants that the debates were not war zones and that there were no winners or losers.

The research participants, the Grade 10 learners, are quite familiar to each other, having grown up together in the same or adjacent villages and having attended the same primary and secondary schools. Familiarity might work against effective argumentation. Sarangapani (2003) in Bricker & Bell (2008, p. 487) states that "in everyday life, if one trusts a speaker or a source of knowledge, then one will believe the claims espoused by that source of knowledge, even given slight evidence." The children in her study would only question and demand evidence from those they did not trust. In this research, participants were told not to accept or reject any knowledge claim without evidence.

If the learners are limited in their understanding and use of English as the language of communication, teaching and learning, then language would become a barrier to the success of the intervention which depended heavily on discursive discourses. Only learners who were judged to be good at English were selected for this study. In addition, the learners were allowed to use a language they felt comfortable in and to code switch whenever the need arose. Someone good at both English and the local language was asked to help in the translation of the scripts and tapes.

Most of the research instruments including the argumentation-based intervention programme were specifically tailored for this group of learners and for this research. Although the instruments were pilot studied, and their validity and reliability coefficient calculated and found to be very high (0.99) and although they were commented on by experts in the field, the research instruments may not be as valid and reliable as they ought to be.

This is a case study drawing its data from a group of 16 learners in one class in one school. It would be over ambitious to generalise these results to the population of learners in the Eastern Cape Province of South Africa. However, the researcher believes that significant insights on integration and argumentation, when two different worldviews come together, were elucidated. Such insights could be used as the beginning of future studies in this area.

Even where theoretical frameworks such as TAP and CAT exist, the evaluation of the quality of statements that are produced by people in an argumentative discourse is not easy. For that reason, this research used an eclectic approach where aspects of the above frameworks and other theoretical frameworks that were judged to be useful for this study were employed.

1.6 The delimitations of the study.

The following were taken as the physical and conceptual boundaries of this study.

The integration of science and IKS is much broader than the integration of the two knowledge systems in the explanation of natural phenomena such as lightning and thunder. Other areas of interest include indigenous agricultural practices, the potential value of indigenous medicinal plants, symbiotic harnessing of natural resources, climatic change, loss of biological diversity, and genomics. This study limited itself to the study of the integration of the two knowledge systems in terms of lightning and thunder.

Examples of the beliefs on these two natural phenomena amongst other indigenous people of Africa are cited here just as exemplars. The study concentrated on the beliefs, knowledge and practices related to lightning and thunder of the Xhosa people of the Eastern Cape in South Africa. Science here means school science.

Factors that could have had some influence on the learners' perceptions about science, indigenous knowledge and lightning and thunder such as age or grade level, gender, home background were not considered important for this study since, except for gender, the rest of the factors were the same for all the learners. The learners came from the same villages where they had grown up and all of them where doing Grade 10 in the same class.

This research is anchored in the qualitative research paradigm. Robust statistical calculations such as those that can be done with the Social Science Statistical Package (SPSS) which work well with quantitative data, especially with data concerned with categorical variables such as age, educational levels, gender differences etc. were not found applicable in this study. However, statistical presentation and analysis such as using the t-test values was done wherever it was felt that such treatment of data would bring out more meaning.

1.7 The significance of the study.

It was believed that this study would be of some importance to various stakeholders in education.

South Africa is a multicultural country where learners come from a range of very different communities and cultures and therefore have varying home explanations of natural phenomena (Sadeck, 2006). "Today's science classrooms are meeting and learning places with a variety of cultural and ethnical backgrounds" (Onwu, 2009). This means that learners will bring from their homes different explanations of phenomena that will be taught in the schools. If the schools teach the learners explanations that differ from what they already know, the learners are likely to be disoriented and confused. It was hoped that this study would shed light on how schools should help learners deal with contrasting explanations of natural phenomena.

It was hoped that the skills of argumentation that a science teacher developed in the learners would not only help in their science lessons, but in other subjects and outside the school in their everyday lives. Learners, and other citizens, are constantly confronted with socio-scientific issues such as abortion, genetically modified organisms, euthanasia, sports and drugs, plastic surgery and many others that they must debate on. They have to explain, convincingly, why they choose one view rather than the other. The existence of these contrary views on many issues, in society and in the everyday lives of the learners, requires that the learners and other members of society acquire the skills of negotiating controversies and the skill and desire to reappraise one's belief systems in order to allow the emergence of new thoughts and perceptions (Leitao, 2000). The people need the skill of argumentation to do this.

This research is based on the premises that indigenous knowledge (IK) is important. Such a stance helps correct past errors where IK was not considered important. The study gives indigenous knowledge systems (IKS) an opportunity to regain their rightful position in the academy alongside other knowledge systems.

Lightning deaths in South Africa are about four times higher than the global average with more than 100 deaths recorded per annum (Source: p. 34 of *Earth and beyond* booklet presented at the *3rd International Conference on the Integration of science and indigenous knowledge systems*, University *of the* Western Cape, South Africa, 2011). The learners are likely to have witnessed or heard about the devastating effects of lightning. (One of our Grade 12 learners was in a room where lightning struck. Although he came out from the ordeal with no physical damages, one cannot fail to wonder the possible psychological impact of the tribulation on the learner. The parents had to take him to a *sangoma* for counselling and to clear him from possible future attacks since the belief is that such a person would be struck again). Various beliefs, myths are attributed to lightning. It seems reasonable that the school system, being the social institution mandated to educate the young ones, must make an effort to help the learners to interrogate their beliefs and the scientific explanations in order to come up with a better understanding of these natural phenomena.

With the coming of Western influence, it is quite possible that indigenous knowledge base on natural phenomena such as lightning would fade from the communities. This would be a tragedy. This study makes a humble attempt to revive interest in the indigenous knowledge systems on natural phenomena and to "provide empirical evidence of the feasibility or otherwise of a Western science-IKS curriculum" (Liphoto, 2009, p.12).

1.8 Definitions of key terms.

The following are brief explanations of some of the terms used in this study.

Argumentation: Articulation of adequate and appropriate, theoretical and empirical evidence to support or refute a knowledge claim.

Worldview: Sire, Phillips & Brown, and Walsh & Middleton in Solomon (2007) define a worldview as: a set of presuppositions or assumptions which we hold consciously or unconsciously about the basic make up of our world; an explanation or interpretation of the world and an application of this view in life; a model of the world which guides its adherents in the world. Ogunniyi (1984) in Ogunniyi (2008b, p. 78) defines a worldview of a society as "prevailing cosmology influencing or controlling the behaviour of the members of that society."

For this research, a worldview will be taken to mean: a set of beliefs about the world, how it works, how it affects us and how we affect it. A worldview determines our thoughts and our actions.

Indigenous knowledge: A cumulative, sum total, body of knowledge and practices, peculiar to a group of non-western people living in one geographical area that describes a long term relationship of living organisms with one another and with their physical environment which covers all aspects of life and has evolved over many centuries and has been passed from one generation to the other (Berkes,et al. 2000; Living Knowledge Project, 2008).

School science: A system of knowledge which relies on certain facts, laws, theories that are thought or believed to have been established through the application of the scientific method (Living Knowledge Project, 2008) and which claims that its knowledge is objective, value and culture free, and universal (Siegel, 2002). It is the science that is taught in the South African schools. This science originates from or is influenced by the so called Western science or Euro-centric science.

School science-indigenous knowledge curriculum: "a convergence of traditional knowledge and Western science" (Castillo, 2009) in the classroom where explanations of natural phenomena from both knowledge systems are taught to learners of all cultures on an equal footing (le Grange, 2004). Ogunniyi (2011) calls it the 'alloyed knowledge', which means a mixture of school science and indigenous knowledge melted together to form a more robust and durable type of knowledge.

Lightning: A discharge of a large amount of energy through space between clouds or between clouds and the earth (ground) (Uman, 2001 in Woo, et al., 2007) as a result a potential difference that is created when the cloud and the ground become charged with different charges, one negative and the other positive.

Natural phenomena: A non-artificial event in the physical sense, not produced by humans, but which affects humans. Examples of natural phenomena are meteorological phenomena such as hurricanes, tornadoes, lightning and thunder and geological phenomena such as earthquakes and volcanic eruptions.

For this research natural phenomena will mean lightning and thunder.

Socio-scientific issues: Sadler (2004, p. 513) defines socio-scientific issues as: issues that encompass social dilemmas with conceptual or technological links to science; scientific issues with social ramifications; dilemmas influenced by both social and scientific factors; scientific issues that display a degree of societal interest, effect and consequent.

For this research, a socio-scientific issue is a controversial science-based issue in society where several different opinions or views on it exist which would require a citizen to make informed decisions about. Questions about whether it is right and acceptable or not are asked when dealing with socio-scientific issues. Socio-economic issues include: genetically modified organisms, plastic surgery, sports and drugs, euthanasia, abortion etc.

Theoretical frameworks: These are theoretical underpinnings which help researchers to anticipate possible outcomes and hence ask appropriate research questions, guide their choice of research design and assist in the interpretation of the collected data (LeCompte & Preissle, 1993 in Sanders, 2006). From these theoretical frameworks we get analytical frameworks which are the 'lenses' through which the collected and presented data are analysed and interpreted. For this study, TAP and CAT are some of the analytical frameworks used.

1.9 Acronyms and abbreviations used in the study.

- ABIIP Argumentation-based instructional intervention programme
- ATLT Achievement test on lightning and thunder.
- BAAS British Association for the Advancement of Science
- CAPS Curriculum and Assessment Policy Statement

- CAT Contiguity Argumentation Theory.
- DAI Dialogical Argumentation Instruction
- DECO Debate on explanations of common occurrences.
- DOCP Debate on controversial positions.
- DOCCI Debate on common controversial issues.
- DST Department of Science and Technology
- ESIKS Essay on Science and Indigenous Knowledge.
- EWIG Essay on what I gained during this research process.
- FET Further Education and Training.
- GET General Education and Training.
- IK Indigenous knowledge
- IKS Indigenous Knowledge Systems.
- LOA Lesson on argumentation
- LOSEL Lesson on static electricity and lightning.
- NCS National Curriculum Statement
- NOS Nature of science
- NOIKS Nature of indigenous knowledge systems
- OSGDA Observation schedule on group discussions focussing on argumentation.
- OSLSELR Observation schedule on lessons on static electricity and lightning.
- QIKLT Questionnaire on indigenous knowledge on lightning and thunder.
- RE Reflective essays.
- SIKSQ Science-IKS questionnaire.
- SIKSP Science and Indigenous Knowledge Systems Project
- TAP Toulmin's Argumentation Pattern.
- WMS Western Modern Science

1.10 Organization of the thesis.

This thesis is made up of five chapters whose contents are highlighted below:

1.10.1 Chapter One: The Problem and its setting.

This chapter looks at what prompted this research, the questions it sought to answer and the importance of those questions and their answers to the education system in South Africa and wherever indigenous people are exposed to a worldview that is different from their own. The possible challenges to the research process are also highlighted.

1.10.2 Chapter Two: Review of related literature.

The chapter examines relevant literature on the meaning and importance of the process of argumentation in integrating two differing worldviews to groups of indigenous people. Promising strategies that could be used to overcome or reduce possible challenges to this process are explored. Specifically, the literature looks at how indigenous learners cope with the challenges of border crossing from their contextual and experiential conceptions of natural phenomena to the scientific explanations of the same natural phenomena and vice versa.

1.10.3 Chapter Three: Research design and methodology.

The main focus of this chapter is to explain the methods and strategies used to put together the research team and participants and to collect, analyse and interpret the research data. Steps taken to construct and validate the research instruments used in the study are clearly described and illustrated. The chapter also gives a detailed explanation of the argumentation-based instructional intervention programme that I put in place and used with the learners.

1.10.4 Chapter Four: Data presentation, analysis and discussion.

This chapter presents and analyses the collected data qualitatively (mostly) and quantitatively. The analysis makes use of the analytical frameworks that were found to be useful for this study. The major purpose of this presentation and analysis is to compare the pre-post learners' knowledge and skills. The chapter also relates the research findings to the research questions and to the reviewed literature in order to find areas of congruence and those of divergence. Possible explanations for both the convergence and the divergence of these findings are offered. Specifically this chapter tries to evaluate the relative impact of the argumentation-based intervention programme on the learners' skills of argumentation, their understanding of the nature of science and IK and of lightning and of thunder.

1.10.5 Chapter Five: Summary, implications and reflections.

A summary of the major findings and their implications for the education systems where indigenous learners are exposed to worldviews different from their own are highlighted in this chapter. The chapter also reflects on lessons and experiences gained by both the researcher and the research participants.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.0 Introduction

This chapter examines research studies done among indigenous populations on the relative impact of argumentation in trying to mediate the integration and harmonisation of explanations from science and from indigenous knowledge about natural phenomena. The chapter shows the views of different authors on an issue and provides a reflection of what the authors are saying.

Before looking at the possible strategies and possible benefits of integration and argumentation, we need to look at key concepts that are central to issues under discussion. These include the meaning and major tenets of indigenous knowledge systems and of science, the meaning of integration and of argumentation.

2.1 The meaning of indigenous knowledge systems (IKS).

2.1.1 Who is indigenous?

Aikenhead & Ogawa (2007, p. 554) see indigenous people as

> the descendants of the first people to inhabit a locality, who self-identify as members of a collective, who are recognized by other groups or by state authorities, and who wish to perpetuate their cultural distinctiveness in spite of colonial subjugation and pressures to assimilate. They generally share a collective politic of resistance arising from commonly shared experiences of oppression, marginalization, economic servitude, and social cultural genocide.

The Xhosa people of the Eastern Cape Province of South Africa, who are the focus of study in this research, and many other African groups on this continent, are, by this definition, indigenous peoples in their geographical areas. Other indigenous people would be found elsewhere outside Africa such as the Aborigines in Australia, the Maoris in New Zealand, and Aborigines in Canada.

2.1.2 What is indigenous knowledge?

Indigenous knowledge is a term used to describe the social, physical, spiritual understandings of non-western people acquired through a long association with their environment which have contributed towards their survival and their sense of being part of this world (Berkes et al. 2000; Department of Education, 2002; Mazzocchi, 2006; Odora-

Hoppers, 2002; Ogunniyi & Ogawa, 2008). It is holistic in that it encompasses science, technology, religion, philosophy, politics, language, culture, practice, spirituality, mythology, customs, and the social organisations of local communities (Castillo, 2009). It emphasises inclusiveness, relatedness, pluralism, holism, and the complementary nature of all human experiences (Ogunniyi, 2011). Kaniki & Mphahlele (2002) define indigenous knowledge as

> a cumulative body of knowledge generated and evolved over time, representing generations of creative thought and actions within individual societies in an ecosystem of continuous residence, in an effort to cope with an ever changing agro-ecological and socio-economic environment. It is the sum total of knowledge and skills possessed by people belonging to a particular geographical area, which enables them to benefit from their natural environment. Such knowledge and skills are shared over generations, and each new generation adds and adapts in response to changing circumstances and environmental conditions (p. 3 - 4).

Ogunniyi (2008b) adds that indigenous knowledge is knowledge that has evolved from a local community based on the community's own creativity and intellectual processing systems. It is "the accumulated experiences and problem solving approaches that have been used by a local community or ethnic group over several generations that enable such a community to live harmoniously with its bio-physical environment" (p.35). Ogunniyi further states that indigenous knowledge is not an imported or imposed idea from the so called superior worldview perspective. This does not mean that indigenous knowledge is incapable of borrowing and assimilating positive aspects of other knowledge systems. Indeed, the author posits that while indigenous knowledge is "knowledge that has not been borrowed from another locality or culture", he acknowledges that it is knowledge where if parts of it have been borrowed from elsewhere, that borrowed knowledge "has become so assimilated into the new culture that it is difficult, if not impossible, to identify its original character or foreignness" (p. 34.).

From the foregoing, one could state that when a borrowed idea or practice has become assimilated to the point of being indistinguishable from ideas or practices of the recipient culture, it can be regarded as indigenous to that culture. In other words, indigenous knowledge is "vibrant, dynamic, creative, deep, rational, progressive, modern", accommodative, living and fluid and far from being "static, moribund, petrified, shallow, uneventful, unimaginative, mystical, irrational or primitive as certain earlier anthropologist have tended to portray it" (Ogunniyi, 2008b, p. 34). The author goes on to state that indigenous knowledge "is a wealth of knowledge in every group of people which is not easily accessible to other groups for reasons of differences in language and other cultural barriers" (p. 34).

Ogawa (1995, p. 585) proposes that every culture has its own science which he refers to as "indigenous science" which he takes to mean "a culture-dependent collective rational perceiving of reality" where collective means "held in sufficiently similar form by many persons (in that community) to allow (effective) communication." Hardesty (1977) in Snively & Corsiglia (2001, p. 10) describes indigenous science as "the study of systems of knowledge developed by a given culture to classify the objects, activities, and events of its given universe." Bang & Medin (2010) call it "Native science". The authors quote Cajele (1999) who describes Native science as

> Native science is not simply folk wisdom accumulated over time that may or may not be validated by modern science; instead, Native science embodies values and epistemological orientations for approaching and understanding the natural world that have integrity in the contemporary practice of science. (p. 1015).

This study agrees with Cajele (1999) in many respects but does not accept the idea of 'validating other knowledge systems using standards of Western modern science'. This study is of the view that each knowledge system should be validated by its own assumptions and standards rather than use one thought system as a frame of reference of another thought system. In other words, this study rejects ethnocentrism which could be loosely defined as a belief in a certain worldview to the extent of using that worldview to judge the adequacy (or lack of) of other worldviews.

IK includes content/concepts (what has to be taught) and methodologies (how it has to be taught). IK methodologies would include songs, storytelling, poems, rituals, demonstration and modelling, imitation and practical experiences (Living Knowledge Project, 2008). Kawagley et al. (1998) posit that indigenous knowledge was/is passed from one generation to another through oral tradition mostly in the form of storytelling, demonstration and modelling by elders, mimicking and guided practice by the young ones, peer teaching, hands-on-learning, and cooperative and communal learning rather than competitive learning. This study is of the view that such methods or strategies could prove very useful in today's science classrooms.

Some terms used to describe indigenous knowledge include: traditional knowledge; local knowledge; community knowledge; rural people's knowledge (Thakadu, 1998, p.3 in Kaniki & Mphahlele, 2002). Not all these descriptions are acceptable to everybody. For example, most people would not agree that indigenous knowledge is just for the rural, poor or uneducated people. IK is not knowledge of backwardness; it is knowledge that is relevant wherever people live.

A number of claims have been made about IK. These include: It fills the knowledge gap in science especially in the attainment of a stable and sustainable environment and offers knowledge that science has not yet learnt to produce (Corsiglia & Snively, 2001); that “a great number of African myths and beliefs have scientific explanations” (Ogunniyi, 1986 in Ogunsola-Bandele, 2009); and that most of the so-called African superstitious beliefs have rationale bases (Onwu & Mosimege, 2004). These claims are not mere utterances by indigenous people seeking to glorify their worldviews. The claims are not “overzealous and sycophantic” as Brown-Acquaye (2001, p. 69) would want us to believe. They are based on empirical and theoretical evidence that is all around us for anybody to see.

For this study, indigenous knowledge will be taken to mean a body of knowledge that has been generated over many years, by a group of people living in a particular physical environment, through careful observation and interpretation of local events and phenomena and has enabled that group of people to survive in and live in harmony with that environment. Indigenous knowledge changes with time because it is sensitive and responsive to prevailing situations or contexts.

2.2 The meaning of Western modern science (WMS).

2.2.1 The history of WMS.

To understand the meaning of Western modern science we need to understand its history. This history will show us that Western modern science is a very recent creation of a very few influential people. Furthermore, the so called Western science is really a ‘concoction’ or blend of scientific ideas from many places of the world. The word West here means Western Europe and North America.

This section is based on Aikenhead & Ogawa (2007), Ogunniyi (2008b), and from Wikipedia, the free encyclopaedia (see actual internet source in the reference list).

The word science comes from the Latin word *scientia* which means knowledge. Defined in this inclusive way, it is not difficult to appreciate that science is not synonymous with the West. For example, many ancient civilisations, including those of indigenous peoples all over the world, collected enormous quantities of knowledge about their natural world in a systematic manner through careful observations over many years and could use that knowledge for many purposes related to their survival in the world they lived in including predicting weather patterns for both agricultural purposes and for taking necessary measures to avoid catastrophes such as floods, droughts, storms etc. The word scientist was coined very recently, in the 19th century, by William Whewell. Previously, people investigating nature called themselves natural philosophers.

Aristotle (384-322 BC), the Greek philosopher, introduced the notion that universal truths (knowledge) can only be arrived at via observation (empiricism), thereby laying the foundation of the scientific method. The modern scientific method was developed by medieval Muslim scientists who had borrowed it from the Greeks. Put simply, the scientific method and scientific knowledge are not an invention of the West.

Greek and Muslim writings profoundly influenced European scholarship. Clear unbroken lines of influence lead from ancient Greek philosophers to medieval Muslim philosophers and scientists to European philosophers and scientists. European contact with the Islamic world in Spain and Sicily, during the Crusades, allowed the European access to Greek and Arabic scientific texts. In addition, Europeans began to venture further and further East (Marco Polo, for example). This led to the increased influence of Indian and even Chinese science on the European traditions. *The new book of knowledge* (p. 80) explains this eloquently when it asserts that: "...the people of northern Europe realised how much knowledge they were missing and began travelling more. They found Arabic writings on science that were far better than their own" and started owning these as their own. Kawagley et al. (1998) add their own view on this issue when they argue that no single origin of science exists and that science has a plurality of origins and a plurality of practices. The authors state further that after all Western science is not strictly Western in origin but a blend of the observations and insights of many cultures, notably, Egyptian, Greek, and Arabic.

In Western Europe itself many events shaped the development of science as we know it today. For example, a few influential people decided what constitutes science and what does not. Examples of such influential groups of people are the British Association for the Advancement of Science (BAAS) founded in 1831 and the Vienna Circle (1922). Their definition of science proved very exclusive and restricted. For example, some knowledge systems such as IKS, did not qualify to be called science since their knowledge could not be experienced empirically.

It is this distorted version of science, this Euro-centric science, which gave rise to the school science that is taught in our schools today (Chinn, 2007). In this study, the concept science means the science that is taught in South African schools as informed and directed by the NCS and CAPS.

2.2.2 The relationship between science and indigenous knowledge.

This section begins by looking at the implications of universalism and multiculturalism on the meaning and essence of scientific knowledge. This is because there seems to be a relationship between these two philosophies and the way both science and indigenous knowledge are viewed.

Universalists believe that science embraces the search for universal and invariant laws which are testable, predictive and deeply explanatory (Siegel, 2002). Siegel goes on to claim that science transcends cultural boundaries which makes it superior to 'ethno-sciences'. By ethno-sciences Siegel means the indigenous knowledge systems which he takes as inferior science or non-science.

According to Siegel, the Universalists insist or claim that science provides the most effective and reliable way to discover knowledge about the world. Chinn (2007, p. 1251) claims that "Western science and its product, school science, portray science as the discovery of universal truths based on evidence gained through objective, reproducible experiments stripped of emotions, cultural contexts, and values."

Multiculturalists, on the other hand, maintain that science is culturally produced and different cultures have disparate ways of understanding the natural world. "Science is recognised as a sub-culture of Western culture." (Aikenhead, 1997, p.217). All knowledge is mediated through our cultural and historical locations (Margolis, 1993, 1995 in le Grange, 2004). Feyerabend, 1987 in Mazzocchi, 2006) feels that any form of knowledge makes sense only within its own cultural context. Driver, Newton and Osborne (2000) argue that "any statement we make--- will be situated and located in our culture and in our particular stance and commitments----(and that the) claims that scientists make are influenced by the scientific and cultural environments of the time and by the commitments and value positions of the scientists themselves" (p.293).

In other words, learning school science is not acultural. It is steeped in cultural values and epistemologies of the learners. This is an acknowledgement that both science and indigenous knowledge are a product of the cultural experiences of the people claiming that knowledge. Science is only one way of understanding the natural world and should not be granted superior status to other ways of knowing (Stanley & Brickhouse, 1994, 2001). Different ways of knowing should be recognised as science. After all, "Western science success and universality was partly aided by use of military power and imperialism so much so that its cultural fingerprints are not as obvious as other ways of knowing" (le Grange, 2004, p.210). Chinn (2007, p. 1249) concurs when she writes

> The history of Western science as a cultural enterprise suggests that knowledge building and technological innovation are driven by the interests of dominant elites. Science as a quest for knowledge developed in the historical context of Europe's search for new lands and economic resources.

Kawagley et al. (1998, p. 133) posit that

> Western science has become the prototype for what counts as science today, and other ways of thinking and doing science have been largely discounted by the Euro-American scientific and educational communities. With its emphasis on controlled experimentation, replicability, and alleged objectivity, science as practised in the laboratories and as traditionally taught in schools does differ from the practice and thinking in many indigenous cultures but does that mean that what occurs in other cultures is not truly science?

This seems a rhetoric question as the Kawagley et al. (1998, p. 133) answer their own question when they say

> such indigenous groups practice science in ways that have similarities to- and important and useful differences from- Western science, and that the worldview underpinning this indigenous vision of science has valuable implications for science instruction.

Ogunniyi (2011) laments the exclusion of indigenous knowledge when he posits that

> By arrogating itself as the voice of all peoples of the earth, it has succeeded in depriving the whole of humanity of the insight and wisdom resident amongst diverse populations particularly the indigenous communities that form the bulk of earth's population. Thus, the knowledge that could have enriched and increased our chances of survival as a race has been greatly depleted or lost altogether (no page).

The 'it' in this quotation refers to Western Europe.

Kawagley et al. (1998) contend that a view that presents school science as the only true science is a narrow view of science and diminishes and devalues the legitimacy of the indigenous knowledge- a knowledge accumulated through generations of careful naturalistic observations and insight- a knowledge that has enabled the indigenous people to survive for thousands of years.

Snively & Corsiglia (2001, p. 6) contend that the Universalist definition of science is

> a defacto "gatekeeping" device for determining what can be included in a school science curriculum and what cannot.---in most science classrooms around the globe, Western modern science has been

> taught at the expense of indigenous knowledge. However, because Western modern science has been implicated in many of the world's ecological disasters, and because traditional wisdom (in the form of traditional knowledge) is particularly rich in time-tested approaches that foster sustainability and environmental integrity, it is possible that the universalist gatekeeper can be seen as increasingly problematic or even counterproductive.

Snively & Corsglia (2001) argue that because Western scientists are increasingly acknowledging the importance of indigenous science, there are sound reasons for changing the definition of 'science' so as to accommodate and include multicultural science. Elkana (1981, p. 1437) in Snively & Corsiglia (2001) proposes that "every culture has its science" --- "something like its own way of thinking and/or its own worldview" and defines science as "a rational (i.e. purposeful, good, directed) explanation of the physical world surrounding man." In short "science is just a system of understanding the natural world" (Irzik, 2001, p. 72). When science is viewed from this perspective, it becomes easy to accept that indigenous knowledge is indeed a science in its own right.

In this section we have seen the efforts made to change the meaning of 'knowledge' and of 'science' by a few influential people who had their own agenda of excluding other forms of knowledge including indigenous ways of knowing. The section has, however, shown that there is now a positive rethink about the meaning of 'science' and the role of indigenous knowledge systems in the academia.

2.3 The meaning of a science-IK curriculum.

There is a wide diversity of knowledge systems through which people make sense of and attach meaning to the world in which they live (Department of Education, 2003, p.9) and different knowledge systems, such as science and indigenous knowledge systems, can work together in mutually beneficial ways (Dei, 2000; Mazzocchi, 2006). This calls for the integration of different knowledge systems. Davis & Linn (2000, p. 819) view "science learning as a process of integrating ideas." They take integration to mean reflecting on what the student already knows and on the new ideas the student meets, in the school, in order to add information, promote some ideas while demoting others, recognising the link between the old and the new ideas and combining the compatible ideas so that in the end the student has an expanded and refined repertoire of ideas on the concept. In this study, the old ideas are the indigenous knowledge explanations and the new ideas are the school science explanations.

Although universalists and multiculturalists disagree on the status that should be accorded to Western science and indigenous knowledge in science education programmes, they are both agreed that both knowledge systems should be taught to all learners of all cultures (le Grange, 2004, p.212). The question though is: How exactly should the two systems be integrated?

Universalists would insist that when the two knowledge systems are infused in the education system, learners must be taught that science is superior to indigenous knowledge but that the learners should respect the ideas and beliefs about the natural world held by other cultures (Siegel, 2002). Multiculturalists would argue for equal treatment of the two knowledge systems, rejecting the idea of presenting one knowledge system as superior or as more successful than other ways of knowing (le Grange, 2004; Stanley & Brickhouse, 1994, 2001). They would argue that the criteria used by science to produce 'genuine knowledge' are not universal but a product of a particular culture (Western culture) and can therefore not be used to dismiss other knowledge systems as inferior or non- science.

le Grange, 2004) says that a universalistic interpretation would mean a dominance of the science over the indigenous knowledge on the curriculum while a multiculturalist interpretation would mean a reduction of the importance attached to science and a promotion of indigenous knowledge until the two are comparable in their importance.

Rhea (2002); Mazzocchi (2006); Ogunniyi & Ogawa (2008) argue against the selection of only those parts of the traditional knowledge that seem to measure up to scientific criteria and ignore the rest. It is felt that such an approach could distort or compromise the integrity of indigenous knowledge. Garroutte, (1994. p. 104) in Ogunniyi (2004, p. 295) maintains that "when parts of traditional knowledge that do not fit with scientific assumptions are excluded from the classroom, something vital to traditional knowledge is lost. Young people are cut off from important knowledge possessed by their ancestors." Bang & Medin (2010) contend that it is not enough to "take some pre-existing science curriculum and build in a cultural connection by 'adding culture to it' (p.1015).The authors insist that such an approach has been widely advocated and used but has failed to have the desired impact. They believe that cultural practices and their connections with Native ways of knowing must be the foundation of a community-based science curriculum.

This study is of the notion that science and indigenous knowledge should be taken and integrated on an equal footing. The study also accepts Ogunniyi's (2011, p. 13) notion that when integrating the two thought systems, "the idea is not simply to romanticise old ways of life per se but to critically engage the production process of such knowledge and its relevance in today's world."

2.4 Promising strategies that could be used to integrate the two knowledge systems.

Onwu and Mosimege (2005, p. 3-4) suggest several ways of integrating two apparently disparate worldviews. These ways include asking learners to research about how their communities use IK, in whatever form, for their livelihood and subsistence; employing the constructivist strategy of using learners' previous experiences or prior learning as a point of departure in providing relevant science learning experiences that engage and build on existing knowledge, and using science to evaluate IKS and vice-versa. I, however, agree with those authors [Rhea, 2002; Mazzocchi, 2006; Ogunniyi & Ogawa, 2008] who argue that no attempt should be made to analyse one knowledge system using the criteria of another, or to modify one to suit the other.

Kawagley et al. (1998, p. 141) insist that because Western methods of teaching science often run counter to the students' own cultural experiences, indigenous students have been disenfranchised not only by *what* is taught but also by *how* it is taught. They suggest that the most effective way to improve the learning of school science among indigenous learners is to infuse indigenous knowledge content and practice into the school curriculum. The authors feel that this could be achieved by adopting some of the following strategies:

- Invoking a more holistic view of science, minimising the artificial divisions between subject areas, emphasising interconnectedness and interdependence of all dimensions of nature and human activities. This means bringing to the classroom, a multidisciplinary, multidirectional, and multisensory learning style, with the total environment, natural or artificial.
- Allowing the students the freedom to learn on their own and from their peers and only seeking the wisdom of the elders, such as their teachers, after exhausting their own ideas.
- Everyone has the opportunity to express opinions, if they wish, and decisions are arrived at by consensus.
- Incorporating elders in the life of the school, for example, by asking the community knowledge holders to come and give lessons to the class. Not only do these elders bring in a wealth of the much needed indigenous knowledge but by involving them, the respect of the elders by the children is restored.

- The teacher and any other elders present in the lesson provide a non-judgmental facilitative learning environment.
- Allowing the use of both English and the local language as each language has its own contributions to make in the learning process.

Ogunniyi (2011, p. 5) posits that

> A number of analogies and theories have been proposed by scholars about how two dissimilar worldviews interact or can be integrated to form a type of hybrid knowledge that does not compromise the essence of what each one stands for as a legitimate way of knowing or interpreting human experience.

The two relevant theories are collateral learning (Jegede, 1995, 1997) and cultural border crossing (Aikenhead, 1996) both in Aikenhead & Jegede (1999).

Aikenhead & Jegede (1999) contend that science learning amongst students in former colonies rests on two pillars which are the ability of the students to move between their everyday life-world and the world of school science, a phenomenon known as cultural border crossing and the ability of the students to deal with cognitive conflicts between the two worlds, a phenomenon known as collateral learning. According to these authors, there is a feeling amongst these students, in these former colonies, that school science is a foreign culture. The students already have other but different explanations of natural phenomena to those offered by the school science. The school science explanation often conflicts with indigenous norms, values, beliefs, explanations, and expectations. The authors feel that there is need to develop culturally sensitive science curricula and teaching methods that reduce the foreignness felt by the students.

Aikenhead & Jegede (1999) maintain that the capacity to think differently in diverse cultures and the capacity to resolve conflicting beliefs between cultures differ from person to person. For some students, who the authors refer to as the 'potential scientists', this transition is smooth. This is said to take place when the culture of the home and that of the school are congruent. The school science harmonises with the student's life-world culture. Cultural and knowledge borders seem invisible or non-existent in this case. In short, school science is compatible with the student's indigenous knowledge. Such a student would need little or no help to transit from the home culture to the school culture and vice-versa. For some students, who the authors refer to as 'other smart kids', this transition is manageable. This is said to occur when the two cultures are somewhat similar or a little different from each other. The learners find some discomfort or disquiet with the school science culture as they find the school science generally irrelevant to their personal lives.

Aikenhead & Jegede (1999) insist that such students still find school science foreign to them but they develop mechanisms to pass school science examinations without learning science in any meaningful way. For yet other students, who the authors refer to as 'I don't know students', the transition is hazardous. This is said to occur when the cultures are diverse. It is said such a student is concerned more with preserving his/her self -esteem and would avoid situations where his/her ego was threatened, at risk or in jeopardy and/or situations where he or she would appear stupid in front of the class. The last group of students, who the authors refer to as 'outsiders', find the transition to be impossible. This is said to occur when the cultures are highly discordant. This means that the two cultures are not harmonious at all. Such students are likely to withdraw from school science lessons intellectually or even physically.

The Contiguity Argumentation Theory as espoused by Ogunniyi

> assumes that (cultural) border crossing (Aikenhead, 1996) is a learning experience brought about by relating one worldview to another. The success or otherwise of such an activity depends on how one intellectually navigates between two distinct thought systems (Ogunniyi, 2011, p. 6).
>
> In other words, learning is thought to be an attempt to seek harmony between competing ideas and experiences.

From the above discussion one can see that integration through argumentation must show the relationship between IK and science so that the process of border crossing can be as smooth as possible. What ought to be emphasized is the communality or sameness and interdependence of knowledge rather than the dichotomy or differences of knowledge (Ryan, 2008).

Jegede (1995, 1997 in Aikenhead & Jegede, 1999) defines collateral learning as the ability of a learner to construct scientific concepts side by side, and with minimum interference and interaction, with their indigenous concepts. This means holding an indigenous and a Western scientific view of a phenomenon simultaneously. It involves "two or more conflicting schemata held simultaneously in long term memory" (Aikenhead & Jegede, 1999, p. 278). The authors describe four different types of collateral learning. These are parallel, secured, dependent and simultaneous collateral learning. Parallel collateral learning refers to a situation where the two conflicting schemata do not interact at all. There is compartmentalisation of the two worldviews. Each worldview exists independent of the other. The two worldviews coexist in the mind and heart of the learner. Secured collateral learning refers to a situation where the conflicting schemata consciously and consistently interact and the conflict is resolved in some manner. The common elements in the two worldviews outweigh the differences.

The dependent collateral learning refers to a situation where a schema from one worldview challenges a schema from the other worldview to the extent of permitting the student to modify, with reason and conviction, the existing schema without radically restructuring the existing worldview. This seems to be suggesting that, only a portion of the worldview and not the whole is modified. This leads to acculturation which Spindler (1987) in Aikenhead & Jegede (1999) defines as the selected modification of currently held ideas and customs under the influence of another culture. Simultaneous collateral learning refers to a situation where learning a concept in one culture facilitates the learning of a similar or related concept in another culture. It refers to situations where some elements of the two worldviews are mobilised and used to explain a natural phenomenon. For this study, the belief, amongst some indigenous people that lightning is a bird that lays her eggs at the same place may reinforce the scientific concept of lightning striking at some places more often than at other places.

Aikenhead & Jegede (1999) propose that to learn science is to acquire the culture of school science, a process known as enculturation which occurs when the culture of the school science harmonises with the student's life-world culture. This means that when the school science tends to support the students worldview, then there is a smooth transition from one worldview to the other. The authors also say that a school science curriculum that is at odds with the students' worldview will tend to disrupt or destroy the student's worldview and force the student to abandon or marginalise his/her worldview and construct new ways of thinking. This process is known as assimilation. Aikenhead & Jegede (1999) point out that assimilation can alienate students from their cultural worldview or attempts at assimilation can alienate students from school science. Some authors, however, are of the opinion that efforts to replace indigenous worldviews with Western worldviews, over the many years of colonial rule, have not been successful. Ogunniyi (1988), for example, maintains that, it is futile to try to replace indigenous knowledge with Western science because both the teacher and the learner will always have the indigenous knowledge with them at heart and in their minds. In his book, *The wretched of the earth,* Frantz Fanon (1982, p. 17) puts the same idea succinctly when he writes: "they can't choose; they must have both. Two worlds: they dance all night (to appease their ancestors) but fill the church in the morning to receive mass (from the local Christian priest). (In brackets, my own addition).

Ogunniyi (1988) suggests that both educators and learners need the skills to cognitively border cross from IK to science and vice versa since they are exposed to these dilemmas on a daily basis. He says that learners must be helped to border cross between IK and science and to reconcile the two knowledge systems or to at least identify and choose the most appropriate system to use in each given circumstance, otherwise they will be perpetually torn between the two worlds. Successful border crossing between two worlds may be an indication that durable learning has taken place, and, perhaps, that a deeper level of understanding has been achieved (Solomon, 1992 in Aikenhead & Jegede, 1999).

Ogunniyi & Ogawa (2008, p.11) suggest several ways of doing this. These include starting with learners' prior knowledge before introducing them to new ideas; extending classroom discussions to include other ways of knowing; lessons to include current social problems such as HIV and AIDS, drugs and sports, genetic engineering and genetically modified organisms, plastic surgery which tend to lend themselves into discussions where knowledge claims must be backed with concrete evidence; assessing each knowledge claim using its own criteria, assumptions and standards rather than using science as a frame of reference for IKS; providing learners with opportunities to solve theoretical and practical problems; allowing learners to express themselves freely during lessons without feeling intimidated by others who may hold different opinions or by the teacher who is seen as an authority figure; and encouraging cooperative and communal learning rather than competitive learning.

Two major issues seem to emerge out of the above discussion. Recognising and acknowledging the legitimacy and importance of indigenous knowledge systems has profound implications for the conceptions of science (Bala, 2007) and how it should be taught and learnt. It seems clear that the authors cited above are recommending argumentation as a tool to ensure effective integration of the two worldviews. In terms of collateral learning, this study recommends secured collateral learning where the common elements in the two worldviews outweigh their differences; or dependent collateral learning that results in selected modifications of currently held ideas, whether they are Western or indigenous, in light of or under the influence of another worldview; or simultaneous collateral learning where the learning of a concept in one culture or worldview facilitates the learning of a similar or related concept in another culture or worldview, for example, the learning of creation of the universe facilitating the learning of evolution of the universe.

2.5 The meaning of argumentation

Binkley (1995) says that argumentation seeks to influence the opinion of an audience by supplying the audience with reasons or evidence to support or refute a given point of view. In other words, argumentation is about supporting or undermining ideas with evidence.

van Eemeren (1995) views argumentation as a social, intellectual and verbal activity serving to justify or refute an opinion or knowledge claim. van Eemeren & Grootendorst (2004, p. 1) in Bricker & Bell (2008, p.477) define argumentation as "-----a verbal, social, and rational activity aimed at convincing a reasonable critic of the acceptability of a standpoint by putting forward a constellation of propositions justifying or refuting the proposition expressed in the standpoint."

Billig (1987) posits that argument has both an individual and a social meaning. Driver, Newton and Osborne (2000) concur when they say that " argumentation can be seen to take place as an individual activity, through thinking and writing, or as a social activity taking place within a group – a negotiated social act within a specific community" (p. 290 - 291).

Sadler (2000) arguing along the same lines, describes two perspectives of argumentation. The first one supports the cognitive view of learning, which assumes that thinking and cognition are processes residing in the minds of students that produce outcomes that can then be transmitted verbally. In other words, this is the individual thinking and then articulating what he or she is thinking. Argumentation is then seen as an individual process. The individual meaning of argument is seen as an inner chain of reasoning within a person. This means that the individual engages in an internal, personal, private debate, where he or she provides evidence for or against an idea. This is what Ogunniyi & Kwofie (2011) refer to as individual brainstorming or self-conversation or intra-dialogical argumentation. The second perspective is the socio-cultural perspective that shifts the focus of learning from individual mental operations or processes to interactions amongst learners, from individual ideas to group or collective ideas. In other words, argumentation is a social activity where the process of meaning making and learning is a collective responsibility. The social meaning is that of a dispute between people opposing each other with contrasting sides to an issue. It could also refer to a situation where a group of people collaborate to come up with a more convincing point of view to support or refute a knowledge claim. This is what Ogunniyi & Kwofie (2011) call inter-dialogical or trans-dialogical argumentation.

Kuhn (1992) sees a link between the individual and the social aspects of argumentation. According to Kuhn, social dialogue offers a way to externalise internal thinking strategies embed in argumentation. Argumentation makes people's internal ideas visible (Bricker & Bell, 2008). It is through dialogue that our thoughts are revealed to others (Billig, 1987).

This study views argumentation as both individual, internal dialogue and social, external dialogue.

van Eemeren et al. (2002) in Bricker & Bell (2008) distinguish between argumentation and other forms of discourse such as explanation, elaboration, and clarification which they claim are used when discussing matters that are already accepted. Argumentation, according to these authors, is about matters that have not yet been accepted or resolved. I seem to get the message that an opinion would have to be justified or refuted before it can be accepted or rejected and that one can explain, elaborate or clarify a concept or subject that one does not necessarily agree with. For example, a science teacher could explain *evolution* although the teacher could be a believer in *creation.*

According to these authors, the purpose of argumentation is to "settle differences of opinion between the discussants" (Bricker & Bell, 2008, p. 478) and to "change people's minds by convincing them to accept standpoints not yet accepted" (Bricker & Bell, 2008, p. 479). The purpose of argumentation seems to convince people having different opinions, initially, to come to a common understanding of the subject under discussion.

Kuhn (2010) quoting Walton (1989) identifies two purposes of argumentation.

> The first is to secure commitments from the opponent that can be used to support one's own argument. The second is to undermine the opponent's position by identifying and challenging weaknesses in the opponent's argument (p.813).

Kuhn & Udell (2003) see an argumentative discourse as a "dialogical process in which two or more people engage in a debate of opposing claims" (p. 1245) whose goals are "to secure commitments from the opponent that can be used to support one's own argument" (p. 1246) and "to undermine the opponent's position by identifying and challenging weaknesses in his or her argument" (p. 1246). Felton & Kuhn (2001, p. 135) quoting Willard (1983) view argumentation as "a social activity in which two or more people advance, defend, and compare arguments in support of opposing positions." To all these authors, during argumentation, the speaker is either defending his/her point of view or seeking to weaken the opponent's point of view. Put differently, these authors view argumentation as confrontational or oppositional.

Andriessen (2006, p. 443) cited by Bricker & Bell (2008, p.490) proposes the notion of collaborative argumentation by claiming that "argumentation in science is not oppositional and aggressive; it is a form of collaboration discussion in which both parties are working together to resolve an issue, and in which both scientists expect to find agreement by the end of the argument". Bricker & Bell (2008, p. 481) insist that "scientists argue solely to build sound theories for the collective good of the enterprise." This means that these authors see argumentation as collaborative where the aim is to come up with a stronger supportive or refutal position.

Duschl & Osborne (2002, p. 41) give two versions of argumentation when they state that "---there is a tension between the lay perception of argumentation, as war that seeks to establish a winner, which contrasts with a view of argumentation as a social and collaborative process necessary to solve problems and advance knowledge." The first view is that argumentation aims at contesting different viewpoints in order to determine the winner in that contest. The latter is that argumentation is a collaborative activity whose aim is to bring out, from the arguers, a strong case for supporting or refuting a knowledge claim. The latter is the view taken in this study. The view does not mean that the community of arguers are agreeing all the time. Indeed, there should be situations where the argumentation is quite 'hot and controversial' but with the aim of finding the best consensus or position.

What seems to emerge from the literature is that argumentation is both an individual and a group activity. It begins within the individual who, after going through individual brainstorming, intra-argumentation or self- argumentation, would then communicate his or her thoughts on the subject under discussion to others who would in turn express their own views on the issue. These views from others may or may not mirror the views of the individual and may influence the original views of that individual. Indeed, the views of the individual could influence the views of the others. Argumentation need not be about oppositional or confrontational positions. It could be about building a stronger case by a group of learners, together than was possible from individual effort.

The underlining principle that seems to run through all these definitions of argumentation seems to be that of advancing appropriate and adequate evidence to support or refute positions that one has or that are given by others. Andrews (2005, p. 110) defines argumentation as "the process of developing arguments, the exchange of views, the seeking and provision of good evidence to support (or refute) claims and propositions." This is the meaning of argumentation adopted by this study. I would, however, add that the clarification, transformation of ideas/opinions/positions in light of new available evidence resulting in the personal growth of the learners is one important reason for argumentation.

Also, for this study Sadler's (2000) view of argumentation as reasoning in the context of ill-structured, controversial, and debatable problems that may possess multiple, plausible solutions and that can be viewed from a variety of perspectives is very relevant. This is because the causes of lightning are certainly controversial and debatable and open to a multitude of plausible explanations.

This study also took argumentation as collaborative where learners work together to produce a more convincing argument rather than it being always confrontational.

Whereas other scholars such as Groake (1996) and Slade (2003) in Bricker & Bell (2008) argue that arguments can be presented visually as well as in cartoons, for this study, argumentation was mainly restricted to verbal exchanges through the use of the spoken or written word.

2.6 Promising strategies when teaching argumentation and using it as an instructional method.

A number of approaches and strategies have been suggested on how argumentation can be taught and used effectively in the classroom. Kuhn (2010) identifies two broad approaches that could be used. These are direct and explicit instruction in argument and the experiential approach where the learners are taught the skill of argumentation through practising it. Both approaches were used in this research. The learners were taught how to argue effectively. They were also given plenty of opportunity to practise and refine their argumentative skills.

Other scholars have suggested specific strategies. The following are some of these suggestions:

- Key terms such as explanation, argumentation, claim, evidence, reasoning, counterclaim, rebuttal, and reply should be defined and explained to the research participants. It is important to make scientific inquiry practices explicit to the learners as this helps to facilitate their understanding and use of those strategies in their learning (Herrenkohl, et al. 1999). Argumentation is one of the scientific inquiry practices (Duschl & Osborne, 2002).

- Learners must know why the practice they are doing or using is important (Kuhn, Black, Keselman, & Kaplan, 2000). In this study the importance of argumentation in the learners' everyday life and in their school work was emphasised.
- Argumentation must be appropriated by students (Erduran & Jime'nez-Aleixandre, 2008). It has to become part of their repertoire of skills. Explicit instruction in argumentation helps the students to argue more effectively (Bell & Linn, 2000; Mercer et al. 2004; Kuhn, 2010; Kuhn & Udell, 2003). Quoting Hidi, Berndorff, & Ainley (2002) and Knudson (1992), Kuhn & Udell (2003, p. 1246) contend that "instructional units devoted to construction of arguments have been found to be productive in enhancing the quality of arguments supporting (or refuting) a (knowledge) claim." To achieve this, argumentation must be taught by teachers through suitable instruction, tasks and modelling. Modelling scientific inquiry practices by the teacher helps learners to use the same practice or strategy effectively (Crawford, 2000; Crawford, Kelly & Brown, 2000). The learners learn by imitating their teacher. Teachers teach by giving and explaining concrete examples of strong/weak; appropriate/inappropriate arguments (Osborne, Erduran & Simon, 2004). This way, the learners develop an understanding of what counts as a good argument. In other words, improving at argumentation is possible if it is explicitly addressed and taught. The research participants in this study were involved in a lot of debating sessions on socio-scientific issues and on static electricity and lightning.
- Naylor, Keogh & Downing (2007, p.27) found that worthwhile argumentation could be generated by young students (they were working with 9 year old pupils) by providing a combination of factors that include: providing an engaging or interesting stimulus (learners must be involved in what they consider interesting); the curriculum must be relevant to the lives of the learners; the learners must be given frequent opportunities to practice argumentation; modelling, by the teacher, the skills involved in argumentation; and helping the students to evaluate the quality of other people's and their own arguments. The concept of static electricity and lightning is not only relevant to the lives of these learners who live in a geographical area prone to lightning strikes but is also relevant to their school

work since it is part of the National Curriculum Statement and of the Curriculum and Assessment Policy Statement. It is believed that both facts motivated the learners to be interested in this research.

- Naylor, Keogh & Downing (2007) found that “argumentation appeared to be more productive in the absence of the teacher with teacher presence (not necessarily intervention) having an inhibiting effect” (p. 37). As a result, I was as inconspicuous as I could possibly be, only coming in when really required.
- Kuhn (2010) feels that the argumentation process must be seen, by the research participants, to have a clear goal, a purpose that goes beyond mere simple mechanistic motion through the process. They must be able to reflect on and learn from what they are doing. The debating sessions emphasised this very much.
- Establishing ground rules for acceptable argumentation creates an equitable intellectual environment and neutralises issues of social class, leading to greater participation by most of the students including the marginalised (Vellem & Anderson, 1999; Mercer et al. 2004). A modus operandi was produced and explained to the research participants *(See Appendix 4 for details on the modus operandi).*
- Certain conditions are necessary if argumentation is to be done effectively (Ogunniyi, 2007a, p. 5). According to the author, these conditions include: the ability to follow an argument (clearly a good grasp of the language used and mental alertness are critical for this to happen); a willingness to submit to the force of a better argument; the ability to treat each other as equal and reasonable arguers; and a willingness to learn something new.

Clearly there is need to teach the skill of argumentation to the learners before they can use it to integrate IK and science.

Most of these suggestions were put into practice during the intervention programme.

2.7 The nature of lightning

[Source of this information: WebEcoist website and Kedler(2006)]

Lightning is one of the oldest observed natural phenomena on earth. At any given time, there are about 1800 thunderstorms happening over the earth. It is estimated that about 100 lightning flashes occur every second somewhere around the globe, totalling 8 million lightning flashes per day. A bolt of lightning can travel at a speed of 160 000 km.h$^{-1.}$ The atmospheric discharge of electricity is hot enough to fuse soil or sand into glass. A lightning bolt is hotter than the surface of the sun. The brilliant white-blue flash of lightning is caused by its intense heat. Lightning starts fires, strikes trees and tall objects.

South Africa is a lightning prone country with one of the highest cloud to ground lightning flashes densities in the world. Lightning deaths in South Africa are about four times higher than the global average with more than 100 deaths recorded per annum (*Earth and beyond* booklet: SIKSP project: The University of the Western Cape, 2011).

There are different types of lightning. These include the cloud-to-cloud lightning, cloud-to-sea lightning and the cloud-to-ground lightning. Most of the lightning is cloud-to-cloud (80%) but the cloud-to-ground lightning poses the greatest threat to life and property.

Water is an excellent conductor and so it is strongly advised to stay away from water sources during a lightning storm. Tall objects are often struck by lightning. Electricity will also seek the path of least and lowest resistance.

A science explanation of the cloud- to- ground lightning (the lightning we are concerned about in this study) could be summarised as follows: During a thunderstorm, clouds and the ground act together to form a huge natural capacitor where one plate, the cloud, is negatively charged and the other plate, the ground, is positively charged. Water droplets in the cloud ionise as a result of constant movement and friction. Negative electric charges accumulate at the base of the cloud. These charges induce a positive charge on the ground below the cloud. The electrostatic field between the cloud and the ground produces ions and free electrons in the air. When the potential difference between the cloud and the ground becomes too great, ions and the free electrons provide a path between the two charged masses and an electrical discharge erupts. This discharge produces a lot of sound and creates a flash of lightning which we call thunder and lightning.

2.8 Indigenous people's notion about lightning

Indigenous knowledge about natural phenomena is based on practical and real life experiences of the indigenous people. Sources of the following information are learners, educators, community leaders, community knowledge holders, experts and literature.

Grayson et al. (2005) and Kelder (2006) say that indigenous people used their keen sense of observation and talent of story-telling to explain natural phenomena of lightning and thunder. They knew the dangers of thunder and lightning and their stories often carried warnings.

Kelder (2006) gives the following examples: The /Xam or Khoisan distinguished between violent *male* rain that was often accompanied by thunder and lightning and soft soaking *female* rain. The supernatural being,! Khwa, was able to use the thunder and lightning of *male* rain to punish disobedient children. Some African tribes believed that lightning took on the form a bird that they called the lightning bird or *chimunga.* It was a large black bird with a long curled beak which it could use to cause serious wounds on its victims. (People struck by lightning have wounds on their bodies).

Another tribe believed that thunder was an elderly mother sheep and that lightning was her swift, short tempered son who, when upset, would destroy people and property. Her mother would then raise her voice to shout at him and try to restrain him but she was always too slow for him. (Light travels much faster than sound. It travels at $3 \times 10^8 ms^{-1}$ compared to the speed of sound which is $340ms^{-1}$). It is believed that the mother and her son were banished from the earth by the ruler of the tribe. They went up the skies where they live but visit the earth now and again in the form of lightning and thunder.

According to the experts and the indigenous knowledge holders, the Xhosa people call lightning *umbane* and they differentiate two types of lightning.

The first type is one they call *kuhambele umhlekazi. Kuhambele* means a visit while *umhlekazi* means honouring or respecting. Lightning would then be seen as a respected visit from a high level usually the ancestors or God. The ancestors and/or the Almighty would have a purpose when they make that visit. There is a reason why lightning strikes. It is either the ancestors are angry or they want something done for them. Such lightning is not associated with evil. The village elders or those affected (whose homes, property or relatives were destroyed by the lightning) would then consult *inyanga or sangoma* who would then tell them the meaning of the visit. The *inyanga* could be *igqrrha* –the traditional healer who can talk with the ancestors and get their message, or *ixhwele* -the medicine man, the person who knows the herbs and their functions, or *isasuse* –who is a combination of the two *inyanga* above.

A traditional cleansing and preventing ceremony would then be conducted by the *inyanga*. The cleansing ceremony involves the affected people being given different herbs to drink and lose through forced vomiting and defaecating, a process known as *ukugabha* or *ukuchatha*. The whole process is meant to erase *(ukucima)* the effect of the lightning. However, it was emphasised that the relationship between the living and the ancestors must first be mended before these ceremonies could be done because "Physical treatment will not be effective unless the (broken) relationship is first mended" (Ryan, 2008, p. 668). The preventing ceremony is meant to prevent further attacks by lightning. Even before the lightning, some people would protect their homes from lightning and other evils through a ceremony known as *ukuqinisa umzi. Ukuqinisa* means to strengthen or protect while *umzi* means homestead.

The second type of lightning is the one that is associated with powerful but evil people who use the lightning bird, *umpundulu,* to send lightning to their enemies. It is believed that such people need only a few clouds in the sky to create and send their lightning.

To prevent lightning several things could be done. These include:

- When lightning is threatening a village, a diviner, in an effort to protect his village from the lightning would come out of his hut clad in traditional attire with a medicined spear in his hand and do some traditional dances, singing and challenging the lightning to strike. The other villagers could be beating the drums and singing. It is believed that when the lightning bird saw and heard this, it would become afraid and move on to some other place. Folklore has it that sometimes the diviner would get killed by the lightning in this process. When that happened, the explanation would be that the diviner made an error in doing some of the rituals or that the diviner was pompous, not realising that the powers that he had come from the ancestors. The ancestors would be angry and punish him with death.
- A person would hold a thorny branch above his/her head when lightning is threatening. It is believed that when the lightning bird sees the thorns, it becomes afraid to attack and moves on to some place.
- The Xhosa people grow a special plant on the thatch of their huts to divert lightning strikes. They also plant it around their huts for protection. (Science recommends the use of lightning conductors that would take the lightning into the ground rather than into the house.)

- Certain behaviours were prohibited. These include: not playing with or in water during a thunderstorm (Water is a good conductor of electricity and so it is strongly advised to stay away from water sources during a lightning storm.); not to sit near a window or door (Electricity will seek the path of least and lowest resistance), not to sit near a fire place in the kitchen and fire in the hut must be put out (lightning travels more easily through warm air than through cold air and smoke is a good conductor of electricity; (this could also explain why huts, where the cooking is done and hence where heat and smoke are generated are targeted by lightning most of the time at a homestead); to open windows (probably to reduce the warmth in the hut); people must be seated and not standing, they must not take refuge under tall trees, they must not walk alone in a plain field (lightning targets tall objects); switching off electrical gadgets and covering shiny objects such as mirrors.

Stories and beliefs from Zimbabwe about lightning

For this research, I talked with a number of people from various walks of life in my country, Zimbabwe, to find out what they knew and believed about lightning and their experiences with this natural phenomenon. The following are a few descriptions of what I was told. I have no reason to doubt these episodes and stories.

A lecturer in Philosophy of Education at a Teachers College who is doing post graduate studies with UNISA told me his own experiences with lightning. One day lightning struck and burnt a hut in which he had been only a few moments before the lightning bolt. He was the only occupant of the hut at that time. The elders in the village told him that the lightning had been sent to him by his enemy. They advised him to consult a *n'anga* (an indigenous medicine man) to get protection against possible future lightning attacks on him. He ignored their advice. He was already a teacher at that time and according to him "It was just coincidence that I had left the hut just in time." Then one day as he was herding his cattle, there was a lightning bolt that killed two of his big oxen. Again the elders pleaded with him to get protection and again he ignored their advice. That was until, according to him, 'I read for my studies about post modernism which taught me that Science was not the only explanation of natural phenomena.' I did not ask whether he went to the *n'anga* for protection after this revelation. (It would have been culturally insensitive for me to ask that question). It is, however, clear that the man is questioning his original beliefs about the cause of lightning. He seems to think that there could be other causes besides or in addition to the scientific explanation that he was taught at school.

Two men (X and Y) quarrel at a beer party. X threatens Y with unspecified consequences. One day a lightning bolt hits Y's homestead. Y is not at home at the time of the bolt. He is at some beer party. The people at Y's homestead at the time of the bolt are not hurt but are very terrified by the enormity of the lightning. Word reaches Y and he rushes back home. A lightning bolt hits the homestead where there was the beer party. Again it terrifies people but does not hurt anybody. Y had left the beer party. Before Y gets home, there is a third lightning bolt that kills Y. The villagers believe that it was X's lightning that was hunting for and eventually killed Y. (In my discussions with my research participants, we came across similar stories, not from Africa but from Western Europe, written in a *Physics* book. Lightning had followed certain people, according to that book, and struck them several times before, in one case, the man eventually got killed by it. In that same case, the lightning followed the man even after death and struck his grave. Amazing indeed!) *(See Appendix 11 for details on these stories from the Western world).*

A man arrives at a police station carrying a small bag. He says to the policeman in charge of the station 'I have come to leave a magic potion that I no longer need because I am now a born again Christian.' The police officer is curious. He wants to know what the magic potion is for and he is told that it is for causing lightning. The policeman challenges the magic man to prove that his magic potion works to which the magic man quips 'would you want to be the victim?' The police officer is terrified. The story then goes on to say that the magic man directed his lightning at a nearby tree which got burnt. I have seen the burnt tree but one cannot tell by looking at it how it got burnt.

Other beliefs from Zimbabwe include: lightning is a hen that lays its eggs in one place. The hen then comes back either to lay more eggs or to check its eggs. (There are some places that are prone to lightning. They are struck again and again.); moving objects are easier targets of lightning than stationary objects; lightning is attracted to red objects or red clothes.

2.9 Theoretical framework

This study is anchored on several theoretical frameworks on integration and argumentation. I will describe some of these in some detail and zero in on those conceptual frameworks that informed this study.

2.9.1 Theories for integration

In order to address the question of integration of indigenous knowledge with the scientific knowledge about lightning, this study drew on theoretical frameworks associated with prior knowledge of learners such as the constructivist perspectives and the World View Theory.

The constructivist perspective supports the view that learning outcomes (what learners will be able to do after going through a learning experience) are a result of the interaction between the learner and the information the learner encounters and how the learner processes it based on perceived notions and existing personal knowledge (Yager, 1995 in Pabale, 2005). The perspective believes that knowledge is constructed or built by the learner (Cohern, 1993 in Naidoo, 2005) at the individual level as the learner processes the new knowledge or as a result of the individual working with others to process the new information. The construction of new knowledge is strongly influenced by prior knowledge, that is, concepts gained prior to the point of new learning (Ausubel et al. 1978 in Naidoo, 2005). From a constructivist point of view, meaning is constructed as students interpret and re-interpret new events and new information through the lens of prior knowledge (Barnes, 1992; Berk & Winsler, 1995). Rivard & Straw (2000, p. 567-568) argue that

> Constructivism posits that personal knowledge and understanding result from the myriad connection that learners make while integrating new information with prior knowledge. Some constructivist approaches have emphasized the personal construction of knowledge in which the individual's idiosyncratic experiences within the learning environment are paramount, whereas others have underlined the importance of social processes in mediating cognition. Science education would benefit from a synthesis of these two perspectives.

Prior knowledge includes the traditional knowledge that learners have and bring to the classroom. According to this perspective, school science learning can make more sense if it is related to the knowledge that the child brings to the classroom from his or her culture. This calls for integration of the two thought systems.

Contemporary perspectives on science education are underpinned by the view that knowledge cannot be transmitted but must be constructed by the mental activity of the learner (Driver et al. 1994). These authors go on to state that this is the constructivist view of learning which argues that knowledge is built up by the learner individually through the learners' interaction with physical objects and events in their daily lives and/or through social processes that make different viewpoints available to other learners through discussions. The individual makes use of his/her present knowledge schemes to make sense of incoming information. In the process of accommodating the new and the old, previous knowledge schemes may be modified. This idea of contextualizing knowledge as part of teaching and learning is based on the principle of moving from known to unknown.

Learning is described as "a process of conceptual change" (Driver et al. 1994, p. 6). Classrooms are seen as

> places where individuals are actively engaged with others in attempting to understand and interpret phenomena for themselves and where social interaction in groups is seen to provide the stimulus for differing perspectives on which individuals can reflect (Driver, et al, 1994, p. 7).

Bruner (1985), quoted in Driver et al. (1994, p. 7) explaining the importance of social interactions or peer support says "There is no way, none, in which a human being could possibly master that world without the aid and assistance of others---."

The role of the teacher is to provide learners with physical experiences that "induce cognitive conflict and hence encourage learners to develop new knowledge schemes that are better" (Driver et al. 1994, p. 6) supported by group discussions which the learners can use to stimulate learning. In addition, the teacher promotes thought and reflection by requesting for argument and evidence in support of assertions made by the learners.

The perspective seems to suggest that connecting the science content being taught in class to the learners' experiences and prior knowledge (the learners' indigenous knowledge) maximises the learners' involvement in and understanding of the learning programme. Also, the authors referred to above clearly advocate for social interactions, discussions and the provision of evidence for knowledge claims made. This is a very direct way of suggesting that science knowledge production can be achieved much better through argumentation. Argumentation is the main focus of this study.

Allen & Crawley (1998, p.113) define a worldview as

> ---the way people think about themselves, their environments, and abstract ideas such as truth, beauty, causality, time and space. It is the way people have of looking at reality, the basic assumptions and images that provide a more or less coherent way of thinking about the world, the cognitive structure into which an individual fits new information.

Kearney (1984), Kilbourn (1976), Ogunniyi (1984) all in Ogunniyi (2008b) define a worldview as assumptions of a people that determine much of their behaviour and decision making influencing their thoughts and actions; a set of beliefs which guide action which have consequences for self and for others; prevailing cosmology influencing and controlling the behaviour of members of a society or community.

The World View Theory believes that every person has presuppositions about what the world is really like and on what constitutes valid and important knowledge about the world (Cobern, 1993 in Pabale, 2005). These presuppositions are the views that a person holds about natural phenomena. Ryan (2008, p. 666) adds that "worldview theory describes how we understand our relationships with others and with the phenomenal world." Allen & Crawley (1998) believe that the worldview as a theoretical model is a powerful way of understanding conflicts in cross-cultural teaching. Worldviews which the students bring with them into the science classroom may affect not only how they make sense of science information, but also the extent to which they are willing to participate in the educational experiences. Care must be taken to ensure that indigenous learners do not feel like outsiders or guests in the school science classroom. The assumption is that, an education system that ignores or refuses to recognise the learners' presuppositions, the learners' worldview, is likely to be unsuccessful.

The argumentation-based instructional intervention programme that I put in place for my research participants, the Grade 10 learners, attempted to help the learners to negotiate the process of border crossing from one worldview to another without causing conceptual disharmony or dissonance or to help learners identify contexts in which one worldview is more applicable than the other or to at least help the learners to find ways of living harmoniously or equipollently (CAT) in the two worldviews.

Ng'etich (1996) has come up with a model of integration. He distinguishes three forms of integration which are summarised in the following table.

Table 2.1: Ng'etich's (1995) models of integration

Integration form	Symbolic representation	Description of strategy
IKS into science	IKS → science	Unidirectional. IKS smaller, less valuable, less useful, less important, less grounded
IKS with science	IKS ↔ science	Bi-directional. The two world views are of equal importance.
IKS and science	IKS ─ science	Non- directional. The two co-exist independent of each other

This study is of the view that integration should take the two systems on an equal footing. The study rejects the idea of taking one worldview as superior to the other; it rejects the notion of one worldview being used as the yardstick to measure the adequacy of another worldview; and it rejects the idea of taking the two worldviews as separate entities with nothing in common or that do not influence each other.

2.9.2 Theories for argumentation

There are several theoretical frameworks that can be used to analyse arguments. Much of the argument analysis in science education research has been based on Toulmin's (1958) Argumentation Pattern (TAP) (Bell & Linn, 2000; Mason & Santo, 1994 in Tippet, 2009). Toulmin's framework focuses on the content of the arguments produced by individuals. The main features of TAP are:

- Claim → an assertion, a declarative statement or a belief about a phenomenon; a knowledge claim. It is a conclusion whose merits are to be established through argumentation. Berland & McNeill (2010) see a claim as an answer to a question. For example, the question could be: 'What causes lightning?' The answer to that question is the knowledge claim.

- Data → evidential or supportive statement of that assertion. This means the facts that those involved in the argument appeal to in support of their claim or to refute another's knowledge claim. Leitao (2000, p. 339) defines data as "facts that serve as a basis for a claim". Berland & McNeill (2010) say that this data or evidence could be obtained from a variety of sources which include experience, observations, measurement or experimental work, reading, and hearing from others.
- Warrants → statements that show the relationship between the claim and the evidence. These are the justifications for moving from specific grounds or evidence to specific claims (Bricker & Bell, 2008). Leitao (2000, p. 339) sees a warrant as "a general statement that authorizes the movement from data to claim."
- Backings → implicit or underlying assumptions of the data used to strengthen the warrant. These are the more general reasons for the warrants' authority (Bricker & Bell, 2008). Leitao (2000, p. 339) views a backing as "specific information that may support the warrant."
- Qualifier → contingent conditions on which the claim is based. To Leitao (2000, p. 339), a qualifier is "an estimation of the degree of certainty of a conclusion" or of a claim.
- Rebuttals → contrary statements to the claim which point to circumstances in which the original claim would not hold up i.e. is not true. Kuhn (2010) says rebuttals are "counterarguments to arguments" (p. 816). Berland & McNeill (2010) view a rebuttal as a claim that says an alternative claim, known as a counterclaim, is correct and it does this by providing additional evidence and reasoning to justify that point of view. The authors further say that rebuttals are important in that they teach the learner to discuss and evaluate competing arguments and alternatives by identifying their strengths and weaknesses. Arguments that contain rebuttals are more complex than those without as they involve and require more complex thinking (Kuhn, 1991; Osborne et al. 2004).

I see a difference between a rebuttal and a counterclaim in that a rebuttal shows a weakness in the statement of the speaker while a counterclaim is a different explanation of the event. For example, if the claim is: 'The person was struck by lightning because he was the tallest man in the crowd', a rebuttal could be 'there is no much difference between the height of people' while a counterclaim could be 'the man has an enemy who sent the lightning.'

Toulmin's structural framework is seen as an analytical framework and tool for evaluating the strengths and weaknesses of arguments (Bell & Linn, 2000). Toulmin's ideas have been adopted by many scholars in a variety of disciplines including science education but many people have experienced problems as they attempted using this framework in its totality. Others have found it more pragmatic to use aspects of the framework e.g. Tippet, (2009). For example, working with primary and secondary school science teachers who were participants in the Science Indigenous Knowledge Systems Project (SIKSP) in the Western Cape in South Africa, Stone (2009, p. 72) found that "the participants have problems with the terminology and meaning of the components of Toulmin's Argumentation Pattern." Simon, Erduran, & Osborne (2002, p.16) point out that "nearly all researchers have found the application of Toulmin's schema problematic."

For these reasons and as shall be shown below, this study makes use of aspects of TAP.

Leitao (2000) proposes an analytical tool that looks for three elements in an argument. These elements are:

- A claim which the author describes as "a viewpoint and a support idea" (p. 333). To this author, a claim is both a knowledge claim or a position and the supporting evidence.
- A counterargument which the author describes as "any challenge to an argument" (p. 333). It is a statement that casts doubt on the accuracy or correctness or truthfulness of a given knowledge claim. The author believes that a counterargument could perform any of the following two purposes: Firstly, a counterargument aims "to bring the truth of a claim or a reason-position link into question" (p. 355) In other words, a counterargument brings the merit of an argument into question. It does this by either just rejecting or dismissing a given claim or it advances a statement that reverses or opposes what the speaker claims. Secondly, a counterargument can be aimed at shifting the focus of the argument.
- A reply which the author takes to mean "the arguer's reaction to the counterargument" (p.333). The author thinks that a reply "captures the impact of a counterargument on the arguers' thoughts and to follow moment-by-moment transformation in their knowledge" (p. 356). This means that we can tell whether the arguer maintains his/her original position or accepts a modified version of his earlier position or shifts from his earlier position by the kind of reply the arguer gives when confronted with a counterargument. For example, the arguer shows,

by rejecting or dismissing the counterargument that he/she maintains or preserves his/her original position and that he/she has shifted or withdrawn from his/her position by accepting the counterargument.

Osborne, Erduran, & Simon (2004, p.1008) came up with an analytical framework that has five levels as shown in the table below.

Table 2.2: Analytical framework on argumentation by Osborne et al. (2004)

Level	Description of argumentation
1	A simple claim versus another claim
2	Claim with data but no rebuttals
3	Claim with data and weak rebuttal
4	Claim and data and a good rebuttal
5	An extended argument with more than one rebuttal

Adapted from Osborne, Erduran and Simon (2004)

Downing model cited in Naylor, Keogh & Downing (2007) focuses on the nature of the interaction between individuals, rather than on the content of the argument itself (as in Toulmin, 1958). The model recognizes the importance of the group in analysing argument. A focus on the individual takes no account of the quality of the interaction. (On the other hand, a focus on the group may not do justice to the different contributions of the individual [Naylor, Keogh, & Downing, 2007]). Downing model has seven levels which attempt to identify and differentiate the nature of the interaction.

Table 2.3: Downing (2007) Analytical model of argumentation

Level	Description
1	Pupils are unable or unwilling to enter into discussion
2	Pupils make a claim to knowledge but offer no evidence to support the claim
3	Pupils begin to offer evidence to support their claims
4	Pupils offer further evidence to support their claim.
5	Pupils respond to ideas from others in the group
6	Pupils are able to sustain an argument in a variety of ways.
7	Pupils evaluate the evidence and make judgements

Felton & Kuhn (2001) came up with an argumentative discourse assessment scheme which consists of several discourse codes some of which are shown below.

Table 2.4: Felton & Kuhn's (2001) argumentative discourse assessment scheme

Column 1	Column 2
Agree?	A question that asks whether the other arguer will accept or agree with the speaker's claim. "Do you agree with me?"
Case?	A request for the other arguer to take a position on a particular case or scenario. "What is your argument/position?"; "What are you saying?"
Clarify?	A request for the other person to clarify his or her preceding utterance. "I cannot follow what you are saying. Please clarify."
Justify?	A request for the other person to support his or her preceding claim with evidence or further argument. "What is your evidence?"
Respond?	A request for the other person to respond to the speaker's utterance. "What do you say about what I said just now?"
Add	An extension or elaboration of the other person's utterance. This could be in order to attack the other's position or to support it.
Agree	A statement of agreement with the other person's preceding utterance (with own evidence).
Aside	A comment that does not extend or elaborate or address the other person's utterance.
Clarify	A clarification of the speaker's own argument in response to the other person's preceding utterance.
Coopt	An assertion that the other person's preceding utterance serves the speaker's argument.
Counter A	A disagreement with the other person's preceding utterance, accompanied by an alternative argument.
Counter C	A disagreement with the other person's preceding utterance, accompanied by a critique
Disagree	A disagreement without further argument or elaboration. "That is not true. I do not agree with you."
Dismiss	An assertion that the other person's preceding utterance is irrelevant to the speaker's position. "How is what you have just said related to what I just said?"
Refuse	An explicit refusal to respond to respond to the other person's question or request.
Continue	A continuation or elaboration of the speaker's own last utterance that ignores the other person's preceding utterance.

[Adapted from Felton & Kuhn, 2001, p. 141]

The Contiguity Argumentation Theory (CAT) (Ogunniyi, 1988, 2000, 2004) deals with the nature of interactions between distinctly different thought systems such as science and IK.

The theory is concerned with how distinctly different or conflicting ideas are resolved to gain a higher level of consciousness or understanding (Runes, 1975 in Ogunniyi, 2011). When two cultures or systems of thought meet, co-existence can only be possible through conceptual appropriation, accommodation, integrative reconciliation and adaptability otherwise the two systems will remain incompatible. This is to say that cognitive shifts are necessary if concept dissonance is to be resolved. The theory explains a dialogical framework for resolving the incongruities that normally arise when two competing thought systems meet or are placed side by side (Ogunniyi, 2007a) as the National Curriculum Statement (NCS) and the Curriculum Assessment and Policy Statement (CAPS) have done with IK and science. This theory suggests that:

- Such curricula have a great potential for creating cognitive conflicts among students (inter-conflict) and within the student (intra-conflict). When two disparate worldviews come together, each will probably seek to accommodate or even assimilate the other (Ogunniyi, 2011). This results in cognitive conflict or cognitive dissonance.
- When a conflict arises in the mind of the student, as a result of being exposed to science at school and IK at home, an internal argument or conversation arises within the student. "Some sort of 'internal dialogue' or argument ensues within the individual's working memory to resolve the conflict between the competing thought systems" (Ogunniyi, 2011, p.6). Leitao (2000) uses the following phrases to describe this type of argumentation: silent, private deliberation; self-conservation; solitary discourse; people conferring with themselves; and argumentation with an imaginary addressee or virtual other.
- There is also argument between people exposed to the two conflicting ideas. The ideas or worldviews tend to argue or dialogue with each other to obtain a higher level of meaningfulness or consciousness. Ogunniyi (2011) feels that the resulting 'alloyed knowledge' or culturally enriched knowledge is better than knowledge of either worldview alone. (An alloy is a mixture of metals which is more durable, more resistant to corrosion and more attractive than any of the constituent metals. In the same vein, knowledge obtained by integrating different thought systems is believed to be better than knowledge from one thought system).
- The purpose of such argument (internal and external) is to learn new things in order to enable some meaningful co-existence of the two systems in the mind of the learner or

in order to enable the learner to shift from one knowledge position to another with reason.

Ogunniyi (2007a, p. 13) says that CAT recognizes five steps of adaptive co-existence that occur within a student confronted with two distinct forms of thought. These are:

- Dominant → a thought system or an explanation is seen to be more convincing or more appropriate than the other thought system or explanation at that moment and for that context or a powerful idea explains facts and events more effectively and convincingly than another idea or that resonates with the acceptable social norm that affords an individual a sense of identity.
- Suppressed → a thought system is seen as less convincing than another. The less convincing or subordinate thought system becomes suppressed. An idea becomes suppressed (it is not allowed to come out) in the face of more valid, appropriate, adequate and convincing evidence.
- Assimilated → the dominant thought system is taken by people who initially held the suppressed thought system. The initially held thought system is supplanted or subsumed by the dominant worldview. This means that a less powerful, less convincing idea is assimilated (taken in, swallowed by) a more powerful, a more persuasive idea.
- Emergent → no previous idea, opinion or position on an issue really exists in the learner. An idea emerges as the individual is exposed to new teaching. For example, many science concepts learnt at school are really new to the indigenous learners and are added to the indigenous worldview of the learner (Ogunniyi, 2011).
- Equipollent → the two competing thought systems are seen as equally powerful, adaptable, active, effective or significant in making sense of the observed phenomena. The two rival thought systems coexist and exert equal cognitive force on a person’s beliefs. For example, a person could find both creation and evolution as attractive explanations for the origin of the universe and humankind (Ogunniyi, 2011).

The meaning and implications of CAT to this study are that:

- Science and its explanations of the world has been the dominant thought system while indigenous knowledge and its explanations of the world has been the suppressed thought system. This study rejects this position.
- The assimilated adaptive co-existence would mean the swallowing of indigenous knowledge by science or the use of science standards to judge the adequacy of indigenous knowledge. This study rejects this position.
- The emergent adaptive co-existence would mean the addition of new information through school science to the already existing indigenous knowledge. This means building on, expanding and enriching the known (indigenous knowledge) by adding the unknown (science). It could also mean the emergence of something new and different from either worldview, what Turnbill (1987) called the third space. This study accepts both meanings of the emergent adaptive co-existence.
- The equipollent cognitive state would refer to a situation where a learner sees science and indigenous knowledge as two equally effective and legitimate ways of explaining natural phenomena or where the two thought systems complement each other. This study accepts this position.

Which of the above adaptive co-existence will prevail in any given situation will depend on the socio-cultural context or the experiences shaping the dialogue in question. These cognitive states are dynamic in that they can change from one form to another depending on the context at that time, the context in vogue (Ogunniyi, 2011). The author gives an example of this dynamism when he states that

> a scientific claim (backed by convincing empirical evidence or a convincing explanation) is likely to be dominant in a science lesson than in a religious setting where respect for authority, cultural ethos and metaphysical allusions hold sway (Ogunniyi, 2011, p. 10).

This research makes use of aspects of each of these theoretical frameworks. This eclectic approach was chosen rather than using the full range of one model in order to tap the best from each of the models and also because the use of most of these frameworks have proved problematic to many researchers as was shown above. Some researchers have found the suggested assorted approach practical. Researchers have tended to use only aspects of a model (e.g. Jim’enez-Aleixandre & Pereiro-Munoz, 2002) or they combined aspects of different models (e.g. Duschl et al. 1999) in order to obtain a more workable analytical model (Tippet, 2009). This is the approach adopted in this study.

2.10 Conclusion

This chapter has highlighted the meaning and relevance of key issues that this study is all about: Indigenous knowledge systems; science, integration, argumentation and lightning. In addition, the role of pertinent issues to this study such as border crossing, multiculturalism, universalism, World View Theory, collateral learning, constructivism, collaborative learning, conceptual change, and contiguity principle were also looked at. The literature emphasized the need for integrating the two knowledge systems and the role that argumentation could play in helping learners to border cross from one worldview to the other and how the learners could harmonise natural phenomena explanations that appear to be or are different. The aim of all this was to emphasise knowledge communality and interdependence rather than knowledge dichotomy.

The next chapter will explain how the data necessary for addressing the research problem and questions were collected. That chapter will explain in detail the intervention programme that I put in place and how the collected data was analysed and meaning drawn from it (discussed).

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.0 Introduction

This chapter discusses the methods and approaches used in carrying out this study. The chapter includes the sampling of the research participants, the designing and improvement of the quality of the research instruments used, and the data collection and analysis techniques employed. The aim of the chapter is to elucidate how the data that was used to address the research questions were collected, analysed and interpreted. The details of the argumentation-based instructional intervention programme that was designed for this study and for these learners will be given in the chapter. The chapter attempts to show and justify the appropriateness of the methodology used for the study while at the same time acknowledging the limitations of the approaches used.

3.1 The research paradigm

A paradigm is a worldview of looking at reality. Guba & Lincoln (2005, p.105) define a paradigm as “the basic belief system or worldview that guides the investigator, not only in choices of method but in ontologically and epistemologically fundamental ways.” A paradigm is essentially a whole framework of beliefs, values and methods within which research takes place.

Krathwohl (1993) argues that research is a creative art that cannot and should not be fixed into firm categories. It can also be argued that the classification of educational research is primarily academic and essentially an arbitrary process. However, this research has certain characteristics that need to be highlighted.

This study adopted the qualitative research approach which falls under the descriptive interpretive paradigm. This paradigm is based on a naturalistic-phenomenological philosophy that views reality as multi-layered, interactive and a shared experience interpreted by individuals (McMillan & Schumacher, 1993). ‘Naturalistic’ would mean studies in a natural setting, in real-life contexts or situations, where real life issues and problems are discussed and where the research participants have an open ended and free way of giving their views on issues under discussion (utexas.edu website). In this study, real life experiences of the learners, as they interacted with their community lives and with their school lives, were the centre of their discussions. Phenomenological inquiry investigates the experiences and beliefs of a group of people by asking them to narrate these experiences and beliefs. The focus is on the social actions, beliefs, interpretations and perceptions of the research participants. Groenewald (2004) maintains that phenomenologists are concerned with understanding what they are studying from the perspective of the people involved, in other words, from the point view of the research participants. Lester (1999) states that the purpose of a phenomenological approach to research is to gather deep information and perspectives of the research participants and representing it from their point of view always ensuring that one is faithful to the participants and that one remains conscious of and guarded against possible biases, misrepresentations and distortions. In this study, the focus was on the learners' own understanding of the nature of science, indigenous knowledge and lightning as expressed by them.

Ontology is a branch of philosophy dealing with the nature of reality. It looks at how we perceive the world.

> Our ontological perspective comprises the values, attitudes, and beliefs that form the framework we use to make sense of our experiences. The ontological frameworks through which we see the world give rise to an accumulation of what is considered to be knowledge (Ryan, 2008, p. 666).

Epistemology is a branch of philosophy that studies the nature, origin and scope or limits of knowledge. It makes a distinction between 'true' and 'false' knowledge and on how knowledge is acquired. "It is essentially concerned with how we know what is true and the type of statements we accept to support this" (Green & South, 2006, p. 17). Qualitative research believes in the existence of multiple realities and truths based on one's understanding of what constitutes reality. This study rests on the premise that there are many ways of knowing and that natural phenomena have many possible plausible explanations. In other words, there is neither one truth about nor one explanation of a natural phenomenon.

It was believed that this research paradigm would enable the researcher to gain a deeper and sharpened appreciation and understanding of the learners' perceptions, values, and beliefs on science, indigenous knowledge and lightning.

3.2 Research design

A research design is a plan or road map and structure of the envisaged investigation used by the researcher to obtain data used to address the research questions.

This study adopted a case study research design. A case study is an intensive study and analysis of an individual unit. According to Best & Kahn (1993), a case study examines a social unit as a whole where “the unit may be a person, a family, a social group, a social institution, or a community” (p.193). The authors define a case study as “ a thorough observation of a group of people living together in a geographic location in a corporate way” (p.194) while Cohen & Manion (1994) define a case study as an observation of “the characteristics of an individual unit - a child, a clique, a class, a school or a community” (p. 106). In this study, the social group, the unit, the case, was a group of grade 10 learners in a high school in a geographical area in the Eastern Cape Province in South Africa. The advantage of a case study is that it “probes deeply” (Best & Kahn, 1993, p. 193) in order to “analyse intensely the multifarious phenomena that constitute the unit with a view to establish generalisations about the wider population to which that unit belongs” (Cohen & Manion, 1994, p. 106-107). In this study that wider population is all the learners from the indigenous groups of people who have to grapple with contrasting worldviews in their daily lives.

During a case study, the researcher investigates the case in depth using a variety of data gathering methods to produce evidence that leads to the understanding of the case and to answering the research questions. The data gathering methods used in this study included: debates and discussions; questionnaires; focus and follow up interviews; experimental work; reflective essays; and observations. The reliance on multiple sources of evidence in studying a case study is meant to add breadth and depth to the study resulting in a richness of data through triangulation. It strengthens the study. It was hoped that such an approach would add to construct validity, internal validity and external validity of the research (utexas.edu website). This website defines construct validity as the correctness of the measures used to study the concepts; internal validity is the robustness of the research process; external validity reflects whether or not research findings can be generalised beyond the immediate case.

The case study is generally held in low regard, or simply ignored, within the academy (Wikipedia free encyclopaedia). The reason for this is mainly because the case study is widely misunderstood as a research method (Flyvbjerg, 2006). I discuss two of those misconceptions or criticisms here.

The critics of the case study believe that the study of a small number of cases offers no grounds for establishing reliability or generality of findings. Wikipedia free encyclopaedia gives an example of a case study that falsified a scientific view that had been held for two thousand years. Aristotle's incorrect view about gravity (that heavy objects fall faster than light objects) dominated scientific thinking for nearly two thousand years until it was falsified by Galileo's **one** experiment (Galileo demonstrated that a metal ball fell at the same rate as a feather if air resistance is removed). A large sample (many experiments) was not necessary. By selecting case studies strategically, e.g. by using information-oriented sampling rather than random sampling, one may arrive at case studies that allow generalisation. In this study, the group of learners involved in the research was a critical case which was an information-oriented sample. A 'critical case' is defined as a case having strategic importance in relation to the general problem. The general problem in this study is the attempt by indigenous people to border cross from one worldview to another as they try to extract meaning from their experiences in the two worldviews. The argument here is: If it is valid for the group of indigenous learners who took part in this study, it must be valid for other groups of indigenous learners because they share the same problem.

Other critics of the case study feel that the intense exposure to the case biases the findings. The critics argue that there is a tendency to confirm the researcher's preconceived notions. A good and professional researcher would not go into a research with some preconceived notions and would certainly not allow bias to enter into the research. The knowledge of the possibility of bias would make the researcher more objective and careful. It is this strategy that was used in this study.

The impact of an intervention programme on learners was assessed by examining the attributes, perceptions and abilities of the learners before and after the intervention programme. This makes the research a pre-test-post-test experimental research design. This is a research design where the attributes of the research participants before an intervention programme are compared to their attributes after the intervention programme.

Diagrammatically, the pre-test-post-test design would be shown like this:

O_1 X O_2 where O_1 shows the attributes of the learners before the intervention programme; X is the argumentation-based instructional intervention programme and O_2 shows the attributes of the learners after the intervention programme.

In this study, I was interested in the learners' ability to argue; the learners' understanding of the nature of science, indigenous knowledge, lightning and thunder before and after the argumentation-based instructional intervention programme.

3.3 Description of the study population.

The following information was accessed from the curiouschameleon website and from "Religion" in "The Republic of the Transkei" (1976), Chris van Rensburg Publications.

South Africa is a nation of more than 50 million people speaking 11 different official languages and an even greater number of local dialects. This kaleidoscope of cultural heritage makes it truly the 'Rainbow Nation.' One of the principal ethnic groups in South Africa is the Xhosa people. The Xhosa are part of the Nguni tribal group who migrated from northeast Africa. They first settled in Zululand, and later, as a result of conflict with other tribes, moved south towards the Great Fish River. They settled in the beautiful region now called the Eastern Cape Province of South Africa where one finds cities such as Umtata, East London and Port Elizabeth.

The area was originally inhabited by another tribe called the KhoiSan, and due to the interaction of these two groups, the Xhosa began integrating many of the KhoiSan traditions into their culture. Most notably, spoken Xhosa now includes the distinctive 'clicks' of the KhoiSan language. Traditionally, Xhosa children learned/learn, from their elders, the norms, values, traditions, culture of the tribe and the work that they would do during their adult life. Many Xhosa people, as with many other people of African origin, still hold strong spiritual beliefs and follow traditional customs. The Xhosa believe that their ancestral spirits guide them through life and they will appeal to their ancestors for assistance whenever major decisions need to be made. The following example will show how much the Xhosa people are traditional and religious, steeped in their culture. During this research, I lived in a village in a rural area in the Eastern Cape. One day some bees came into my house. The bees were getting uncomfortably too many and so I informed the landlady of this development. Moments later she came together with an elderly man who stood at the door of my house and started speaking to the bees in a very respectful manner. He referred to them as important messengers who had brought a message or messages from the ancestors. The man promised the bees that the ancestors would be invited into the homestead, officially and properly, after the family had met and made the necessary arrangements. (These arrangements mean brewing the traditional beer, *umqombothi,* to appease the ancestors).The family had not forgotten their ancestors, the man told the bees. The man then instructed the bees to go back where they had come from since they were now frightening the children. (I was obviously one of the children who had been frightened by these ancestral visitors). To my utter surprise, the bees left my house one by one. Coincidence or was it the ability of the man to communicate with his ancestors?

For this study, what is of paramount importance is that the Xhosa people are a typical example of a people whose cultural values were undermined and whose voice was silenced by the colonisers and whose local knowledge has been repressed and replaced by forms of Western privileged knowledge and understandings but who remain, deeply and resolutely, steeped in their cultural values and practices making them a classic example of a people who would battle to harmonise the indigenous and the scientific explanations of natural phenomena.

In traditional society, there is a widespread belief in *umpundulu*. The *umpundulu* is the huge lightning bird that stands as tall as a man and, when the creature flaps his wings, the roar of thunder is heard. When it spits, so the superstition goes, lightning flashes across the sky. As has been explained before, the Xhosas also believe that lightning could be a message from their ancestors which they call *kuhambele umhlekazi. (Kuhambele* means a visit and *umhlekazi* means honouring or respecting).

At school, their children are taught that lightning is the movement of charges from the negatively charged cloud towards the positively charged earth. This is a different explanation from their cultural explanation that they know.

My own interactions with the Xhosa people gave me the impression that this was a group of people who were religious, cultural and respectful of their ancestors and other “invisible forces” and “powers within the environment” Ryan (2008, p. 666 and p. 668). Even the Xhosa Christians that I interacted with gave me the notion that they feel the closeness and loving care of their ancestors. This clearly shows the contradictions experienced by these people.

It is from this group of people who strongly believe in and practice their culture that this group of Grade 10 learners, who took part in this research, came from.

3.4 The sample and the sampling of the participants.

In a case study, the sample size could be as small as "a person, a family, a social group, a social institution, or a community" (Best & Kahn, 1993, p.193) or "---- one group of students in a class, in one school---" (McMillan & Schumacher, 1993, p. 375). For this study, a group of sixteen (16) Grade 10 learners at a rural high school in the Eastern Cape Province of South Africa was selected as the research participants. These learners were very familiar to each other having grown up in the same village or in adjacent villages near the school and having attended the same primary and secondary schools.

Ochs & Taylor (cited in Bricker & Bell, 2008, p. 487) claim that "environments conducive to collaborative explaining and critiquing are those marked with familiarity." In other words, these learners would find it easy to communicate with each other in our discussions since they were already engaging in discussions with each other in their everyday lives. Other authorities, however, point at weaknesses associated with this familiarity. For example, Sarangapani (2003) in Bricker & Bell (2008, p. 487) observe that "in everyday life, if one trusts a speaker or a source of knowledge, then one will believe the claims espoused by that source of knowledge, even given slight evidence." By extension, if one is close and familiar to another person, as was the case with my research participants, one would perhaps avoid contradicting that person for fear of spoiling their good relationship. (As will be seen in the results section of this thesis, both weaknesses referred to above did not seem to apply to this group of learners. For example, the learners quickly learnt that argumentation was not about personalities but about ideas).

Grade 10 was chosen because that is the grade where the topics lightning and thunder are mainly taught (bits and pieces of the topic are found in grades before and after grade 10) and also because the grade is under less constraints and demands from the Department of Education public examinations since such examinations can have a very significant negative impact on the implementation of a curriculum. Taba (1962), claims that: given a choice between good education and good public examination marks, many parents and students would choose good marks at the expense of good education despite the observation that "test-driven schools will not educate citizens and leaders with the experiences needed to make wise decisions in an increasingly complex, interrelated world" (Chinn, 2007, p. 1249).

Only learners who were good at English language were selected. This is because of the importance attached to language in the process of argumentation. Vygotsky (1978); Lemke (1990); and Mortimer & Scott (2003) maintain that the student should be able to use spoken and written language to articulate and defend his/her knowledge claims. The learners had to be good at science as well since we were dealing with scientific concepts. Koslowski (1996) feels that it is a prerequisite for one to know what is being talked about (the content) if one is to make meaningful arguments and come up with meaningful evidence. The quality of argumentation depends on the body of appropriate knowledge that can form the data and warrants of an individual's arguments (Osborne, Erduran & Simon, 2004). Norris & Phillips (2003) argue that comprehending, interpreting, analysing, and critiquing (scientific) texts requires knowledge of the substantive content of science. Without this resource, constructing evidence of quality would be severely curtailed, restricted and hampered. Any learners who demonstrated considerable reticence at verbalising their thinking were not included in the study (Osborne, Erduran & Simon, 2004). Only those students who were willing to participate in the research process were selected.

From the above description, it is clear why I used purposive, information-oriented sampling (Groenewald, 2004; Flyvberg, 2006) or a deliberately selected sample (Lester, 1999) based on my judgement of the participants and on the purpose of the research. I looked for research participants who had experiences relating to lightning explanations as given by two worldviews and who were likely to be able to articulate those experiences.

What they would be involved in the study and my expectation of them during the research process was explained to the learners *(See Appendices 3 & 4).* The learners had to make informed decisions about whether to take part in the study or not. It was thought that informed and willing research participants would likely be more productive and come up with more reliable insights than coerced research participants.

Sixteen learners were chosen for this study because the number is large enough to allow meaningful argumentative discourses but small enough to monitor closely. The team was divided into four groups of four participants each. It was felt that a group of four would be ideal for the kind of debates and argumentation discourses the participants would go through because even if members of the group decided to team up against other members, it would likely be two against two which would still be fine for argumentation purposes. An odd number such as three for a group could have potential problems of possible isolation of a member of the group.

Alexopoulou & Driver (1996) noted that if pupils are to scaffold each other's learning, then the groups must be large enough to enable this to happen but small enough to allow each member of the group to have an opportunity to engage in worthwhile argumentation. In deciding on the size of the group, I was also guided by Naylor, Keogh, & Downing (2007, p. 35) who noted that

> Pairs did not engage in extended discussions like the bigger groups. Lack of variety in the pupils' views (when the pupils were too few in the group) resulted in consensus being reached quickly and the opportunities of argument correspondingly reduced. The added intimacy of a very small group might also make disagreement with the views of other group members more difficult. Whole class discussions also appeared unsuccessful in generating sustained argument by pupils.

3.5 Research Instruments

3.5.1 *What is a research instrument?*

A research instrument is a tool or device used to collect data that will be used to address the research problem. Research instruments include psychometric tests, questionnaires, interview schedules, observation schedules or guides, document analysis checklists used to analyse documents such as essays written by the research participants, discussion and debates, analysis and inventories. Lester (1999) states that a phenomenological approach to research would make use of qualitative methods such as interviews, discussions, participant observations, analysis of personal texts (analysis of what the participants are saying verbally or in written form) in order to gather deep information and perspectives from the research participants about the issue or issues under study.

3.5.2 *Research instruments used*.

Which instruments where used in this study, for whom and for what purpose? These were:

- ***Questionnaires***

The questionnaire labelled *Appendix 6* was administered twice to the learners in order to get their initial and later views on the nature of science and indigenous knowledge. The questionnaire labelled *Appendix 9* was administered to learners, educators, community leaders, indigenous knowledge holders and experts in order to solicit information on causes, dangers and prevention of lightning.

- ***Individual and group activities.***

  The learners were involved in individual and group activities during lessons on argumentation *(See Appendix 5).* Most of these activities took the form of debates and role playing. Learners were given various tasks that they had to interact with and interrogate at individual, group and whole class levels. For each task the learners were to come up with evidence to support their positions and also to come up with evidence to refute or counter other people's knowledge claims. The purpose of these activities was to show the learners how to argue effectively. This was done by using their responses to improve their skill of argumentation by evaluating the quality of the learners' knowledge claims, their counter claims, and their evidence.

  The learners were also involved in individual and group activities during lessons on static electricity *(See Appendix 10).* The major purpose of these activities was to determine whether the learners could use the experimental results from their investigations to come up with reasonably argued conclusions about static electricity. Section D of Appendix 11 shows the activities based on stories related to lightning that the learners engaged in. The learners had to interact with these stories and work out possible causes of lightning.

  The learners were asked to work in groups because working collaboratively in problem solving promotes scientific discourses; it promotes argumentation (Herrenkohl et al. 1999). All group discussions were followed by a session where group arguments were shared with the whole class through group presentations followed by class discussions. Through listening to other participants' views, the listeners had an opportunity to reshape or even change their own original views (Simon, Erduran & Osborne, 2006).

Both the questionnaires and the learners' tasks were, typically, made up of very few questions (sometimes as few as two questions). Alternatively, a task was divided into sections so that the learners would work on one section of the task per time. This was to allow the research participants enough time to really think through each given question to enable them to come up with a well thought out answer to the question. Few questions also allowed a thorough analysis of the responses of the research participants. Generally, the purpose of these questionnaires and tasks was to evaluate the quality of argumentation of the learners before, during and after the instructional intervention programme.

- ***Follow up interviews and discussions***

  Follow up interviews and discussions were conducted with the learners individually or in groups. The aim of these interviews and discussions was to seek further clarification of ideas the learners would have raised in their earlier responses. This gave the learners another opportunity to explain further their earlier responses to questions on the questionnaire or to ideas they had raised earlier in their debates and in their essays. This was done in order to determine and improve the learners' quality of argumentation and their level of understanding of the nature of science, indigenous knowledge and lightning. These interviews and discussions were unstructured. Their content was determined by the initial responses of the research participants. Precautions were taken to ensure and allow the students to talk freely without unnecessary restrictions.

  Unstructured interviews were also held with the learners, educators, community leaders, indigenous knowledge holders and experts on what they knew about the causes, dangers and prevention of lightning. These open-ended interviews where the interview is held in a conversational manner allowed participants to feel free to express themselves as they wished, instead of the researcher restricting the discussion to certain predetermined questions rather than others. Simosi (2003, p.190) claims that in her study, she found such an "approach (open-ended interviews) enabled the gathering of information which is richer in comparison to other methods of data collection".

- ***Guided and Reflective essays.***

  The guided essay was given to the learners to determine their pre and post levels of understanding of the major tenets of the nature of science and the indigenous knowledge systems and the relationship between the two thought systems *(See Appendix 7).* This essay was written twice, before and after the intervention programme, in order to assess the relative impact of the programme. The reflective essay was aimed at finding out the qualitative gain, if any, made by learners in terms of their level of argumentation; of their levels of understanding and harmonisation of the two thought systems; and of their understanding of the causes, dangers and prevention of lightning. This essay was administered once at the end of the intervention programme *(See Appendix 13).*

- ***Observation schedules***

Observation schedules were used during participant observation of group discussions and during the lessons on static electricity and lightning *(See Appendix 12)*.

The researcher participated in the group discussions, as a member of the group, a more informed member of the group but not as the leader of the group. Sometimes, I would act as a moderator of the group discussions. The major purpose of joining learners in their discussions was to **listen** to their arguments and counterarguments in order to evaluate the quality of their arguments. I also took this opportunity to model the process of good argumentation, to scaffold and facilitate learner argumentation by asking questions such as 'Why do you say so? Where is your evidence? Can you think of an argument against that view?' (At a later stage, such questions would come from the participants themselves. Initially, however, the participants needed to be shown how this could be done). In addition to these questions, I proposed ideas for further exploration. Participant observation also allowed me to redirect the argumentation process whenever it seemed derailed. It was thought that, "These interventions can offer students opportunities to validate their previous arguments and view them in a more integrated and elaborated way" (Patronis et al. 1999, p. 752). Care was, however, taken to ensure that the learners' argumentation would not be curtailed by the presence of the researcher. Naylor, Keogh & Downing (2007) found that "argumentation appeared to be more productive in the absence of the teacher with teacher presence (not necessarily intervention) having an inhibiting effect" (p. 37). I tried to take cognisance of this observation throughout the learners' discussion sessions.

Naturally, balancing these two positions, of wanting to influence what was taking place in the discussions on one hand and of wanting to be as inconspicuous as possible on the other hand, was not easy. Scaffolding was provided until the researcher was convinced that the learners could operate on their own without his consistent assistance. Care was taken so that scaffolding could not be removed too early as this could easily result in the whole process of argumentation crumbling. " One sets the game, provides a scaffold to ensure that the child's ineptitude can be rescued by appropriate intervention, and then removes the scaffold part by part as the reciprocal structure can stand on its own" (Bruner, 1983 in Baumann, Bloomfield & Roughton, 1997, p. 74).

On the other hand, one would not want to continue to scaffold even when the learners could stand own their own. "Success by a child then indicates that any subsequent instruction should offer less help than that which preceded the success to allow the child to develop independence" (Wood, 1991 in Baumann, Bloomfield & Roughton, 1997, p. 74).

Non-verbal behaviour of the students and their communication patterns were captured and recorded. Non-verbal communication is a very significant way of communication. Some people believe that when there is a contradiction between what a person says with his words, with his mouth, and what the person says with his body language, people would believe the body language more than the spoken words. That shows how important body language is.

The researcher observed how the learners conducted activities on static electricity. The major purpose of these activities and observations was to determine whether the learners could use the experimental results from their investigations to come up with reasonably argued conclusions.

- ***Achievement test.***

  Learners wrote an achievement test on lightning *(See Appendix 11).* Although this was labelled 'test', it was emphasised to the learners that except for Sections A and B, there were no correct or wrong answers and that nobody would fail or pass the test. The important thing was to express their opinions freely and honestly and to support their opinions with reasons.

  Sections A and C of the test were administered twice before and after the intervention programme in order to assess the relative impact of the instructional intervention programme.

- **Field notes.**

  Groenewald (2004) suggests that because the human mind tends to forget quickly, a researcher must make use of a process he calls 'memoing'. This means recording what the researcher hears, sees, experiences and thinks in the course of collecting data. The researcher must make what Groenewald (2004) called observational notes (recording what happened) and theoretical notes (attaching meaning to what was observed) during the research process. These field notes are both part of data collection and part of data analysis since memoing involves interpretation of what is happening or being said. These memos or field notes are a reflection on the research process as it unfolds.

I recorded my feelings and intuitive hunches, the 'aha' experiences, questions that came into my mind, testimonies from the learners, stories from the learners and other sources, illustrations, observations, and indeed anything that I judged could help me later with my studies. Field notes help in that they can point at an impending pattern (good or bad) and in determining whether or not the inquiry needs to be reformulated or adjusted or redefined based on the observations being made (utexas.edu website).

- ***Informal and serendipitous sources of information.***

  Following the suggestions made by Allen & Crawley (1998), the researcher interacted, informally, with the research participants outside normal research sessions and used these interactions to collect research data. In addition, the research participants were allowed an 'all-time-communication system' so that they could supply any information they serendipitously came across. The attraction of this method is that it removes the 'artificiality' associated with interviews, especially where there is a special rapport between interviewee and interviewer (Simosi, 2003).

3.5.3 Improving the quality (validity and reliability) of the research instruments.

Comments on the instruments from specialists

The research instruments were revised on several occasions as a result of useful comments made by experienced Physical Sciences teachers two of whom became part of the research team and four doctoral and post-doctoral colleagues at or with links with the University of the Western Cape and the University of Fort Hare. I also consulted former colleagues who are now involved in research at the University of Kwa-Zulu-Natal and the Central University of Technology in South Africa. I asked these colleagues to concentrate on clarity of instructions and clarity of the task given, suitability of language used in terms of both its level and its sensitivity to cultural contexts, difficulty level of the tasks and the relevance of the task to the issues under study: argumentation, lightning, and the two knowledge systems. The time required to complete the task was not considered an important factor since groups were given as much time as they needed to complete a given task. An English language specialist, a teacher of English at the school where this study was done, was asked to comment on the suitability of the language used in the research instruments.

Pilot study

A pilot study is a mini version of the full scale study encompassing the pretesting of specific research instruments (Teijlingen & Hundley, 2001). This is to check the efficacy of the research instruments and the feasibility of the main study. Teijlingen & Hundley (2001, p. 1) feel that a pilot study: "-- might give advance warning about where the main research project could fail, or where proposed methods or instruments are inappropriate or too complicated.'

The research instruments were pilot studied at the schools of the two Physical Science teachers who were part of the research team. The learners who took part in the pilot study had the same characteristics as the learners who would be involved in the main study. Learners' responses were analysed in order to identify potential difficulties inherent in the instruments.

From both the comments of the experts and from the responses of the learners in the pilot group, poor items were identified and either revised/reworded or discarded. As a result, the final version of the instruments had fewer but better items than the original.

Determining the validity of the research instruments

Seven research instruments with a total of 89 items were sent to experienced science teachers and researchers in science for rating each item on each research instrument on a 0 to 5 point scale where 0 meant a completely irrelevant item and 5 meant a very appropriate item *(See Appendix 14).* Eight of these raters responded.

If all the 8 raters had rated each item 5, then we would have 89 × 8 = 712 ratings at the point 5 scale making a total of 712 × 5 = 3560 scores. The results of the ratings have shown that 607 ratings at 5 point scale were made making a total of 607 × 5 = 3035 scores. As a percentage, 3035 scores = 85.3% of 3560. This means that 85.3% of the research items were considered very appropriate items by the raters. This makes the research instruments very valid and reliable.

I also calculated the Spearman rank order correlation coefficient. I identified two raters who showed the most variance in their ratings. I also identified research instruments where a lot of variance in the rating had been registered. These proved to be The Science-IKS Questionnaire [SIKSQ] and The Achievement Test on Lightning and Thunder [ATLT]. The correlation coefficient for the SIKSQ items was found to be 0.98 while that of the ATLT items was found to be 0.99. These calculated correlation coefficients show that the research instruments are quite valid and reliable.

3.6 Data collection procedures

This research took place in three major phases.

Phase 1: Preliminary activities

a) Sampling the main research participants

The rationale for the sample used was explained in section 3.4 above. It will not be repeated here. What happened at this level was the physical identification and nomination of the learners who would be involved in the study.

b) Explaining the research process and the modus operandi.

This activity was made up of two related parts

1.1 *Explaining the whole research exercise to the learners.* (*See Appendix 3*). The following was done at this stage:

- I introduced myself as a student doing research work that needed their assistance.
- The area of interest was explained as the conceptions on natural phenomenon called lightning as given by both science (the science taught at school) and indigenous knowledge (the knowledge possessed by local indigenous people).
- I explained that the topic chosen was part of the National Curriculum Statement and the Curriculum and Assessment Policy Statement. This would mean that the participants who would take part in the research would learn relevant science concepts that were important in their school work while they were enjoying the research activities at the same time.
- The participants were told that they would be involved in a number of activities, individually, in groups and then as a whole class. These activities would be done outside the normal school programme. This would ensure that the research participants would not be disadvantaged in terms of the school activities. This,

however, meant that the participants would have to create time outside the school hours to do the research. It was explained to them that we would be working together as a team for several weeks. (In actual fact, we worked together for four months meeting three times a week for two hour sessions).

- While they would be no material (monetary) benefits for any of us, participants would be supplied with food and drinks during the research sessions since they would not be expected to work long hours on empty stomachs. An outing to celebrate the end of the whole research process would be held. (In reality, we could not afford an outing. We had a braai and drinks at the school. The research participants enjoyed it very much).

1.2 *Establishing the modus operandi and the ground rules.* (See Appendix 4).

The modus operandi spells out clearly how members of a group will work together. Establishing ground rules for acceptable argumentation creates an equitable intellectual environment and neutralises issues of social class, leading to greater participation by most of the students (Mortimer, et al. 2004; Vellom & Anderson, 1999).

It was emphasized that:

- During the discussions: Everybody would be free to make their thoughts known to others without any fear of intimidation or ridicule from the other group members or the researcher. Where one member of the group differed in opinion with another member, the procedure would be to advance evidence against the opposed point of view. The same would apply to those who agreed with a point of view: we would want to know why they agreed with that point of view. The major question they were told to always keep in mind and answer was: What is your evidence to support what you are saying or to refute another person's point of view?
- No answer, no matter from whom, would be treated as wrong or right but we would expect a reasonable explanation to support each answer.
- Participants were encouraged to make their contributions no matter how small they thought these were. It was emphasized that what they thought was small could prove significant to the group and that many small contributions build up to become big important ideas.

- Participants were told that it was quite in order and legitimate to change their earlier way of thinking if they found the opposing argument to be stronger than their own argument (Simon, Erduran & Osborne, 2006). There was nothing shameful or belittling about this shift in position. In fact it was seen as a sign of being reasonable and mature.
- Group members were expected to listen attentively and not to disrupt those that would be presenting their case. Group members would be given a fair opportunity to put across their points of view. They would be expected and in fact required, to speak and to listen. Both processes (speaking and listening) are important in argumentation (Simon, Erduran & Osborne, 2006).
- All group members were seen as equal and all were interested in learning.
- If there were any issues or questions of disharmony that arose during the group interaction, those issues or questions would be resolved quickly before they derailed the whole research process. (I am happy to say that we did not witness any ugly incidents during our research process).
- Participants were told that, in the final analysis, they belonged to and owned the research process and it to them. This was seen as important because: Programmes succeed when participants in the programme feel a sense of ownership of the programme: "that it belongs to them and is not simply imposed on them" (Ogborn, 2002, p. 143).

c) *Selecting and putting together a research team (See Appendix 1 for letter of invitation to join the research team).*

This is a team that I considered helpful to me in this research. Consequently, I selected and put together a research team made up of the following people:

- A local person who was conversant with the necessary protocols, a respectable person who could interact with community/traditional leaders and the knowledge holders with relative ease. This person introduced me to the Chief of the community who in turn introduced me to the traditional leaders and the indigenous knowledge holders.
- A Xhosa language speaker and teacher who could, not only interpret what was said in Xhosa into English and vice versa, but who could unlock the 'hidden and subtle' meanings and ramifications of what was being said in the local language.

- A historian who helped by filling in gaps in the data collected and giving the data its historical importance/significance/perspective.
  One teacher, at the school, fitted all the above requirements: He was a local person, a teacher of both Xhosa and History at FET level.

- Two Xhosa speaking Physical Science experts and teachers at FET level who helped by allowing the pilot study with their learners and in interpreting the learners' attempts to integrate, through argumentation, science and IK on lightning.

- An expert in English who identified Grade 10 learners with a flair for English and who would comment on the language aspects (language level and clarity) of the questionnaires.

It was impressed upon both the research team members and the research participants that they would be in partnership with the researcher. This was done in order to provide the research team and the research participants with a sense of ownership of the research process.

Phase 2: Baseline study: Collecting data on indigenous knowledge about lightning.

Interviews and a questionnaire to students, educators, community leaders, indigenous knowledge holders and experts on what they knew about causes, dangers and prevention of lightning were used. Relevant literature was consulted. The purpose of this phase was to collect data that were used to construct research instruments for the study and to design the teaching learning programme. *(See Appendix 9 for the questionnaire).* For expert knowledge I consulted personnel at the University of Fort Hare.

There are protocols that need to be followed when researching on indigenous knowledge from the communities (Mosimege, 2005). The author contends that research findings among Canadian Aboriginal communities and in South Africa between 1996 and 1998 show that unless these protocols are followed, the community knowledge holders (the experts in indigenous knowledge) will either refuse to cooperate with the researchers or they would deliberately give the researchers incorrect information in order to mislead the researchers and thus protect their knowledge from exploitation, piracy, misappropriation or misuse by foreigners but that where the proper protocols were followed, the researchers got a lot of cooperation from the community knowledge holders. Bang & Medin (2010) identified the following as prerequisites when researching amongst indigenous people: elder input, use of local language, community participation, respect for cultural values, and informed consent. In pursuance of a desire to follow those protocols the following was done:

- A local, respectable member of the community who was a teacher of History and Xhosa at the school where this research was done was chosen to become part of my research team. This man took me to the Chief of the community who introduced me to the community leaders and the knowledge holders of the community at their Traditional Council Meeting. The same man also helped me in the protocols that should be followed when asking for information from the elders in the community and in transcribing and translating texts on the tapes and in the written work.
- Permission to conduct the research in the area and with the learners from the communities was obtained from the Chief of the community. It was explained to the Chief that this research was part of the teaching of topics in the National Curriculum Statement and the Curriculum and Assessment Policy Statement and that the research was aimed at promoting indigenous knowledge systems that had been side-lined, marginalised or even demonised by the colonial Western powers. The Chief was assured that the research would be used for academic purposes only and not for any material benefit to anybody. Snively & Corsiglia (2001, p. 11) posit that "oral information may only be shared under particular circumstances, for example, when it is clear that no one intends to use the knowledge for gain."
- Four prominent knowledge holders, identified by the Chief were consulted on indigenous knowledge on the nature of lightning. I decided to consult several knowledge holders for purposes of triangulation. One of these knowledge holders was then invited to come and explain the causes, dangers and prevention of lightning to the Grade 10 learners who took part in this research *(See lesson 7 in Phase 3 below).*

Phase 3: The instructional and learning programme.

This programme consisted of several lessons as shown below. (The term lesson is used here to mean a number of activities related to each other and covering a concept or idea. In reality, a lesson was really a series of related lessons on a topic).

Most of these lessons were really activities that were done by the research participants. During these activities the participants were asked to **listen, talk, read and write**. This is because of the importance of these language modalities in argumentation and in the production of scientific knowledge.

Rivard & Straw (2001, p. 567) argue that "one of the goals of science education is the creating of active learning environments in which students construct knowledge (construct personal meanings) and achieve understanding of fundamental scientific ideas while engaging in discourse within the classroom learning community." Discourse 'within the classroom learning community' invariably involves the use of language. Britton (1982, p. 115) in Rivard & Straw (2001) says "we come to an understanding (of a concept) in the course of communicating it" (to and with others) while Bruffee (1993, p. 155) puts it succinctly when he says "knowledge is socially constructed and learning socially interdependent." It seems clear that language is key to learning science. Rivard & Straw (2001) go on to say that

> Talk is important for sharing, classifying, and distributing knowledge among peers, while asking questions, hypothesizing, explaining, and formulating ideas together are all important mechanisms during peer discussion. Analytical writing is an important tool for transforming rudimentary ideas into knowledge that is more coherent and structured (p.566). Classroom activities that feature listening, talking, reading, and writing can all be used to achieve the cognitive processing of information (p. 568).

Writing in order to explain scientific concepts demands that the learners connect these into an integrated web of meaning. In other words, writing about a concept results in greater and deeper understanding of that concept (Rivard & Straw, 2001). These authors support the use of both talk and writing as teaching and learning strategies when they argue that talk and writing, used separately, may not be as helpful for conceptualizing relationships as a strategy that combines them in order to obtain the benefits of both modalities. To these authors, talk and writing are complimentary modalities. The authors further state that

> The use of writing as an instrument of learning, underlines the personal construction of knowledge, whereas the use of talk for learning is consistent with social constructivist thought. An instructional strategy encompassing both should enhance learning more than another using either of the two language modalities alone (p. 569).

Norris & Phillips (2003) posit that

> Reading and writing are inextricably linked to the very nature and fabric of science, and, by extension, to learning science. Take them away, and there goes science and proper science learning also, just as surely as removing observation, measurement, and experiment would destroy science and proper science learning (p. 226).

By reading, the authors do not mean the simple "word-recognition-and-information-location" (p.225). They mean "inferring meaning from text" where text means "whatever is meant to be read" and includes "printed words, graphs, charts, tables, mathematical equations, diagrams, figures, maps, and so on" (p. 228). By inferring meaning the authors mean the "integration of text information and the reader's (prior) knowledge" in order to create something "new, over and above the text and the reader's knowledge" which means "going beyond surface meaning "of the text. This includes "making judgement about what is meant or intended in contrast to what is being said" (p.228). Science writing is not mere reporting of experiments done but is seen as construction of scientific knowledge (Myers, 1990 in Erduran & Jim'enez-Aleixandre, 2008).

This explains why these four language modalities or skills were used and emphasized in this research. The learners were given texts to read and to react to in writing and orally. There were many opportunities for the learners to discuss (talk and listen to others).

Lesson 1: Teaching argumentation through debates (TATD) (See Appendix 5).

To make maximum use of the debates, I borrowed suggestions from Kuhn & Udell (2003) and Kuhn (2010) who suggested that the debate should take place in phases. For this research, each debate was divided into four sessions or phases.

Session 1: Preparing for the debate.

The group members supporting a certain position in the argument explored, evaluated and organised arguments to support their position as well as to anticipate their opponents' responses and then worked out possible replies to the opponents' counterarguments (rebuttals). In other words, teams of participants collaborated to develop their own argument to justify and defend their chosen position. Specifically, the participants would put together their reasons for supporting or opposing a position; reflecting on whether they were good reasons (leading to a discussion of what makes a reason a good one); eliminating duplicates; revising the wording of their reasons; finding ways of strengthening their reasons, for example through use of examples and evidence; deciding the order of presentation of these reasons and choosing one of their members to present the argument.

Session 2: The actual debate.

This is the actual debate where a team engaged with the opposing team. The emphasis was on the students' ability to articulate and defend their position and to address, directly, each of the opponents' claims and to weaken those claims with counterarguments. After the presentation of the spokespersons of each group, there was an open discussion of the two presentations where each team questioned the other team on certain issues that needed clarification. Social collaboration within members of the team in constructing responses to the opposition was highly valued at this level of the debate. Although video tapping them would have been better, these sessions were only audio tapped because of financial constraints.

Session 3: Reviewing and reflecting on what happened during the actual debate.

Members in each small group reflected on how they had fared during the actual debate. For each of their arguments, the group members identified the opponents' counterarguments and their own comeback argument. They then identified their strong and weak moves during session 2 and came up with better and more effective comeback arguments or replies. For this session, they used both what they remembered from the debate and the audio tapped recordings. To do this, each team recorded each argument of the other team and for each argument, they thought of how to strengthen their own argument in order to avoid criticism or they came up with a counterargument or a rebuttal or they decided to drop their reason. They were also encouraged to identify compelling reasons from the opposition with which they were willing, with good reason, to agree with. This step is very important in this research where I was teaching the learners the importance of shifting positions when confronted with reason and evidence. In all these discussions, consensus within the group was emphasised. For this reflection, they were guided by the following questions:

- What did you say which your opponent found weak? How are you going to strengthen it or will you drop it?
- What did the other team say which you found weak? How are you going maximise that advantage?
- What did the other team say which you found attractive? Why did you find it attractive?

Session 4: The final "showdown".

The opponents engaged in another but more informed and refined debate. Points of continued disagreement and of agreement were explained.

The lesson on teaching argumentation through debates was taught through three related activities.

Activity 1*:* The learners were given controversial statements such as ***'Learners should wear uniform to school'; 'The rich should pay more than the poor for social services'*** and asked to defend or oppose the statement. The participants were divided into two groups: one group defended the statement while the other group opposed it.

Activity 2: Learners were given scenarios where family members were divided into two groups, with one group supporting a certain point of view while the other group opposed that point of view. For example, one family group would support euthanasia while the other group opposed it; one family group would support plastic surgery while the other group opposed it. Participants, in their two groups, role played the two family groups and provided reasons for supporting or opposing the point of view. In other words, the participants were then told to defend those opposing positions. Opposition and argumentation were encouraged by putting the participants into these positions of two groups of people who held different opinions on some socio-scientific issue.

Activity 3: The learners were given two very short stories. For each story they were given four possible explanations. The students were asked to identify the explanation they agreed with and to justify their choice. If they agreed with more than one explanation, this was accepted but they had to justify each choice. If they did not agree with any of the given explanations, they were challenged to come up with their own explanation and justify it.

The purpose of these debates was to teach the learners how to argue effectively and to determine the quality of the explanation / justification / evidence given by the learners for their position and how this quality improved, if it did, as the learners engaged in more debates. For this reason, lesson 1(above) and lesson 2 (below) are presented here separately for purposes of clarity. In reality, the lessons were conducted simultaneously. For example, learner responses were used to show the meaning of claims, evidence, counterarguments and so on.

Lesson 2: Teaching the meaning and importance of argumentation

The class was taught the meaning, process and importance of argumentation through four activities as shown below *(See Appendix 5).*

Activity 1: The terms claim, data or evidence, rebuttal were explicitly defined as recommended by Herrenkohl et al. (1999)

Activity 2: The importance/ purpose/ rationale of argumentation were explained as recommended by Kuhn et al. (2000).

Activity 3: The class was taught how to build a good and effective argument. This was done in order to improve the learners' understanding of the nature of argument in general and of argument in a scientific context in particular. Osborne & Young, (1998) cited in Osborne, Erduran & Simon, (2004) maintain that students must be helped to practice articulating and defending scientifically valid ways of arguing. The aim was to enhance the quality of argumentation of the learners about scientific issues.

To initiate and promote effective argument, Erduran (2006) and Osborne, Erduran & Simon (2004) suggest the use of the following strategies, which were used in this study:

- Learners were taught the importance of justifying or refuting claims using appropriate and adequate theoretical and/or empirical evidence and the importance of thinking of and coming up with counter claims. Counter claims are arguments that challenge other arguments. It would seem that counter claims are important in that they would strengthen good arguments and weaken poor arguments.
- Students were encouraged to begin their claims with phrases such as 'My idea is---'; 'I think---'; 'I am of the opinion that---'; 'My argument is---' ; to begin their data/ evidence with phrases such as 'My reasons for saying so are---'; 'The reason for my argument is---' and to begin their counter claims with phrases such as ' An argument against your idea is---'; 'To oppose your idea I would say that---.'
- Argumentation prompts were used to facilitate and scaffold student argumentation. Argumentation prompts are open ended questions designed to elicit justification of a claim. For example, listeners were encouraged to ask questions such as 'How do you know that what you are saying is true?'; 'What or where is your evidence?'; 'What reason do you have?' (In my teaching, outside the research process, the research participants would shout at me or other learners saying 'where is your evidence?' when I or other learners made a knowledge claim. I felt gratified by this development).
- The researcher asked questions such as 'How would you argue against that claim?'; 'What evidence would you provide to show him/her that his/her idea is right or wrong?'; 'Can anyone think of something to say to oppose that?' In other words, the researcher played the devil's advocate.

Further questions included; 'What do you mean by that? Can you please explain further?' 'How does that fit in with what has just been said by---?' 'How did you figure that out?' 'Can you give us some examples of that?'

Learners were taught and encouraged to listen attentively while the other group member was talking. Attentive and purposeful listening is an essential ingredient of meaningful argumentation (Simon, Erduran & Osborne, 2006).

Activity 4: Modelling the process of argumentation using concrete examples (Osborne, Erduran & Simon, 2004). This involved offering learners examples of both weaker and stronger arguments, enabling discussion of the features that make one better than the other. These authors say that strong arguments draw on a wider range of evidence and include rebuttals or counterarguments while poor arguments rely on no or minimal use of data to justify or refute the claims. The researcher used some of the participants' reactions/ responses in order to teach about good and poor arguments and evidence *(See Appendix 5).*

Lesson 3: Questionnaire on the nature of science versus indigenous knowledge

Basically, the session aimed at making the learners aware of the existence of these two worldviews as possible explanations of natural phenomena. The learners were given statements that are related to science and IK and asked to decide whether they agreed or disagreed with each of those statements and to explain their positions. Examples of such statements were: '***Science is based on facts only'; 'indigenous knowledge is based on beliefs only'; 'science is universal'.*** They also had to indicate the source of information that influenced their positions or opinions from a given number of possible sources of information. They were encouraged to add any information they felt was important about each statement as well *(See Appendix 6).*

Lesson 4: Guided essay on science and IK

Learners wrote a guided essay in which they answered questions related to science and IK such as ***'Is science superior to indigenous knowledge or is indigenous knowledge superior to science or are they of equal status?' 'Are indigenous knowledge holders trained to do what they do or say?'*** *(See Appendix 7).*

The purpose of the questionnaire in lesson 3 above and of the guided essay in lesson 4 above was to identify the learners' initial understanding of the meaning and the major tenets of science and IK and the relationship between the two thought systems. This provided one set of data for the period before the intervention programme.

Lesson 5: The major and general tenets and claims of science and of the indigenous knowledge *(See Appendix 8)*

The major tenets of WMS and IKS were discussed with the learners. Some of the issues discussed were: ***'the origin and history of science'; 'the fallacies and myths of science'; 'the source of indigenous knowledge'; 'the fallacies and myths about indigenous knowledge'; 'the education and training of indigenous knowledge holders'; 'the verification and authenticity of the two knowledge systems'.*** The emphasis was on the commonality and interdependence of the two worldviews rather than on their dichotomy. The relationships of the two thought systems were illustrated. The aim of the lesson was to try and show the learners that both science and indigenous knowledge were legitimate ways of knowing and explaining natural phenomena and that they complimented each other. "Each is necessary and none is redundant" (Brown-Acquaye, 2001, p. 68).

Lesson 6: Learners were again asked to complete the science-IK questionnaire and to again write the guided essay on comparing science and indigenous knowledge in light of what they had learnt about the two knowledge systems in lesson 5 above *(See Appendix 6 and Appendix 7).*

The purpose of this lesson was to determine the relative impact of an argumentation-based instructional intervention programme on the learners' understanding of the two knowledge systems.

Lesson 7: Lesson on static electricity and lightning *(See Appendix 10)*

A number of activities were done during this lesson. The following are some of the issues that were discussed and the activities that were done: the history of static electricity; activities and experiments on static electricity including the charging and discharging of an electroscope leading to the laws of electrostatics; linking static electricity to lightning and thunder; and some facts about lightning.

The scientific explanation of the causes, dangers and prevention of lightning was taught to the class through several group activities. An expert on the indigenous knowledge on lightning explained the phenomenon from the traditional, indigenous point of view. An attempt was made, by the research group, to identify the relationship between the explanations about this natural phenomenon as given by the two worldviews.

The purpose of the last part of this lesson was to attempt to convince the learners that both systems of thought had their strengths and weaknesses in their attempt to explain natural phenomena and that indigenous knowledge explanations had their own legitimate bases.

Lesson 8: Achievement test on lightning *(See Appendix 11).*

The learners were given a 'test' on lightning. The test was made up of six sections. Section A was some version of a cloze test where the learners were asked what they knew about static electricity. They completed given sentences on lightning by filling in blank spaces with the most appropriate word. The answers were either right or wrong. Section A was written before and after the intervention programme. Section B was based on the experiments and activities that the learners had done on static electricity and lightning. They were asked what they had observed and to offer explanations for those observations. Answers were either right or wrong.

In Section C the learners were asked to give possible explanations to events or scenarios related to lightning and to give reasons for their explanations. For example, the learners were asked to explain why a certain homestead was struck by lightning several times. In Section D the learners were given case studies or stories of people who had been struck by lightning mysteriously and/or on several times. The learners were asked several questions on each of these case studies. The aim of these questions was to find out the learners' conceptions on lightning.

In Section E the learners were asked to explain why they agreed or disagreed with given statements related to lightning. Statements such as ***'It is dangerous to stand under a tall tree during a thunderstorm'*** were used. Learners were asked to indicate the source of information they had used to come up with their position. The aim of this section was to find out the learners' conceptions of lightning. In Section F the learners were given statements related to lightning and thunder and asked whether they thought such a statement would come from science or from indigenous knowledge or from both. They were challenged to identify a word or words in the statement that they had used to come up with their conclusion. Statements such as ***'Lightning is a messenger from high levels, from ancestors'*** were used.

As can be seen from the above description, this was not a test in the usual sense. Except for the first two sections of this test, there are no right or wrong answers to the questions. The learners were told that what was important was that they gave their honest opinions on the issues under discussion and that they supported those positions with evidence.

Lesson 9: Reflective essay

Learners were asked to write a reflective essay on "**What I gained and learned from this experience"** *(See Appendix 13).* The learners had to reflect on their previous and their current positions on how they saw and understood science and indigenous knowledge and on causes, dangers and prevention of lightning. The aim was to find the qualitative gain made by learners, if any, as a result of this argumentation-based instructional intervention programme.

3.7 Description and explanation of some parts of the instructional intervention programme in detail.

The intervention programme consisted of lessons on how to come up with good argumentation; the major tenets and fallacies of science and of indigenous knowledge lessons on static electricity and lightning; how the skill of argumentation could be used to harmonise the explanations of lightning, as given by the two worldviews.

In all these cases, these lessons took the form of activities by the research participants with very little teaching in the traditional teacher-centred manner.

Generally, these activities followed the stages suggested by Langehoven & Ogunniyi (2009). These are:

Stage 1: Introduction of the issue or task to be discussed or interrogated by the learners

The researcher presented and explained the task to be done to the learners.

Stage 2: Individual task

Individually, the learners engaged with the task in order to formulate an opinion or claim supported with reason or evidence. This was an intra-dialogical argumentation stage during which the individual engaged in conversation and argumentation with one's self.

Stage 3: Group task

In small groups of 4, individuals shared their views. This inter-dialogical argumentation was meant to facilitate the emergence of claims and counterclaims ultimately coming up with a group consensus.

Stage 4: Group presentations

A selected member of each of the four groups presented the group's consensus to the rest of the research participants.

Stage 4: Whole group discourse

Facilitated by the researcher, the learners engaged in trading claims, evidence and counterclaims at each other. The major aim of this activity was to facilitate joint co-construction of knowledge.

Throughout these activities, the researcher (a) assessed the level of understanding of the topic or issue under discussion and (b) used TAP and/or CAT to determine the level at which dialogical argumentation occurred.

Below is a description and explanation of some parts of this argumentation–based instructional intervention programme.

On static electricity and lightning

The major concepts learnt by the research participants, through experimental work and discussions about static electricity are clearly indicated in chapter 4 and therefore will not be repeated here.

Some facts about static electricity and lightning were discussed with the learners to arouse their interest in the activities they would do later on. These facts were:

1.0 Lightning can pass through human beings and other animals and through buildings on its way to the ground and cause a lot of damage or even death. Lightning starts fires, strikes trees and tall objects.

2.0 Some places get lightning bolts more frequently than others. For example, "the Empire State building in New York is hit by lightning about 500 times each year" (Lombard & Geyer, 2010, p.99).

3.0 Metals are good conductors of electric charges and so can be used to carry the charge from the cloud safely into the ground without damaging buildings where the metal rod is attached.

4.0 ***The history of static electricity*** (Brookes, et al, 2005; Lycoudi, et al, 2008).

This short history was given in order to show the research participants that science knowledge is constructed over a long period of time and through the work of several people. This means that science knowledge construction is a collaborative enterprise. This is the reason why the research participants were asked to work together and collaborate in this research.

The following historical facts were mentioned:

- It was about 600 BC when the Greek philosopher, Thales, noticed that if he rubbed a piece of amber (the petrified tree resin) with some wool, both the amber and the wool attracted small pieces of dry leaves and feathers. The Greek word for amber is '*elektron*' and so now, in English, we have the words 'electric' and 'electron' from that Greek word.
- William Gilbert (1540-1603), an English scientist, found that a glass rod rubbed with a silk cloth attracts light weight objects such as small dry leaves, feathers and paper.
- In 1733, Dufay, a French physicist, noticed that there were two types of electrostatic forces- attraction and repulsion.
- From their various experiments, scientists came to the conclusion that there are two kinds of charges. Benjamin Franklin (1706-1790), an American inventor and politician, gave the names 'positive' and 'negative' to the different charges. He also proved that lightning is a form of electricity (Rogers, et al, 2001). Today we know that lightning is a form of static electricity.

5.0 ***Some facts about lightning.***

Source of this information is the webEcoist website and Kedler (2006)

The reason why this was included as part of the intervention programme was to arouse the interest of the learners in the natural phenomenon.

Some facts about lightning are:

- A bolt of lightning can travel at a speed of 160 000 km.h^{-1}.
- In South Africa it is estimated that 100 people are killed by lightning every year (*Earth and beyond Curriculum Workshop booklet, University of the Western Cape, 2011).*
- "The temperature of a flash of lightning is around 30 000^{o}C. This is hotter than the temperature of the surface of the sun" (Lombard & Geyer, 2010, p. 91). The atmospheric discharge of electricity is hot enough to fuse soil or fuse sand into glass. A lightning bolt can deliver enough energy to boil seven thousand litres of water. The brilliant white-blue flash of lightning is caused by its intense heat.

In all these lessons, the research participants were made to appreciate the fact that what is presented as facts about static electricity and lightning in the science books and in science lessons are mere mental models or pictures of what scientists believe is happening. The research participants had to accept that while some people believe in those models, others find it difficult to believe them and hence they come up with their own explanations of the same phenomena. **These other explanations are not necessarily wrong just as the scientific explanations are not necessarily correct**. Also, it would be much easier to believe these scientific models if we could see , not with our minds, but with our own eyes, these charges as they accumulate in one place and move from one place to another. The message I was trying to put across to the learners is that both traditional and scientific knowledge can be used to infer unobservable behaviour (Stephens, 2003 in Liphoto, 2009). This is crucial in this study which is trying to show that each of these two worldviews has something worthwhile to offer and that none of these worldviews should be seen as inferior.

For activities on static electricity

1. For each of these activities and questions, learners had to begin with their own individual observations and explanations, listen to other people's explanations, compare and debate the various possible explanations, and then as a group, come up with an agreed explanation. They answered the following questions:
    - *What is your observation? Compare your results with those of other groups.*

- *Explain your observation. Begin with your own individual explanation, listen to other people's explanations, compare and debate the various possible explanations, and then as a group, come up with an agreed explanation.*

2. Allowing the learners to argue, debate, interrogate, share, and discuss ideas or explanations is believed to be useful in that it helps the learners to externalise their thoughts, clear their doubts, change their conceptions and understand the issues under discussion better (Liphoto, 2009). It leads to a collective search for valid and justifiable positions on the issues (Ogunniyi, 2006).

3. Requirements: These are the materials that were used in the experiments on static electricity:

- Materials to be rubbed: plastic ruler, plastic comb, balloons, glass rod.
- Materials to rub with: pieces of woollen, silk, nylon cloth; participants' hair, sleeves of shirts, and dresses.
- Light- weight materials: small pieces of dry leaves, paper, feathers; a thin stream of water.
- An electroscope
- Other materials: cotton thread, tripod stand

4. The different groups used different but similar materials and compared their results. They also experimented with other materials in addition to those supplied for these experiments.

Lessons on static electricity and lightning

These are described in chapter 4 and in Appendix 10. Not all of them will be reproduced here.

An introduction to static electricity

The meaning of static electricity and its differences from current electricity were explained. The aim was to arouse the interest of the learners about this electricity that was stationary as compared to the current electricity they were used to. The fact that this electricity would move, if forced to do so, in a zigzag manner and through space (not through wires as with current electricity) would also interest the learners.

The major concepts that would be dealt with were stated. These included: neutral and charged objects, charges, forces called electrostatic forces, attraction, repulsion, lightning and thunder. The learners were told that although these words or ideas could be new to them, the presence of static electricity was not new to them as shown by the following examples:

- Some of their clothes produce a cracking sound and sparks of light when they take them off in a dark room or cling to their bodies when they put them on or when they remove them.
- TV screens or computer monitors collect dust very easily.
- Thin but strong plastic paper is used to seal food such as meat in a plastic container.

  All these and many more phenomena are related to static electricity.

Activities on static electricity

These were described in Appendix 10 and in chapter 4. They will not be repeated here.

Discussing and explaining the phenomenon of lightning

Activity 1: Introducing the concept of lightning

The following issue were raised with the learners:

- A thunderstorm with lightning and thunder can be a really frightening experience. Lightning strikes are very dangerous. It is estimated that 100 South Africans are killed each year by lightning. For this reason, this is a topical and important issue at all levels of society.

- *What causes lightning? What are the dangers associated with lightning? How can we protect ourselves against lightning?* People, all over the world, have tried to answer these questions. Unfortunately, these explanations differ from one group of people to another.

- In this programme we will look at two such explanations, one from the science point of view and another from the indigenous knowledge point of view. We will **NOT** attempt to decide which of the two explanations is better than the other. We will try to understand each point of view and to see where the two explanations mirror each other and differ from each other. In fact, the aim of these activities is to convince you that the knowledge that you have from your communities is as useful and valid as the knowledge you get from your school science lessons no matter how different this knowledge might appear to be.

- We will begin with the science explanation.

Activity 2: Linking static electricity and lightning.

The example used was the experience the learners have when they remove certain types of clothing from their bodies in a dark room. They were asked to describe their observations (what they see and hear).

[Expected answers: cracking sounds and sparks of light].

The following explanation was then offered:

- The clothes become charged as they rub against the body.
- The cracking sounds and the sparks of light are caused by the movement of electric charges.
- Thunder and lightning are also caused by the movement of electric charges. Lightning is, in fact, a large number of negative electric charges (electrons) moving from the clouds to the earth.

Activity 2: What causes lightning?

The following explanation was discussed with the learners.

During a storm, electric charges build up in the clouds as a result of friction between the moving clouds and the moving air. By induction, when the cloud accumulates a negative charge at its bottom side, the side closer to the ground, the ground becomes positively charged by induction. When too much or enough charge has built up in the cloud, a huge electric charge moves through the air towards the ground. The movement of the charge from the cloud to the ground is called lightning. The charge moves through the air at very high speed, causing the air molecules in its path to be displaced quickly and roughly. This displacement of the air causes a sound which we call thunder.

The learners were then given an opportunity to say what they knew about the causes of lightning and to relate what they knew to this scientific explanation.

Activity 3: The dangers of lightning.

Working in groups and using their experiences (what they saw, read, and heard, in the communities, in newspapers, over the radio and television), the learners were asked to produce a comprehensive list of the dangers associated with lightning.

Expected answers include:

- Can kill people and other animals.
- Can damage buildings, property.
- Can cause wild fires which can destroy habitats, ecosystems, and living organisms.
- Can damage communication systems.

Activity 4: How can we protect ourselves against lightning?

Working in groups and using their experiences (what they saw, read, and heard, in the communities, in newspapers, over the radio and television), the learners were asked to produce a comprehensive list of how to prevent lightning. The list had to include what to do and what not to do during a thunderstorm.

I would then give them what science says about how to prevent lightning. We would then compare the two lists and see where they agree and where they may not agree.

Expected answers include:

- Do not use or play with water. *(Water is a good conductor of electricity).*
- Avoid plain grounds or open fields. *(the person then becomes the tallest object in the field and thus becomes the most obvious target of lightning)*
- Do not take shelter under tall trees. *(see bullet above)*
- Switch off electrical appliances in the home. *(Lightning is electricity).*
- Put off cooking fires, for example, in the kitchen. *(Smoke is a good conductor of electricity and heat accelerates rate of conduction of electricity through the air).*
- Electrical (metal) conductors on buildings.

- Placing car tyres and certain plants on top of a building.
- Consulting a traditional doctor.
- Planting certain trees around the homestead

Activity 5: What causes lightning? What are the dangers of lightning? How can people protect themselves from lightning? An indigenous knowledge point of view

An invited community knowledge holder explained these ideas to the research participants. This expert was briefed before presenting the lesson in terms of what was expected of him, what would happen after his lesson delivery and that he should not be surprised or annoyed when the learners ask him questions. (Culture might have it that the young believe, without question, what the elders say).

A question and answer session to seek further clarification from the knowledge holder was held immediately after the presentation.

Activity 6: What causes lightning? What are the dangers of lightning? How can people protect themselves from lightning? Comparing the explanations given by the two world views

In groups, the research participants identified similarities and differences between the scientific and indigenous explanations of lightning using the information they obtained from the science and indigenous knowledge lessons. This was followed by a class discussion was held to identify common points of similarities and differences between the scientific and indigenous explanations of lightning

Expected similarities include: lightning comes from the clouds; it is very powerful and dangerous; there are ways of minimising its effect. Differences would be in the details of the two worldviews. For example: Different types of materials could be used to protect a family from lightning but the main issue is that lightning can be prevented by using certain materials around a homestead. On a more general level, the issue emphasised was that: *In addition to using their senses to observe the world in which they live, both systems of thought use mental pictures or models to present what they think is the nature of lightning. In other words, both worldviews infer from unobserved behaviour, unobserved events the nature of reality.*

3.8 Data analysis techniques used.

Developing a coding scheme for analysing argumentative discourse is a formidable task (Kuhn & Udell, 2003). An effort was made to borrow ideas from as many sources as possible. Like Kuhn & Udell (2003) I would consider my efforts "largely successful if students became proficient in advancing, critiquing, and defending claims in reasoned discussions with peers" (p. 1245); where "participants showed increased frequency of usage of powerful argumentative discourse strategies such as counterarguments, and decreased frequency of less effective strategies" (p. 1245).

General procedures

Using data from the pre and post intervention questionnaires, interviews, class discussions, and essays, an attempt to determine the ***'The relative impact of an argumentation-based instructional intervention programme on Grade 10 learners' conceptions of lightning*** was made**.** Like Allen & Crawley (1998), this research captured, recorded and analysed reported data (what the participants said), observed data (as reflected by the participants' actions and behaviours), and inferred data (impressions of the researcher). This means that both etic and emic perspectives were used for data analysis. Bricker & Bell (2008) quoting Harris (1987) and Pike (1954) define etic perspectives as the observer's or researcher's accounting and interpretation of the action or event. The authors define emic perspectives as the member's or participant's accounting and interpretation of the action or event.

Pre and post intervention programme data were used as a means of evaluating the overall effect of the intervention programme in terms of the students' development with argumentation; their level of harmonisation of the two knowledge systems and their level of understanding of the causes, dangers and prevention of lightning. This was done at both individual and group levels. The gain made by individuals and by the groups were noted, recorded and used in this analysis. Hogan (1999) believes that it is quite legitimate to assess group cognitive processes and products rather than just concentrating on assessing the mental constructions of individual learners. This is the view that I took in this research. The principal focus was to determine the changes, if any, shown by the learners, individually or as a group, after the intervention. This research accepted Kuhn's (2010) position that the argumentation skills, just like conceptual knowledge, have their own learning progressions.

> Students at the beginning of the intervention often focus entirely on their own arguments, using their turns in the dialog exclusively for this purpose. Once they begin to listen to what the opponent has to

> say, the second challenge becomes constructing a counterargument that successfully weakens the force of the other's argument. Students' early counterarguments efforts very often consist of disagreement with the opponent's statement-----followed not by a critique of it but by an alternative argument----that leaves the opponent's argument unaddressed (p. 816).

Later there is an increase in the students' ability and willingness to attend, critically, to the other's argument (Kuhn & Udell, 2003). These authors call the first phase *exposition* which means: articulating and clarifying one's own position and perspective. They call the second phase *challenges* which means addressing the opponent's claims and seeking to identify weaknesses in them. It was the purpose of this analysis to see if there was evidence of such qualitative changes in the research participants.

Specific procedures

Analysing the quality of the argumentation in the statements produced by the learners

Through careful reading and re-reading of the written texts and the careful listening and re-listening of the tapes, on different and separate occasions, students' discussion statements were analysed and evaluated in order to determine whether the statements had or contained the following:

- Claims that were not explicitly stated but implied. Further questions would be asked to elucidate the claim. Questions such as: 'What exactly do you mean by that?' would be asked.
- Claims that were clearly stated but with no data or evidence to support the claim. Although Zohar & Nemet (2002) and Berland & McNeill (2010) did not think that such statements were of any value, this research agreed with Osborne, Erduran & Simon (2004) who feel that such statements are important "because they are the first step toward initiating the process of establishing difference" (p. 1008). Such statements could be followed by questions such as 'Why do you say so?'
- Claims that were clearly stated and were accompanied by data/evidence. This evidence is often preceded by words such as 'because'; 'since'; 'as'.
- Statements that contained rebuttals or counter claims. Rebuttals are an essential element of an argument of better quality and demonstrate a high level of capability with argumentation. The ability to use rebuttals is "the most complex skill" as the individual must "integrate an original and an alternative theory, arguing that the original theory is more accurate" (Kuhn, 1991, p. 145) or less accurate. "Episodes

with rebuttals are of better quality than those without" (Osborne, Erduran & Simon, 2004, p.1008).

- Opposition statements that are explicitly stated. These statements could contain such phrases as 'I do not think so'; 'I do not agree with you' and would signify a truly argumentative discourse. Such statements would then have to be followed by evidence. Bricker & Bell (2008) refer to oppositional talk as talk created to stand in opposition to what another party has just said. These authors claim that such talk provides opportunities to test and realign current thinking amongst the interlocutors.
- Statements which were reinforced or elaborated by additional data.

Berland & McNeill (2010) have come up with a regime of related ways of evaluating arguments. The following are some of their suggestions:

- There is need to look at both the argumentative product and the argumentative process. By argumentative product the authors are referring to a reasoned piece of discourse in which a claim has been justified (or refuted). By argumentative process the authors mean the social interactions between participants in the argument.
- For argumentation as a product, the analyst asks the questions: Is the claim made by the speaker supported by evidence? Is the evidence given appropriate and sufficient? The authors define appropriate evidence as that which is relevant to the problem and factually accurate. Sufficient evidence means the quantity and complexity of the evidence and its ability to convince an audience e.g. the use of multiple pieces of data to convince the audience.
- The argumentative process looks at the argumentative functions played by the students' contribution. These functions include individuals stating and defending claims, individuals questioning one another's claims and defence, individuals evaluating one another's claims and defence, individuals revising their own and other's claims in light of the arguments they have discussed. The argumentation process also looks at the spontaneity of the students' participation which means finding out if students ask each other questions because their teacher prompted that behaviour or because they, themselves, thought the questions were relevant to what they were doing and that the questions would help them solve the problem at hand. In short, have the students developed ownership of the argumentation process?

This means that the audio-tapped recordings were fully transcribed and analysed for both the components and complexity of the arguments and data produced by the learners. In other words, the analysis determined the presence or absence in learners' written and spoken discourses of positioning i.e. construction of an argument, justifying or refuting the position with evidence, evaluating arguments and coming up with counterarguments and reflection on the argumentation process (Simon, Erduran & Osborne, 2006).

Driver, Newton & Osborne (2000, p. 294) identified factors or precautions which should be considered when analysing argument statements. These include:

- The same statement may have a different meaning in a different context. This means that the context in which the statement is made should be taken into account when analysing the argument statement. Argument is socially constructed and the social and cultural settings in which argument is carried out must be taken into account when analysing the statement.

Simosi (2003, p. 188) making a case for why argumentation analyses must consider the context in which the argumentation is embedded says that some of Toulmin's structural components "may be missing in an argument because the arguer considered them to be well known- or assumed- by his interlocutor, and, thus, he does not regard it necessary to refer to them explicitly in his attempt to persuade the other." This means that different situations have different requirements or demands in terms of what constitutes good argument. In other words, Simosi (2003) is saying that what could be a good argument in one situation or context may not be such a good one in another situation or context.

- Conversation points are not necessarily developed sequentially and reference has to be made across extensive sections of the tape or text in order to identify the features of the argument. This means, for example, that evidence of a claim can come much later in the conversation and not immediately after the claim is made.
- Not all points are made through speech (verbal or written) as some are made through semiotic gestures. These are an important communication feature of argumentation that should be attended to very carefully. A video tape is very useful here (but I could not afford one).

An attempt to consider all these factors was made as the statements from the learners were analysed.

The analysis procedure described above posed some challenges. How reliable is the analysis? Would another analyst, looking at the same work (transcript or tape) come up with the same interpretation? Possible solutions include: getting several analysts to go through the work independently, meet and compare their analysis and resolve any differences in the interpretation or the same analyst going through the same work and analysing it on several occasions and interpreting it independently of earlier interpretation. The two FET Physical Sciences teachers in the research team were asked to help in the analysis of the argumentation statements from the learners. (In reality, not much came from these teachers. They almost always complained of 'too much work'). And so, for this study, the researcher became the main analyst partly because of the reason given above and also because the researcher was aware of the contextual background of the study.

We have already seen the various analytical frameworks that can be used to assess the quality of arguments produced by the students.

For this research, because the research participants were just Grade 10 learners, Toulmin's data, warrants, backings and qualifiers were put into a single category called grounds to support the claims. This approach is supported by literature (Stone, 2009). Claims can really be seen as hypotheses, theories and predictions and data, warrants, backings, and qualifiers can be seen as evidence (Osborne, Erduran & Simon, 2004). To avoid the usual overlaps among the elements of the TAP, Ogunniyi & Kwofie (2011) adopted a modified version of the TAP by considering data, warrants and backing simply as grounds. Rebuttals would stand on their own. This means that, for this research, argumentation statements were analysed in terms of the claims made, the data provided, the rebuttal or counterargument advanced, and the replies to the counterarguments (Leitao, 2000). It is this modified version of TAP that was used in the analysis of data collected for this study. This is not to say that Toulmin's full framework is not of value but that the suggested modification makes the difficult problem of identifying and evaluating quality argumentation simpler and more manageable.

As stated earlier on, this research used aspects of the various theoretical frameworks discussed earlier on. This eclectic approach was chosen rather than using the full range of one model in order to tap the best from each of the models. Andrews (2003, p. 107) posits that "each is seen to have a different function and to have different strengths and weaknesses as far as a model of argumentation for education is concerned." This eclectic approach was also chosen because the use of most of these frameworks has proved problematic to many researchers. For example, Simon, Erduran & Osborne (2006, p.16) say of Toulmin's framework "Nearly all researchers have found the application of Toulmin's schema problematic." Some researchers have found this eclectic approach of using aspects of several analytical frameworks practical. Researchers have tended to use only aspects of a model (e.g. Jim'enez-Aleixandre & Pereiro-Munoz, 2002) or they combined aspects of different models (e.g. Duschl et al, 1999) in order to obtain a more workable analytical model (Tippet, 2009).

The level of understanding of lightning and of harmonisation, by the learners, of the explanations of the phenomenon as given by the two world views

Evidence of this came from the responses of the learners to questionnaires on what they knew about lightning *(See Appendix 9);* the achievement test on lightning *(See Appendix 11);* lessons on static electricity and lightning *(See Appendix 10)* and the essays they wrote *(See Appendix 7 and Appendix 13).* In all this, the ability of the learners to argue and use argumentation to come up with reasonable conclusions was also assessed. An analysis of these responses indicated the relative impact of the intervention programme in terms of understanding the nature of lightning.

3.9 Ethical considerations.

After explaining the purpose, process and demands of the research, permission to involve grade 10 learners as research participants was sought from the Department of Education, the school, the Chief and the community leaders of the area, the parents or guardians and the learners. The consent was given verbally or in writing. The importance of informed consent is that the information obtained from the research participants is likely to be genuine.

The learners would not be disadvantaged in terms of their curriculum requirements and school programmes since the topic lightning and thunder form part of the National Curriculum Statement and the Curriculum and Assessment Policy Statement. Also, the research sessions were held outside the normal school day. For the same reason of not wanting to disadvantage the learners academically, the researcher resisted the temptation of using the usual and familiar true experimental research design, opting instead for some form of pre-test-post-test research design with the same group of learners where the qualitative impact of the intervention programme on the learners was assessed and determined.

Effort was made to ensure that work of very high standard was obtained and that objectivity in the collection, presentation and interpretation of data with no room for plagiarism, dishonesty or any academic crime was maintained. Lester (1999) warns that because in phenomenological studies, the researcher represents and interprets what the research participants say, the researcher has to always ensure that he/she is faithful to the participants and should be aware of and guard against possible bias, misrepresentations and distortions. This research was quite aware of this obligation.

The rights, welfare, privacy and confidentiality of all research participants were assured and protected. The research results will be made available to those people who made a contribution to this research who may wish to access them in line with world standard ethical practices. Research participants were treated with respect to ensure their integrity as human beings and as useful members of the research process.

Research protocol when accessing information from knowledge holders in the community were observed and adhered to in order to ensure that the research is both ethically sound and culturally sensitive (Lindegger & Bull, 2002; Mosimege, 2005). To ensure this, a mature, local, respected member of the community formed part of the research team. This person helped in ensuring that the information obtained from the community was accurate and correctly interpreted.

The data, results and conclusions will be used for academic and professional purposes only. Furthermore, this research will not cause any physical or psychological damage to the research participants, the institution or the education system (if anything, they stand to benefit intellectually). In the same vein, the researcher did not promise or give any material benefits to the participants as this would amount to bribery which is an unethical behaviour.

3.10 Conclusion

A case study grounded in the interpretive research paradigm was adopted for this research since it was based on the learners' narratives about what they believed in terms of science, indigenous knowledge and lightning and on my own interpretations of those narratives. Several research methods and instruments were used to gather data necessary to address the research questions. A detailed instructional intervention programme based on argumentation was put in place for the learners who took part in this research. An eclectic approach to data analysis, where aspects of several analytic frameworks would be used, was suggested.

A lot of data were collected. That data will be presented, analysed and its meaning and significance unravelled in the next chapter.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND DISCUSSION

4.0 Introduction

This chapter presents, analyses and discusses the collected data. The presentation is done by computing statistical indices such as frequencies, percentages and t-test values for quantitative data and by categorising data by theme for qualitative data. Following suggestions from Harris (1987) and Pike (1954) in Bricker & Bell (2008) both etic and emic perspectives will be used to interpret and analyse the research data. The analysis employs an eclectic approach of the analytical theoretical frameworks that were found to be useful for this study. These include Toulmin's (1958) TAP (and many of its simplified versions) and Ogunniyi's (2008b) CAT.

The major purpose of the presentation and analysis is to compare and assess the learners' pre and post intervention knowledge and skills in argumentation, the nature of science, indigenous knowledge and lightning. The discussion involves a deep meaning-making process where the significance of the presented data to the research questions is unravelled. Both the analysis and the discussion will be done research question by research question. The research results of this study will also be compared with previous research findings as revealed by the related literature in order to show and explain the similarities and differences between the current research findings and those in the literature. A summary, at the end of each section that deals with a research question, will show indicators of the major knowledge concepts and skills that the learners constructed and developed and the major shifts in perceptions about the two worldviews and the nature of lightning that the learners demonstrated.

4.1 Learners' pre-post construction of an argument

This section presents, analyses and discusses data on the learners' ability to argue effectively by examining the statements they made during the debating episodes and when they were discussing the nature of science; indigenous knowledge; activities on static electricity; and causes, dangers and prevention of lightning. While most of the issues related to argumentation will be discussed in this section, because argumentation is central in this study, some issues related to argumentation will feature in all sections of this chapter.

It must be stressed that in this study I did not concentrate on whether given knowledge claims or given evidence were factually correct. The emphasis was on whether the learners supported their claims with reasonable and adequate evidence.

4.1.1 Argumentation during the debating sessions

(See Appendix 5 for details on how these debates were organised)

This subsection presents, analyses and discusses the results of only two of the several debating sessions that the learners were involved in.

4.1.1.1 Groups were discussing whether learners should put on school uniform or not when they go to school. [This was their first debating episode.]

During the first or initial actual debating session, some of the reasons given for wearing uniforms were: for identity since uniforms and learners are associated with their schools and differentiated from outsiders; in order to look the same; minimising the differences between the rich and the poor '*nobody can tell that one comes from a less fortunate family'*; to avoid dress competition amongst learners; to unite people from different backgrounds and cultures; *'uniforms make us look smart, neat and tidy'*; if a learner is involved in an accident out of school premises, one can tell which school the learner is coming from. Some of the reasons for not wearing uniform given were: some learners may not afford to buy uniforms; *'students in higher institutions do not wear uniforms, why should we?'*; '*we look smart in our own clothes.'*

During the open discussions, after the main presenters, the discussions were characterised by 'fierce arguments'; 'battles' to win the argument; what I would call 'quarrelling.' Each side was drawing lines in the sand, refusing to take a backward step. There was no sign of accepting any of their opponents' arguments even when confronted with clear evidence. Their aim was clearly to win the argument. It seemed that, to them, an argument must either be won or lost. (This was so despite the fact that it had been emphasised to them that in these debates there would be neither winners nor losers).

No attempts were made to address, specifically, the arguments that had been advanced by their opponents. In fact, it was almost as if the groups had not heard what their opponents had said. For example, to the claim that *"we look smart when we are in our own clothes'* the opponent quipped *'How do we tell from which school you come?'*, and another one questioned *'how can we then tell the difference between learners and teachers?'* clearly ignoring the claim that *'we look smarter in our clothes than in uniforms.'*

While heated arguments were observed within the group during the preparation for the actual debate, once it came to group presentations, the group members stood together, helping each other to 'win the debate'. The group responses seemed to be a consensus position and the group members collaborated with each other against their opponents in the other groups.

During the final debating session on this topic on uniforms, no real new ideas were brought forward. Groups tended to just repeat what they had said during the initial debate. I took this opportunity to discuss with the learners what they could do to improve their argument and the sort of questions they would need to answer as they prepared for the final debate. I suggested the following questions:

- *What did the other group say which you found weak? How are you going to make maximum use of that weakness?*
- *What did you say which the other group found weak? How are you going to minimise that weakness? Or are you going to abandon that argument?*
- *What did the other group say which you found attractive and are willing to accept?*

4.1.1.2 In another and later debating episode, groups were discussing whether or not a patient suffering from an incurable disease and who is in severe pain should be allowed to die by switching off the lifesaving machines that are sustaining him/her.

During the initial actual debating session the reasons for switching off the machines given included: To save the person and his/her family from physical and emotional pain; *'it is painful to watch your loved one in so much pain'; 'the person was going to die anywhere'*; In other words: 'If the doctors and experts say that there is nothing they can do to save the patient from dying, then, clearly, the patient will die'; it is expensive for the family or government to keep the patient on life saving machines; money used on the patient could be used elsewhere (e.g. for the decent and dignified burial of the person). The reasons for not switching off the machines included: God might have a rescue plan; it is a sin, before God, to kill a person; *'What if the patient is not meant to die?'; 'what if the person does not want to die?'; 'nobody except God has a right to decide on when a person should die.'* In other words: 'God is a God of miracles, anything is possible with Him; Doctors could be wrong, they are just human beings.'

During the open debate, it became clear that the two differing positions were informed by different worldviews. The first position was informed by the group's belief in the authenticity and unquestionable validity of science while the other position was informed by the group's belief in the powers of God. It was a question of Science versus Religion. This debate showed quite clearly that people have different knowledge systems that they use or turn to in order to explain and defend their knowledge claims.

It also became clear that the groups were now responding, directly, to their opponents' arguments. The following excerpt of what was said by the groups illustrates these two points:

Group 1: The doctors have said the patient will not survive.

Group 2: What if God has a rescue plan?

Such exchanges became very common with more debating sessions.

The major findings from these debating episodes were: fierce, heated arguments aimed at 'winning' the debate at the beginning of the debating sessions; discussions focussed on the task at hand; cooperation, collaboration and consensus within the small groups; initially, not responding directly to or accepting the opponents' arguments; arguments informed by different worldviews (science and Religion); questioning the orthodox and often unquestioned knowledge claims coming out of science.

Interpretive commentary

This subsection shows the significance, for this study, of the major research findings in terms of the learners' ability to argue effectively during the debating episodes.

The 'fierce arguments'; 'quarrelling'; 'battles' to win the argument, each group drawing lines in the sand, refusing to give in that was witnessed during the first debating sessions mirror what Bricker & Bell (2008) feel when they posit that young people associate the concept of argument with social dispute where yelling and fighting are seen as legitimate ways of winning an argument. This seems to have applied to this group of learners at the beginning of the intervention programme.

Related to the above observation, initially, the learners seemed preoccupied with their own views and did not seem to hear the arguments of their opponents. This is what Kuhn & Udell (2003) called ‘exposition’, which I took to mean ‘just being interested in exposing one’s own ideas without considering other people’s views’. This could be due to what Leitao (2000, p. 357) calls *confirmation bias* which the author describes as “the tendency (by people) of overlooking information that can potentially undermine their viewpoints” or simply due a desire to win an argument. Later on, there was a progression to a situation where the learners started to attend to and address their opponents’ ideas seeking to identify weaknesses in them. This is what Kuhn & Udell (2003) called ‘challenges’ which I took to be a higher level of argumentation. Kuhn & Udell, 2003) says that while most young adolescents would initially focus their efforts on exposition of their position to the neglect of attending to the opponent’s claims and attempting to weaken their force, they would be able to do so and to generate counterarguments and give reasons against the opposing position, when explicitly instructed and given opportunities to do so. This seems to be what happened to this group of learners.
In terms of levels of argumentation, the learners were now operating at level 5 of Downing’s (2007) model where pupils begin to respond to ideas from their interlocutors.

Even at this early stage of the intervention programme, there was consensus and collaboration within the smaller groups supporting a certain point of view. This is in contrast to Bennett & Cass (1989) and Gabon et al. (1980) in Maloney & Simon (2006) who claim that children often do not work well together when given collaborative work because children’s talk is naturally uncooperative and disputational. While within their small groups, before the report back, discussions tended to be disputational and quite heated up, each small group stood together, working cooperatively to win their argument during the report back. In terms of levels of argument, this could be taken as Felton & Kuhn’s (2001) ‘addition’ discourse code where the arguer extends or elaborates the other person’s utterances in order to attack or support another person’s contribution.

Again, at this early stage, discussions were focused on the task. That the learners kept focussed on the task at hand is quite the opposite to the assertion made by Bennett & Cass (1989) and Gabon et al. (1980) in Maloney & Simon (2006) that most talk amongst the children were off task, uncooperative, and not constructive to learning. Here was a group of learners who were on task, cooperative and constructive, most of the time.

The learners developed clear argumentation division lines along different worldviews. As we saw, during one of these debating sessions, some learners leaned on science while others leaned on religion. This means that the learners were being informed by some thought system to come up with their arguments. The importance, for this study, of this development was the realisation and acceptance by the learners that human beings use or rely on different worldviews to explain their experiences. This seems to suggest that there is no one (correct) way of interpreting and explaining events and phenomena around us. Several ways exist and these should be made full use of if we are to understand this world better.

4.1.2 Argumentation when discussing the nature of science and indigenous knowledge

The learners' conceptions of science and indigenous knowledge will be explained and discussed in section 4.2 below. In this subsection, only the argumentation process that took place during these discussions will be highlighted.

4.1.2.1 Two groups of the learners were debating on whether knowledge about the world around us from school science is superior to knowledge from indigenous communities or vice versa while the other two groups were debating whether medicines from traditional healers were superior to those from medical practitioners or vice versa.

Some of the issues that were raised and emerging from their discussions which are of significance to this study include the following:

- In support of science one group said *'Mostly, the items that we use are scientifically formed and we live in a world of science. Nowadays, everything is science.'* This is the group's evidence to their claim that science is superior to indigenous knowledge. The group was most probably referring to material benefits of science and technology that humankind is enjoying. I had expected that the opponents would challenge this claim by saying that the same science and technology had brought a lot suffering to humankind in the form of pollution, land degradation, depletion of natural resources etc. But this did and could not come out of the learners. It looks like the learners were not able to (quickly) come up with rebuttals or counter claims.
- There is some link between a knowledge claim and evidence as illustrated by the following statements from the group supporting traditional medicines. *'Traditional medicines have no side effects '***because** '*they are natural*', *'they do not expire'* ***because***

‘*they are obtained from the forest when needed.’* I have deliberately connected these statements from the learners with ***‘because’*** although that word did not come from them. In doing this, I was quite aware of and encouraged by the fact that

> An idea is considered a supporting idea if (1) it reads naturally after a typical support indicator (e.g., because) has been inserted between that idea and the speaker’s position and (2) it gives an answer to a query that could typically elicit a justification (e.g., ‘On what basis do you claim that’?). ---- the analyst plays the part of an imaginary audience and tries to identify reasons in the speaker’s speech by asking the sort of question that an audience would typically adopt in a face-to-face dialogue, were this audience unclear about the speaker’s ideas (Leitao, 2000, p. 344).

Although the two corresponding statements were not joined by *because,* one can easily see the connection between the given statements. I was also encouraged to do this by Driver et al. (2000) who argue that evidence of a claim may come much later in the conversation and not immediately after the claim is made.

4.1.2.2 Argumentation in response to some questions on the Science-Indigenous Knowledge Systems Questionnaire (See Appendix 6 for details on the questionnaire).

A very high percentage of the learners (86%) felt that ‘science is based on facts only’. The major reasons for this view were that ‘*science has been tested’; ‘scientists have proof’; ‘they have experimented and found it to be correct’* while the main reason for the few who disagreed was that *‘scientists are human beings. They sometimes make mistakes.’* Clearly, the learners were offering reasons/evidence for their knowledge claims.

All the learners thought that ‘indigenous knowledge is based on beliefs only’. Reasons for this position included: *‘it is based on facts and theories that are not proven’; ‘indigenous does not experiment, they just believe’; ‘they do not know what they are talking about.’* Again, the learners were offering reasons/evidence for their knowledge claims.

The group supporting *sangomas* said: *‘Sangomas can treat mental illness, bewitched conditions and bad luck which medical doctors cannot treat. They can only control the mental illness.’* The group supporting medical doctors retorted: *‘Traditional healers cannot heal fractured bones. Medical doctors can.’*

Clearly, the debating groups were now responding to each other’s ideas. This was a progression from an earlier situation where the learners had ignored the arguments of their opponents.

4.1.2.3 Learners' views about the nature of science and indigenous knowledge in an essay (See Appendix 7 for details on this essay).

The learners were asked what they thought about science and indigenous knowledge before and after the major tenets of the two thought systems were discussed with the research participants. *(Appendix 8 details the discussion of these tenets).* This was done after the learners had gone through some activities on argumentation. The following are some typical responses that I got from the learners.

Before the programme on the major tenets of science learner 2 said '*science is the best'; 'science is superior than indigenous knowledge'; 'science is that something they do they had been tested.'* I took the last statement to mean that 'science is tested knowledge.' After the programme, the same learner said about scientists *'they are something that they guess'* which I interpreted to mean 'Not all science knowledge is tested or testable. It can be obtained through non-scientific methods.'

Before the programme, on the major tenets of science, learner 13 said *'I thought science was the best of all knowledge claims.'* I took 'knowledge claim' to mean 'worldview' or 'knowledge system' or 'thought system.' Later the learner said *'Western science is not always correct or accurate they can make mistakes of their own.'*

For this study, two important observations can be made from the above subsection. The learners were offering reasons/evidence for their statements and they were able to shift their perceptions about science from seeing it as faultless to seeing it as man-made with the potential of error.

Interpretive commentary

Learner 2 provided two related knowledge claims 'science is better than indigenous knowledge'; 'science is superior to indigenous knowledge' which were supported by evidence as he said *because* 'science is tested knowledge'. Later the learner proposed or offered a counterargument which was a clear shift from his original perception about science when he said 'science is a human construct, it can have errors'. In other words he no longer saw science as an infallible body of knowledge. The learner was able to change his perception of science when he was confronted with new, compelling evidence.

In terms of TAP, learner 2 was able to support this knowledge claim and later on was able to come up with a counter claim which showed a shift from his original knowledge claim. In terms of argumentation, this learner was now operating at level 3 (Osborne et al. (2004) where an arguer defends his/her knowledge claim with evidence and/or provides counter claims to the proposed knowledge claim.

Initially, learner 13 did not offer evidence or reason for her knowledge claim that 'science was the best knowledge system.' Later on, the learner came up with a counter claim to the original claim: 'science is not always correct.' This time the learner offered a reason/evidence that '*they can make mistakes of their own.'* The learner has certainly moved from level 1 where a knowledge claim is made without the supporting evidence to level 2 where a claim is accompanied with data or evidence. The fact that this new knowledge claim is a counter claim to the original knowledge claim means that this learner is now operating at level 3 where a counter claim is supplied (Osborne's et al. 2004).

Both learners, 2 and 13, have shifted their positions in light of new evidence. The shift, the new position for both learners can be placed under the emergent category of CAT. The emergent category refers to a situation where a new thought system or knowledge claim emerges as the individual is exposed to more compelling or convincing information. These learners were exposed to the major tenets of science and indigenous knowledge which are likely to have influenced their change of heart or of mind. If, however, the learners subscribe to both positions, then they can be placed under the equipollent category of CAT. The equipollent category refers to a situation where competing explanations are judged to be equally powerful and convincing by the learner. The learner then holds the two apparently opposing positions side by side without any apparent cognitive dissonance. This ability to see reason and to be willing to change one's original position or knowledge claim is, in my opinion, an advanced skill in argumentation.

The above descriptions illustrate that some of the learners progressed from stating knowledge claims with no evidence to stating knowledge claims with evidence; to offering counter claims; and to accepting opponents' points view when confronted with more compelling evidence. Clearly there was a positive progression from poor towards effective argumentation much in line with Kuhn's (2010) assertion that argumentation like conceptual knowledge has its own progressions.

4.1.3 Argumentation during the activities on static electricity. *(See Appendix 10 for details of these activities).*

Static electricity was discussed after activities on argumentation had been done with the learners because I wanted the learners to use the learned argumentation skills to negotiate the explanations of their observations during the activities on static electricity. In this subsection, only the argumentation process that took place during these activities will be highlighted. The learners' conceptions of static electricity will be explained and discussed in section 4.3 below.

The major knowledge claims and evidence given by the learners, in their groups, are shown in the following table. Here the emphasis was on whether the learners could articulate a knowledge claim and defend it. The correctness of the claim or the evidence was not considered significant here.

Table 4.1: Learners' conceptions of static electricity

Knowledge claim or position held by learners	**Evidence or explanation given by the learners**
When the pen was rubbed on a piece of cloth, the pen was charged.	The pen attracted small papers
When the pen was rubbed with a piece of cloth, both became charged	Both the pen and the cloth attracted pieces of paper
The pen and the cloth had the same type of charge	Both attracted the same pieces of paper
The pen and the cloth had different types of charge	The pen and the cloth are made from different materials
The cloth attracted a charged balloon while the pen repelled the same balloon	The cloth and the pen have different types of charge (since the balloon has the same charge for both the pen and the cloth).
The charge on the pen and that on the attracted piece of paper must be different from each other.	Unlike charges attract each other
When a negatively charged polythene strip is brought near the metal cap of an electroscope, the metal cap becomes positively charged.	The electrons on the metal cap were repelled by the electrons on the negatively charged polythene strip.
When a negatively charged polythene strip is brought near the metal cap of an electroscope, the metal leaves on the metal rod become positively charged.	The metal cap, the metal rod and the metal leaves are the same object (they are joined together).
When a negatively charged polythene strip is brought near the metal cap of an electroscope, the metal leaves on the metal rod become negatively charged	The metal leaves got the electrons repelled from the metal cap.
The metal leaves collapsed when the metal cap of the electroscope was touched with a human hand	• The metal plates had attracted each other' (in other words the leaves got opposite charges which attracted each other) • The leaves had become uncharged' (in other words the leaves had lost their charge).

The major observations made during these activities are that the majority of the learners were now able to support their claims and their counter claims with evidence and that there was a lot of disagreement or controversy amongst the learners. There were two other important observations which are not shown on the table.

- The learners were now questioning or challenging knowledge claims from their colleagues and from their teacher (despite their upbringing that taught them reverence for authority). They were demanding evidence for the knowledge claims that we were making. The following questions from the learners illustrate this point.

  'How can the same pieces of paper be attracted by both the pen and the cloth when the pen and the cloth have different types of charges?'; 'How can we tell whether the charge on the pen or on the cloth is positive or negative?'; 'What does a charge look like?' 'If the metal leaves also become positively charged, where are the electrons repelled at the metal cap?' 'If the leaves got different charges (on earthing the electroscope) *'Where and how did the leaves get different types of charges?'* '*Why did the human body attract electrons that were further down the electroscope and not attract protons that were near the finger?'; Why did we not get shocked if the charge went through our bodies?'*
- These learners changed their knowledge claims when they were confronted with compelling evidence, or evidence they found more reasonable than their own. The following are some examples of that shift, of that willingness to accept new ideas and change conceptual positions:

✓ A group of learners had thought that when a negatively charged polythene strip is brought near a metal cap of an electroscope, the metal leaves at the bottom of the metal rod would become positively charged. When they were challenged to explain where the electrons repelled from the metal cap had gone, they changed their position and accepted that the metal leaves must have got the repelled electrons and thus become negatively charged.

✓ When the metal leaves of the electroscope collapsed when the electroscope was grounded, some learners thought that the leaves had got different types of charges and hence attracted each other. When they could not explain how this was possible, the learners accepted that they could have been wrong.

Interpretive commentary

In terms of TAP, these learners were able to state knowledge claims and support them with evidence and to state counter claims and support them with evidence. Some of the evidence or explanation may not be ‘scientifically correct’ but makes a lot of sense, nevertheless. The evidence is logical. For this study and for this research question, what is important is that the learners were able to supply evidence to support their knowledge claims or to refute other people’s knowledge claims. In terms of Leitao’s unit of analysis, the learners were able to come up with an argument which according to Leitao is a position followed by a justification; to come up with a counterargument which to the author is any statement “that casts doubts on the speaker’s position (and) potentially undermines the speaker’s position by making the acceptability of that position uncertain’ (Leitao, 2000, p. 342) and coming up with a reply, which Leitao describes as an arguer’s reaction to the counterargument. In the case of this group of learners and for this activity, the reply came in the form of a shift in the arguer’s original position, i.e. in the form of an agreement with the counterargument.

The table clearly shows that the learners held very different ideas on some of these concepts and supplied their evidence to support themselves. That is to say that there was a lot of controversy expressed by the learners. Controversy in science is seen by many authorities as quite important. For example, Kuhn (1970) asserts that science is advanced more through controversy than through harmony and consensus and Bricker & Bell (2008) maintain that science study scholars consider moments of controversy important. The authors claim that it is during controversy that the teacher can examine the knowledge construction in process and I suppose, identify where learners need help.

Evidence must be used to support or refute knowledge claims no matter from whom the knowledge claim comes from. The observation made by Sarangapani (2003) in Bricker & Bell (2008, p. 487) that “in everyday life, if one trusts a speaker or a source of knowledge, then one will believe the claims espoused by that source of knowledge, even given slight evidence” did not seem to hold water here. This group of learners challenged their colleagues and their teacher to produce evidence. Even in class, outside the research activities, I could hear learners asking ‘where is your evidence?’ when I or their colleagues made certain scientific statements. Also, the fear that I had harboured that learners who are close and familiar to each other, such as my research participants, would avoid contradicting each other for fear of spoiling their good social relationships did not seem to apply to this group. The learners had quickly learnt that argumentation was about ideas and not about personalities. The learners seemed to have accepted Leitao's (2000, p. 342) view that "the dialectical nature of argumentation implies opposition between views (and) not necessarily between individuals." This development, to me, shows a high level of argumentation.

The table also shows that the learners changed their knowledge claims. When people are confronted with new evidence they could choose to reject or accept the evidence based on the strength of the advanced evidence. They could also choose to conciliate or compromise their original positions for interpersonal goals such as maintaining their relationships (Leitao, 2000). In my judgement, these learners changed their knowledge claims when they were confronted with compelling evidence, or evidence they found more reasonable than their own. As alluded to above, this, to me, is a sign of maturity and of a high level of argumentation.

What seems to be the importance of the foregoing results and conclusion on the lives of these learners inside and outside the classroom and in their everyday lives? To me, it would appear like this programme has inculcated in these learners two important virtues, namely: (a) they should not follow blindly the ideas or actions of others. The programme has taught them that they must be convinced of the wisdom of actions and ideas to be accepted or followed, no matter whose ideas or actions they might be and (b) their own ideas are not always correct or the best. They should listen to other voices because those other voices may have greater wisdom than their own.

4.1.4 Argumentation when discussing causes of lightning

Causes of lightning were discussed after activities on argumentation had been done with the learners because I wanted the learners to use the learned argumentation skills to negotiate the explanation of lightning as given by the two worldviews. In this subsection, only the argumentation process that took place during these debates will be highlighted. The learners' conceptions of lightning will be explained and discussed in section 4.3 below.

The learners discussed stories on lightning *(See Appendix 11 for details on these stories).*The first story had appeared in a daily newspaper recently. The second story was a narration of an incident that was said to have taken place in an African village after two men had quarrelled at a beer party. The other two stories were taken from a *Physics* textbook.

The first story in brief: A soccer referee was struck but not killed by lightning while officiating a game. The weather conditions did not suggest that there would be lightning 'as it was just drizzling'. The referee was the only person affected by the lightning. The mother of the referee insisted that a powerful witch had sent the lightning to kill her son.

The second story in brief: A man's homestead was struck by a bolt of lightning but the man was not at the homestead at that time. He had gone to another homestead for a beer party. A lightning bolt struck the homestead where there was the beer party but the man had left for his home (after seeing, from the beer party, his homestead in flames). Before the man reached home, a third bolt of lightning hit and killed the man. It looked like the lightning was hunting for the man.

The third story in brief: A man had been struck by lightning three times dying of the effects of the third strike. A few years after his death, a lightning bolt hit the cemetery where the man had been buried. The bolt hit the man's grave, the only grave to be hit. It looked like the lightning that had followed the man in his life had followed him to his grave. This happened in Vancouver, Canada, during and after the Second World War.

The fourth story in brief: A man earned a place in the *Guinness Book of Records* for being the only known man to have survived seven lightning strikes. The man was a white American, in the United States of America.

The following is the argumentation of the learners as they discussed the first story. Only this story will be used for this discussion because of its richness in argumentation skills displayed by the learners..

The following table shows the group responses or the group consensus as the learners were discussing the mother's claim and her evidence.

Table 4.2: Learners' argumentation during a discussion about lightning

Group	Do you agree with the referee's mother that an enemy sent lightning to kill her son and with her evidence that her son was the only person affected by the lightning?	What other explanation can you offer for the lightning strike on the referee?
1	Disagree	• **Initial response:** *'there must be another explanation'* • **Final response:** *'the referee must have had something that attracted the lightning'.*
2	Agree	• **Initial response**: *'because he was the only person struck by lightning; ''powerful witches can send lightning to their enemies'; 'witches use dead people for their evil deeds'* • **Final response:** *'normal lightning cannot strike one person in a crowd'*
3	Agree	• **Initial response:** *'because he was the only person struck by lightning'* • **Final response:** *'it was a message or a warning from the referee's ancestors'*
4	Agree	• **Initial response:** *'because he was the only person struck by lightning'* • **Final response:** *'he must have been in the path of lightning'*

The **initial response** was before while the **final response** was after scaffolding and prompting the argumentation process.

Through scaffolding using prompts, the learners threw arguments and counterarguments at each other during the open whole group discussions. For example '*the metallic whistle the referee held attracted the lightning to him'* was met with '*the whistle is too small to attract lightning from a cloud'* and *'the sweat on the body of the referee attracted the lightning'* was met with *'was he the only one sweating?'* and *'he was the tallest person'* was met with '*there is very little difference in the height of people, it is not like that between a tall tree and a person.'*

Interpretive commentary

Group 1 rejected the mother's indigenous knowledge explanation. To them, there must be some scientific explanation. They agreed with one learner who suggested that it was the metallic whistle that the referee held that attracted lightning to him. According to CAT, the school science worldview is dominant over the indigenous knowledge worldview. Indigenous people might agree with Group 1 that the referee had something that attracted the lightning. The difference would be that the indigenous people might not think that that 'something' was the metallic whistle.

Group 3 agreed with the mother's explanation and came up with a different explanation that was again informed by indigenous knowledge. ('*it was a message or a warning from the referee's ancestors').* In terms of argumentation, CAT would place this group as dominantly indigenous. They find the indigenous explanation more appealing than the scientific explanation.

Group 4 initially agreed with the mother but later on said that '*perhaps he was in the path of lightning'.* While the mother's explanation is informed by indigenous knowledge, Group 4's second explanation seems to be informed by science or indigenous knowledge or both. The statement that the man must have been in the path of the lightning is reasonable and logical. Both thought systems are reasonable and logical and so could have produced that kind of statement. Indigenous knowledge might, however, go further and want to know why he was in the path of the lightning in the first place and why him and why him alone. It is possible that Group 4 demonstrated Aikenhead & Jegede's (1999) dependent collateral learning where a schema from one worldview (science explanation, in this case) challenges a schema from the other worldview (indigenous knowledge explanation, in this case) to the extent of permitting the student to modify, with reason and conviction, the existing schema. In that case the group would have shifted from their indigenous knowledge position to embrace the scientific explanations. Group 4 were adamant that they had not shifted their earlier explanation but had added another possible explanation. In terms of argumentation, this is in agreement with CAT's assertion that learners can hold two opposed worldviews without experiencing cognitive conflict. CAT calls this the equipollent category, which refers to a situation where the learner finds the explanations of a natural phenomenon from two different worldviews equally powerful, convincing and appealing.

If we use a simplified version of Toumin's (1958) analytical framework adopted from Osborne, Erduran & Simon (2004) we can see that all the groups have graduated from level 1 where a claim is given as evidence of another claim, through level 2 where a claim is supported by appropriate evidence or data. Some of the groups like group 3 and 4 have reached level 3 or even level 4 where counterarguments (other, different explanations or challenges to an argument) are given.

One can also look at the exchange of ideas between the arguers as they attempted to explain why a soccer referee was the only person struck by lightning from another angle. For this analysis and discussion, the speaker is the mother of the referee and the learners in their discussion groups are the arguers.

The speaker's position or argument: *an enemy sent lightning to my son.*

Arguer 1: *his ancestors have a message for him.*

Arguer 2: *the metallic whistle he held attracted the lightning to him.*

Arguer 4: *he was the tallest person in the crowd.*

Arguer 6: *he was sweating and it is the sweat that attracted the lightning to him.*

All the statements from arguers 1, 2, 4 and 6 are counterarguments where a counterargument is defined as: 'the view or the argument of a person who disagrees with or is opposed to the speaker'.

The following statements from the other arguers in response to the above arguers were rebuttals where a rebuttal is defined as: 'a statement that attempts to disarm or weaken an opponent's argument'; 'a statement that tries to bring the merit of an explanation into question.'

Arguer 3: *the metallic whistle is too small an object to attract lightning from the skies.* (rebuttal to statement from arguer 2).

Arguer 5: *there is no much difference in the height of people.* (rebuttal to statement from arguer 4).

Arguer 7: *he was not the only person sweating.* (rebuttal to statement from arguer 6).

Further analysis of the explanations reveals that the explanations of the speaker and arguer 1 are probably informed by indigenous knowledge; the explanations from arguers 2 and 6 are probably informed by science; the explanation from arguer 4 is probably informed by both worldviews.

The claims, on causes of lightning, advanced by the learners during the open whole group discussions could be said to be informed by science and that the counterarguments questioned the validity of those scientific explanations. It must be remembered that before the intervention programme, on the questionnaire on lightning and thunder, all the learners gave scientific explanations of the causes of lightning with none questioning them or giving the indigenous knowledge explanations. There seemed to have been a transformation, a change of position amongst the learners. At the very least, they seemed to be saying: ‘Western science explanations are not wholly adequate and satisfying’. The learners now seemed more accommodative of other possible explanations of lightning. Liphoto (2009), who studied the effect of a cross-cultural instructional approach on learners’ conceptions of lightning, came to a similar conclusion when he claimed that, as a result of that approach, “some learners accommodated both scientific and traditional conceptions of lightning ---- without experiencing any cognitive conflict” (p. 118).

Of importance to this study was the realisation and acceptance by the learners that the school science explanation of lightning may not be adequate to explain the nature of lightning. Other explanations from indigenous knowledge systems may be needed if we are to fully understand natural phenomena such as lightning and thunder. These four stories illustrated this point very convincingly.
What seems to come out clearly from the above is that these learners now seemed to embrace both worldviews as they sought explanations of lightning. This development is extremely significant for this study that seeks to convince learners that there are many viable knowledge systems that seek to explain the world around us.

The major findings during the discussions on static electricity and lightning were that the learners were supporting claims with evidence; coming up with counterarguments and rebuttals to their interlocutors’ positions; offering several possible explanations for a single event; questioning and challenging knowledge claims from their colleagues and their teacher; changing their positions or knowledge claims when confronted with compelling evidence; realising that a full explanation of natural phenomena such as lightning is likely to be found in different worldviews. All these are skills associated with effective argumentation.

4.1.5 Reference to adequate and appropriate sources of information as evidence of higher levels of argumentation.

At the beginning and towards the end of the intervention programme, the learners were asked to state the sources of their conceptions of the Nature of Science (NOS) and Indigenous Knowledge (IK).. Their responses are summarised in Table 4.3 below.

Table 4.3 Sources of learners' pre- conceptions of NOS and IK

Items	Statements	Source of information the learners used			
		Science (%)	Culture (%)	Personal belief (%)	Religious belief (%)
1	Science is based on facts only	13	0	88	0
2	IK is based on beliefs only	0	13	88	0
3	Science is based on research	0	13	88	0
4	IK is only based on experience	0	0	100	0
5	Science is universal	17	0	83	0
6	IK is localised knowledge	0	0	100	0
7	Scientific knowledge is tentative	29	0	71	0
8	IK is final or permanent	33	0	67	0
9	Science changes with new information	17	0	83	0
10	Science and IK are different	13	13	75	0
11	Science and IK have common elements	17	0	83	0
12	Scientists are learned people	33	0	67	0
13	IK knowledge holders are unlearned people	0	20	80	0
14	Science is experimentally testable	31	6	63	0
15	IK is mysterious and non-experimentally testable	0	0	100	0
16	IK can have scientific explanations	17	50	33	0
Average %		**14**	**7**	**79**	**0**

N = 16

Personal beliefs could be informed by science or culture or none of the two.

At the beginning of the study, when the learners were asked to state their sources of information for their arguments, the majority of the learners (79%) used their own personal beliefs as sources of information. Only a small percentage (14%) relied on what they learned at school. An even smaller percentage (7%) relied on what they got from their communities. Nobody chose religious beliefs as a source of information.

At the beginning, none of the research participants referred to or relied on several sources of information for any knowledge claim. They would just mention one source of information for each statement although there were several reasonable sources available to them to choose from.

Table 4.4 Sources of learners' post- conceptions of NOS and IK

Items	Statements	Source of information the learners used			
		Science (%)	Culture (%)	Personal beliefs or own experience (%)	Media (%)
1	Lightning is dangerous	27	27	23	25
2	Clouds are charged when they rub against air	75	0	10	15
3	Clouds acquire negative charge by rubbing	80	0	10	10
4	Charge moves from cloud to ground	89	0	11	0
5	Movement of charge is lightning	89	0	11	0
6	The sound heard is thunder	38	24	34	5
7	There is need for protection from lightning	26	25	29	20
8	Sangomas can protect from lightning	0	46	38	15
9	Dangerous to stand under trees during thunderstorm	52	34	7	7
10	Dangerous to play with water during thunderstorm	50	31	13	6
11	Put out fires during a thunderstorm	0	83	17	0
12	Certain trees can protect people from lightning	3	48	28	21
13	Metal rods protect buildings from lightning	43	14	28	14
14	Lightning is a natural event	50	30	10	10
15	Lightning can also be man-made	0	66	22	11
Average %		**41**	**29**	**19**	**11**

N = 15

Towards the end of the study the percentage of learners relying on their own feelings or views dropped drastically from 79% to 19%; a significant percentage of the learners (41% and 29% respectively) saw both science books or science lessons and the community as relevant sources of information; other sources of information such as *the media* were also now seen as relevant sources of information by a number of learners (11%).

Towards the end of the study, most of the learners referred to several sources of information for one statement.

Interpretive commentary

Argumentation should rely on adequate and appropriate theoretical and/or empirical evidence (Berland & McNeill, 2010). Appropriate evidence refers to evidence that is accurate and relevant to the issues under discussion (Berland & McNeill, 2010). At the beginning, the learners did not seem to value or appreciate the need to refer to authentic sources of information. One's own personal feelings or views cannot be considered as appropriate evidence. For the questionnaire on the nature of science and indigenous knowledge, one would have expected a greater percentage of the participants to rely on science books and science lessons and on the communities for their information. One can therefore conclude that the evidence of the learners, at this stage of the study and in this context, was not appropriate. Relying on several sources of information for knowledge claims and evidence to support the knowledge claims is very important in argumentation. "... Argument requires students to draw on diverse knowledge and practices' (Kelly & Bazermann, 2003, p. 32). Berland & McNeill (2010) also refer to the need for adequate evidence which they take to mean multiple pieces of evidence used to convince an audience. Such evidence is likely to come from several sources of information. We can therefore conclude that at the beginning of the intervention programme, the learners' evidence was not adequate.

Initially, a very small percentage of the learners (7%), referred to indigenous knowledge as their source of information. For this research, this observation is important because it means that at this early stage of the intervention programme, the learners did not think that indigenous knowledge was a viable source of information. This perception seems to have changed as a result of the intervention programme because towards the end of the programme, a significant percentage of the learners (29%) now accepted the community as a legitimate source of information and hence of knowledge.

Perhaps because of the nature of the questions which did not lend themselves into religious issues, religious beliefs were not seen as a possible source of information. This is understandable and explainable. A good source of information in some subject area or context may not be a source, let alone a good source, of information in another context/subject area.

The fact that the learners now relied on a variety of sources and on relevant sources of information to come up with their positions seems to indicate that the learners were now at a higher level of argumentation. As we have already seen, Berland & McNeill (2010) suggest that a good argument must be supported by adequate evidence derived from multiple sources and appropriate and relevant evidence from germane sources.

The significance of the above observations is that the programme seems to have taught the learners to be certain of their facts before uttering them. They must have good evidence for saying whatever they will be saying.

Summary

The above section has shown that the learners' ability to argue improved significantly as they went through many discursive situations and as the study progressed.

The following is a summary of the progression made by the learners in terms of their ability to argue effectively before and after the intervention programme. In this table, the areas of comparison are based on the work of the following authors: Berland & McNeill (2010); Bricker & Bell (2008); Driver, Newton & Osborne (2004); Hogan (1999); Kuhn (1991); Kuhn (2010); Kuhn & Udell (2003); Osborne, Erduran & Simon (2004); Toulmin (1958) and on my own observations.

By the end of the intervention programme, most learners were able to demonstrate most of the argumentative skills shown in the table below.

Other observations were that the learners were focused on the task at hand; cooperated and collaborated and came to some consensus within the smaller groups; used arguments that were informed by some worldview; questioned and challenged the orthodox and often unquestioned knowledge claims from Western science.

The above progression is in line with Kuhn's (2010) assertion that argumentation skills, just like conceptual knowledge, have their own learning progressions. This also means that the argumentation-based instructional intervention programme was helping the learners to argue better than they could do at the beginning.

Table 4.5: Relative impact of the intervention programme on learners' pre-post argumentation skills

Area of comparison	Pre-	Post-
1. Claims that are explicitly stated	✓	✓
2. Claims that are clearly stated and accompanied with data	×	✓
3. Claims that are clearly stated and accompanied with adequate data (The use of multiple pieces of data to convince the audience) (Berland & McNeill, 2010).	×	✓
4. Claims that are clearly stated and accompanied with appropriate data (The use of relevant data that is factually accurate) (Berland & McNeill, 2010).	×	✓
5. Statements that contained rebuttals or counterclaims	×	✓
6. Individuals questioning one another's claims and evidence	×	✓
7. Individuals evaluating one another's claims and evidence	×	✓
8. Individuals revising and shifting from their own original claims or positions in light of available compelling evidence	×	✓
9. Individuals constructing their arguments in response to what the opponent says	×	✓
10. Preoccupation with their own ideas and not listening to and challenging the opponents' point of view	×	✓

× means that most of the learners did not show that skill or ability

✓ means that most of the learners showed that skill or ability. For this table 'most' would mean not less than 75% of the learners.

4.2 Learners' pre-post conceptions of science and IK

This section looks at the learners' understanding of the major tenets of the two knowledge systems before, during and after the intervention programme.

4.2.1 Learners' conceptions of NOS and IK

The following tables (Tables 4.6A, 4.6B, 4.7A and 4.7B) show the learners' pre- post-agreements or disagreements with statements on NOS and IKS based on their responses to the Science-Indigenous Knowledge (SIKS) Questionnaire *(see Appendix 6 for more details).*

Table 4.6A: Learners' agreement with SIKS items on NOS

Item	Statements	Pre-test (%)	Post-test (%)
1	Science is based on facts	86	50
2	Science is based on research	100	75
3	Science is universal	79	50
4	Science is tentative	0	75
5	Science changes with new evidence	14	40
6	Scientists are learned	81	100
7	Science is straight forward	25	40
8	Science and IK are different	75	71
9	Science and IK have common elements	29	44
	t-test	11.05	

critical or table t-value at $p \leq 0 .05 = 2.306$. Since the calculated t-value is greater than critical t, the difference is highly statistically significant.

Table 4.6B: Learners' disagreement with SIKS items on NOS

Item	Statements	Pre-test (%)	Post-test (%)
1	Science is based on facts only	14	50
2	Science is based on research	0	25
3	Science is universal	21	50
4	Science knowledge is tentative	100	25
5	Science changes with new evidence	86	60
6	Scientists are learned	19	0
7	Science is straight forward	75	60
8	Science and IK are different	25	29
9	Science and IK have common elements	79	56
	t-test	11.22	

critical t-value at $p \leq 0 .05 = 2.306$. Since the calculated t-value is greater than critical t, the difference is highly statistically significant.

The calculated t test values in both tables 4.6A and 4.6B mean that the learners showed a significant change in their perceptions about the nature of science as a result of the intervention programme.

The following few examples, taken from the table, illustrate this observation very clearly.

Initially, a very high percentage of the learners (86%) felt that 'science is based on facts only'. After the intervention programme that percentage dropped to 50% of the learners.

The percentage saying that science is tentative jumped from 0% before to 75% after the intervention programme.

The percentage of the learners who thought that science changes in light of new information rose from a pre14% to a post 40% of the learners.

Table 4.7A: Learners' agreement with SIKS items on IK

Items	Statements	Pre-test (%)	Post-test (%)
1	IK is based on beliefs only	100	25
2	IK is only based on experiences	31	87
3	IK is localised knowledge	71	100
4	IK is final or permanent	75	31
5	IK knowledge holders are not learned	86	40
6	IK is mysterious and non-experimentally testable	67	62
7	IK can have scientific explanations	13	31
	t-test	16.88	

critical t-value at $p \leq 0.05 = 2.447$. Since the calculated t-value is greater than critical t, the difference is highly statistically significant.

Table 4.7B: Learners' disagreement with SIKS items on IK

Items	Statements	Pre-test	Post-test
1	IK is based on beliefs only	0	75
2	IK is only based on experiences	69	13
3	IK is localised knowledge	29	0
4	IK is final or permanent	25	69
5	IK knowledge holders are not learned	14	60
6	IK is mysterious and non-experimentally testable	33	38
7	IK can have scientific explanations	88	69
	t-test	16.90	

critical t-value at $p \leq 0.05 = 2.447$. Since the calculated t-value is greater than critical t, the difference is highly statistically significant.

The calculated t test values in both tables 4.7A and 4.7B mean that the learners showed a significant change in their perceptions about indigenous knowledge as a result of the intervention programme.

The following examples, taken from the above tables illustrate this observation very clearly:

At first, all the learners thought that 'indigenous knowledge is based on beliefs only.' After the programme, only 25% thought so.

Initially, only 31% and later 87% of the learners seemed to acknowledge that indigenous knowledge is a result of careful observation of natural phenomena over many centuries. Before the intervention programme, 75% of the learners felt that indigenous knowledge was final and static. That percentage dropped to 31%.

The results displayed in Tables 4.6 and 4.7 above, show that generally, at the beginning of the intervention programme, the learners did not think much of indigenous knowledge. Indigenous knowledge was seen in negative ways while science was glorified or exalted. Then there was a transformation of perceptions. The general shift was an acknowledgement of the viability, strengths and weaknesses of each of the two knowledge systems.

The major shifts about indigenous knowledge were that: indigenous knowledge is not just a belief system but a knowledge system based on careful observation of the world over many centuries; indigenous knowledge changes when new information and evidence becomes available and when situations and contexts change. The major shifts about science were that: it sometimes relies on non-scientific methods to construct its knowledge; it changes when new information and evidence becomes available.

Interpretive commentary

The sessions on the nature of science and indigenous knowledge which I had with the learners aimed at both knowledge construction and the transformation of the perceptions of the learners about the two worldviews especially where the learners had demonstrated serious misconceptions. For example, it was emphasised that both science and indigenous knowledge were sensitive to new contexts and would respond to new information and change their position in light of new evidence. Kaniki & Mphahlele (2002) and Ogunniyi (2008b), for example, contend that indigenous knowledge is dynamic and fluid, changing with and being sensitive to the times.

Initially, a very high percentage of the learners (86%) felt that 'science is based on facts only.' The learners did not seem to know or accept that science can sometimes be quite tentative, if not, downright incorrect. There is evidence that in the past, "science *did* incorporate false beliefs, sometimes under the influence of emotion and fashion" (Bauer, 1992, p. 62 in Aikenhead & Ogawa, 2007, p. 545). As shown earlier on, during the intervention programme, a number of examples from science were used to show that science can sometimes be wrong. Later, half the learners now thought that scientific knowledge was not always tested and experimented knowledge which was infallible and accurate. The learners expressed, on different occasions, the feeling that as human beings, scientists can also make errors resulting in incorrect information being paraded as science facts. A significant number of the learners (25%) now thought that scientists produce some scientific knowledge through non-scientific methods. The intervention programme made reference to science discoveries made by chance.
The following examples were used to illustrate this point: *The discovery of penicillin by chance by Alexander Fleming in 1928 (Roberts, 1986); the discovery of the benzene ring, through a dream by Friedrich August Kekule in 1865* (Wikipedia free encyclopaedia); and t*he discovery of the relationship between an electric current and magnetism by Hans Christian Oersted in 1820* (Wikipedia free encyclopaedia) and Nelkon, (1975).

In all fairness to the scientific method, it should be stated that these discoveries depended heavily on careful observations and correct interpretation of what was observed, which are skills associated with the scientific method. But the role of mere chance, in these discoveries, cannot be ignored.

The majority of the learners now seemed to acknowledge that the indigenous knowledge is a result of careful observation of natural phenomena and events over many centuries augmented by mental rigour in order to make meaning of those observations. In other words, these learners were in agreement with Kaniki & Mphahlele (2002, pp. 3-4) who see indigenous knowledge as "a cumulative body of knowledge generated and evolved over time, representing generations of creative thought and actions within individual societies."
According to Ogunniyi (2008b:35), indigenous knowledge is "the accumulated experiences and problem solving approaches that have been used by a local community or ethnic group

over several generations.” In other words, indigenous knowledge is knowledge that has evolved from a local community based on the community’s own creativity and intellectual processing systems. This is the position that the majority of these learners seem to have accepted and embraced at the end of the intervention programme.

The importance of this is that here is a group of indigenous people who have realised and accepted that their knowledge system is valid and valuable instead of just accepting that indigenous knowledge is inferior to other knowledge systems.

4.2.2 Views of the learners on science and indigenous knowledge on reflection

At the end of the intervention programme, learners were asked to reflect on and express their views on what they thought about science and about indigenous knowledge before and after the intervention programme. *(See Appendix 13 for details).*The learners’ views are summarised and analysed in the following tables.

Table 4.8: Learners’ pre-post views on the nature of science

Learner identity	Pre-test comments	Post-test comments	Observations/comments
2	*‘science is the best’; ‘is superior than indigenous knowledge’; ‘science is that something they do they had been tested’* (I took the last statement to mean that science is tested knowledge).	*‘They are something that they guess’* (I took this statement to mean that not all science knowledge is tested or testable. It can be obtained through ‘non-scientific’ methods such as guessing, intuition, dreams, chance and serendipity etc.).	Before the programme, the learner thought that science is the best and is superior to other knowledge claims because it is tested knowledge. Later on, the learner seems to accept that science knowledge is not necessarily tested since some of it could be or has been obtained through non-scientific methods.
8	*‘I was believing too much in science’; ‘everything is correct and they know everything.’*	*‘It has failed to solve most of the problems’*. (I took ‘problems’ to mean problems faced by humankind).	This learner had a lot of faith in Western science before the intervention programme. He saw it as a panacea of humankind problems. He is disappointed that science has not lived up to his expectations.
13	*‘I thought science was the best of all knowledge claims’* I took ‘knowledge claim’ to mean ‘worldview’ or ‘knowledge system’ or ‘thought system.’	*‘science is not always correct or accurate they can make mistakes of their own’*	The two statements (before and at the end of the intervention programme) show a change in the paradigm shift from ‘hero worshiping’ science to seeing its fallibility.
16	*‘I was thinking that the science people do research before they tell us’.* The same idea was echoed by participant 15 who said ‘*Scientists do research before they give information to the people.’*	*‘science also guess in some places’*. I took ‘some places’ to mean ‘at times’ and I took ‘guess’ to mean methods other than those typically associated with the ‘scientific method’.	This learner had always thought that all scientific knowledge is knowledge that has been researched, tested and verified and that it was therefore accurate. Not anymore.
Responses from some of the other learners	‘*Better than indigenous knowledge’* (7); *‘it was of great important and superior to indigenous knowledge’* (3); *‘I mostly believed in science because everything about it was seems to be true’* (5); *‘science is always doing things perfectly with no errors’* (9).	‘*Not superior to indigenous knowledge’* (3); ‘*Believe in some parts of science and not all’* (14); ‘*Western people think they know better’* (10).	Learner 3 offers a counter argument to demonstrate her shift in her conception of science from ‘it is superior’ to ‘it is not superior’. She seems to have no courage or conviction to say that indigenous knowledge is superior to science. To interpret the statement from learner 10, I had to make some inferences. First the statement means that Westerners think they know better than indigenous people and secondly, the learner does not believe this. The two columns illustrate a clear shift or rethink about science.

Table 4.9: Learners' pre-post views about indigenous knowledge

Learner identity	Pre-test comments	Post-test comments	Observations/comments
2	*'that they guess, beliefs'*. The same sentiments were echoed by participant 1 who said *'indigenous knowledge is some guess.'*	'*indigenous knowledge is other systems of knowing things that are happening in the world'*. By 'things happening in the world', I thought the learner meant 'natural phenomena happening in the world' and not just anything happening in the world.	The learner has shifted from a position where indigenous knowledge systems were conceived as just belief systems to a position of believing that indigenous knowledge systems are capable of explaining, interpreting and predicting natural phenomena.
8	*'was useless and not good for modern people'*	'*our community thing works. It exists and plays order in our lives'*. By 'community thing', I thought the learner meant indigenous knowledge by 'order' I thought the learner meant 'role'. In other words, the learner was saying 'indigenous knowledge plays a role even in our modern lives.'	The learner has shifted from seeing indigenous knowledge as useless to a position where he acknowledged that indigenous knowledge plays an important role even in our modern lives.
13	*'just beliefs of the people it is what the community believe'*	*'it is other way of knowing about the world'*	This learner made the same transformation as learner 2 above.
16	*'I thought indigenous knowledge was not correct. I thought they are just guessing.'*	'*It is very important than the other because it tells us the things that happens every day'.* I inferred from what the learner said that she meant that indigenous knowledge is as important as science; that it can also be used to explain natural phenomena and that it is relevant and useful in today's world, in our lives.	The transformation is that the learner accepted that indigenous knowledge is as important as science because it can also explain natural phenomena and is relevant and useful in our lives.
Responses from some of the other learners	'*Inferior to science'* (7); *'I was not much believing in indigenous knowledge and it is weak'* (14); *'It is something or an information that is known by old people,*(4).	*'I believe in some parts of the indigenous knowledge and not all. Indigenous knowledge also do things right at times but not all the time*'(14); *'It is equal to science'* (9);	Learner 14 needs special mention. He said that he would be selective when using indigenous knowledge. He said the same about science (see above).To me this means that where he finds indigenous knowledge more promising, he will use it and where he finds science more promising he will use it. In other words he will borrow from the two worldviews depending on the situation or context. This means getting the best out of both thought systems. I find this to be very pragmatic and in line with Ogunniyi's (2004) equipollent contiguity.

In both Tables 4.8 and 4.9, the numbers in brackets are the other learners' identities. The views expressed by the learners in both Tables 4.8 and 4.9 were recorded verbatim. The responses of a few of the learners will be discussed in detail. The other responses will be referred to in passing and in a combined fashion because they more or less confirm or reinforce what the detailed responses reveal.

Generally, initially, the learners thought that science knowledge was better than and superior to other knowledge systems because it is knowledge that is researched, tested, validated by others. In short, science knowledge is a result of people applying the scientific method. At the end of the programme, the majority of the learners have begun to question these premises or assumptions by pointing out at the fact that some scientific knowledge has been produced through what can be regarded as unconventional scientific methods.

The majority of the learners seem to have shifted from seeing indigenous knowledge systems as belief systems of communities that are not very useful for modern life to a realisation that these knowledge systems are viable ways of learning about the world around us which are useful and relevant in today's world. The major observations from the two tables above mirror and thus reinforce the major observations made from the Science-Indigenous Knowledge Systems Questionnaire.

Interpretive commentary

An analysis of the two tables above shows that the intervention programme has helped most of the learners to correct some misconceptions that they had about both science and indigenous knowledge. Some of these misconceptions were that: science is infallible since it is tested knowledge; indigenous knowledge system is just a belief system since it is untested knowledge; indigenous knowledge is inferior to science; scientists always get their knowledge through careful scientific methods; science is the panacea of humankind problems; indigenous knowledge is not relevant and useful in today's world; and that indigenous knowledge is for the old, poor and rural people.

One could also look at the above shift in the perceptions of the learners about the two worldviews as the emergence of new perceptions or of new knowledge. This seems to fit very well with CAT's emergent category where new ideas about the two thought systems emerge and are added to or replace the old ones. It can also be seen as a situation where the learners have accepted aspects of the two systems to the extent that those aspects are equipollent and can coexist in the learners' mind without causing cognitive conflict. The views of learner 14 about both science and indigenous knowledge show this position very clearly when he says '*I believe in some parts of science and not all' 'I believe in some parts of the indigenous knowledge and not all. Indigenous knowledge also do things right at times but not all the time.*'

Summary

For this research question, the major findings and conclusions were that the majority of these learners:

- No longer saw science as a wholly researched, verified, tested and infallible body of knowledge. They now regarded science as a human construct that can have errors. In terms of understanding the nature of science, the learners were able to appreciate the tentative, uncertain nature of science and its reliance, at times, on non-scientific methodologies. This by no means plays down the role of the scientific method in science knowledge construction. It is simply to acknowledge and accept the fact that useful science knowledge has come through others avenues besides the hypothesis formulation and testing method.

- No longer perceived science as a panacea of humankind problems. To them, science has not lived up to its expectations because it has failed to solve problems of poverty, disease, pollution, dwindling natural resources, inequality amongst the citizens of the global village and many other such problems. As Ogunniyi (2011) observers, perhaps we set the bar too high in our expectations of what science could for us.
- Have shifted from a position where indigenous knowledge systems were conceived as useless belief systems only good for poor rural people to a position of believing that indigenous knowledge systems are capable of explaining, interpreting and predicting natural phenomena.
- Would be selective when using indigenous knowledge and science. This means that where they found indigenous knowledge more promising, they would use it and where they found science more promising they would use it. In other words, they would borrow from the two worldviews depending on the situation and context. This is done in order to get the best out of both thought systems. I find this to be very pragmatic and in line with Ogunniyi's (2004) equipollent contiguity category.

Again it would be preposterous to claim or even think that the picture painted above would apply to all the learners. The correct picture could be that while most of the learners (not less than 75%) could have achieved these levels of understanding of the two thought systems, not all the learners made all the above shifts and to the same extent.

4.3 Learners' pre–post conceptions of lightning and thunder

Several methods and activities were used to explore the learners' understanding of the nature of lightning and thunder before, during and after the intervention programme. Below is a description of those methods and activities and their results and a discussion of the importance of those findings to this research.

4.3.1 Learners' conceptions of lightning and thunder: results form a questionnaire.

The views of the learners about lightning were sought through a questionnaire that was administered to them before the intervention programme. *(See Appendix 9 for details on this questionnaire).* The learners were asked to indicate what they thought were the causes, dangers and prevention measures of lightning.

On causes of lightning, the learners thought '*lightning was caused by static electricity which is natural, where thunder clouds consists of negative and positive particles which combine and cause lightning'; 'lightning is produced in thunderstorms when liquid and ice below the freezing level collide'; 'lightning occurs between the charges in the cloud and opposing charges on object at ground level.'* All these are scientific explanations of lightning. No learner referred to indigenous explanations of lightning. When asked how they would protect themselves and their property from lightning, the learners stated what to do and what not to do as follows: '*hide shiny objects such as mirrors and metals'; 'put rubber tyres on top of your house'; 'put a stick of a tree called* umquma' and then '*do not sit or stand near windows or doors or isolated buildings or tall trees or a fireplace or electrical appliances or water sources during a thunderstorm.'* Unlike their response on causes of lightning, the learners were now borrowing from both Western science and indigenous knowledge for their protection against lightning.

The learners came up with a number of dangers associated with lightning. Their list included: '*damages or kills animals and people*'; '*damages and destroys houses and electrical appliances'; 'can cause fires, burns, damage to the heart, brain and nervous system.'*

Interpretive commentary

All the learners' explanations of causes of lightning, although not always clear or accurate, were based on school science knowledge. Elsewhere in this thesis, I indicated that this group of learners had a very good repertoire of indigenous knowledge despite the many years of contact with the Western world and its ideas, including science knowledge. I am inclined to think that the fact that the learners did not include indigenous knowledge explanations of lightning cannot be because they did not know them but that the learners did not think that those indigenous knowledge explanations were important or valid. By extension, this means that these learners thought that the scientific explanations of lightning were better and superior to those of indigenous knowledge holders. For this group of learners, at this level of the intervention programme, the scientific explanation was dominant, according to CAT.

The learners came up with a mixture of prevention measures that came from both science and indigenous knowledge. Why did they depend on only one worldview when they were discussing causes of lightning? The explanation for this apparent contradiction could be that when it came to preventive measures, the learners were using their practical experiences based on their observations of what happens in their communities where these methods of prevention are commonly used and are believed to work. They could have relied on their school science lessons to come up with the scientific methods of prevention. This example shows a situation where the learners are borrowing from each worldview in order to come up with a more comprehensive understanding of a natural phenomenon. The knowledge that they get is what Ogunniyi (2011) calls 'the alloyed knowledge'. One could also describe this situation as equivalent to CAT's equipollent category where two contrary ideas exist in the minds and hearts of the learners. Other people might not agree with this classification since, in this particular case, there were really no contrasting points of view.

4.3.2 Learners' conceptions of lightning and thunder: using scenarios related to the nature of lightning.

The learners were given seven scenarios related to lightning and thunder. For each scenario four possible explanations were given and the learners were asked to indicate which of the given explanations they agreed with and why they agreed with that explanation or those explanations. Where they did not agree with any of the given explanations, the learners were asked to provide their own explanations and to defend them. The activity was done before and after the intervention programme. Even the first session was carried out after a number of activities on argumentation were done with the learners. Below, in this table, are the results of that survey.

The following are a few of the major observations that can be deduced from the table and from the narratives from the learners.

Initially, slightly more than half of the learners (57%) suggested that the man whose homestead was struck by lightning should consult a traditional doctor. The reasons given for this advice included*: 'so that he can know exactly what is troubling him'* which I took to mean 'in order to get a reason why his homestead was struck by lightning'; *'traditional* *doctor can give him medicine to protect himself from lightning'; 'so that he can be told* (*by the traditional doctor*- my own addition) *how to get rid of that lightning from his home'; 'so that he may be told what he must do to stop the lightning.'* The two major reasons for consulting the traditional doctor given by the learners were: (1) to know the reason for the lightning attack and (2) to prevent future lightning attacks.

Initially, nearly half of the learners (47%) felt that some people can send lightning to their enemies. *'Sangomas are very powerful they can do that especially witchdoctors.'*

Table 4.10: Learners' pre-post views of lightning and thunder

Items	Pre-intervention explanations and the popularity of each of those explanations amongst the learners.	Post-intervention explanations and the popularity of each of those explanations amongst the learners.
1: *How to get protection from lightning*	• Consult a traditional doctor (57%) • Put a tyre on roof of house (36%) • Appease ancestors (7%)	• Fix a metal conductor (33%) • Consult a traditional doctor (27%) • Appease ancestors (20%) • Put a tyre on roof of house (20%)
2: *Why a house is struck several times by lightning*	• The owner of the house has powerful enemies (47%) • Lightning is a hen that lays its eggs in one place (27%) • Owner of the house's ancestors want to be appeased (20%)	• The house is on a high place (60%) • The owner of the house has powerful enemies (17%) • Owner of the house's ancestors want to be appeased (17%)
3 *: Explaining wounds on lightning victim*	• Wounds are burns from lightning (65%) • Wounded by enemy who sent lightning (35%)	• Wounds are burns from lightning (75%) • Wounded by enemy who sent lightning (13%) • Wounded by lightning bird (13%)
4: *Why not play with water in thunderstorm*	• Water attracts lightning (72%) • Water is a good conductor (22%)	• Water is a good conductor (40%) • Water attracts lightning (40%) • Lightning likes water (20%)
5: *Why not shelter under tree in thunderstorm*	• Tall trees attract lightning (62%) • Lightning lays eggs in tall trees (23%) • Lightning hates tall trees and will destroy them (15%)	• Tall trees attract lightning (63%) • Lightning hates tall trees and will destroy them (25%) • Lightning lays eggs in tall trees (13%)
6: *Why lightning is*	• Lightning is faster than	• Lightning is faster than

seen before thunder	thunder (63%) • Lightning is a fast boy while thunder is his slow mother (25%)	thunder (75%) • Lightning is a fast boy while thunder is his slow mother (13%) • Lightning is more angry and powerful than thunder (13%)
7: *Why Moni and not Mana was struck by lightning*	• Lightning is more angry and powerful (50%) • Moni was in the path of lightning (31%) • Moni is taller than Mana (13%)	• Moni is taller than Mana (50%) • Moni was in the path of lightning (36%)
Additional observations	Each learner chose one explanation for a scenario. No learner gave more than one explanation for a scenario. The importance of this observation for this research is that, at that time of the intervention programme, learners were satisfied with simplistic and monolistic explanations of natural phenomena and that these explanations were informed by either Western science or indigenous knowledge and never by both worldviews.	• There were several explanations given by the learners that came from both Western science and indigenous knowledge for each scenario. • Many learners were now offering several and different explanations, borrowed from both Western science and indigenous knowledge, for one scenario.

The majority (65%) of the learners thought that the wounds on the body of somebody struck by lightning comes from the lightning because *'lightning is like fire'; 'lightning is very powerful, it can even cause fire'; 'lightning is very powerful and dangerous it would not be a surprise to see wounds on his body'; 'lightning got into him very strong'*. The rest of the learners (35%) thought that the wounds came from '*the enemy who had sent the lightning*'; '*the enemy sends lightning with knife to make wounds.'*

Almost three quarters of the learners (72%) said that water attracts lightning. The majority of these learners thought that this was because '*water is shiny.'* In an earlier activity, the learners were asked to indicate how they would prevent lightning attacks. Covering or hiding shiny objects came up very frequently because these objects *'attract lightning'*. Other objects that were said to attract lightning are trees and sour milk *(amasi)*. Slightly less than a quarter of the learners (22%) gave the scientific explanation: '*water is a good conductor of lightning.'*

Sixty two per cent of the learners were of the opinion that tall trees attract lightning. The reasons given were that '*tall trees are near the sky where the lightning comes from'*; (this same explanation was given by 7% of the learners who thought that the homestead that was struck was on high ground which is *'closer to the lightning in the sky'); 'these trees protect us from lightning so the it stays there'; 'the tall tree is where the lightning strikes so that it cannot make danger.'* I took the last two statements to mean that trees are struck by lightning instead of people and animals.

Half of the learners thought that an enemy sent lightning to the boy who was struck. Their reasons were: '*lightning wont choose Moni from Mana'* which I took to mean 'lightning alone cannot choose between Moni and Mana, it must have been directed towards Moni'; *'if it was normal lightning it would have attack them both.'* The apparently fairly logical explanation that the boy who was struck was in the path of the lightning was supported by 31% of the learners.

At the end of the intervention programme, the major observation is that the majority of the learners now seemed to accept that most of the given scenarios could have more than one possible explanation and that these explanations could come from both the science worldview and the indigenous knowledge worldview. A very good example of this observation is scenario 1 where consulting a traditional doctor is traditional; fixing a metal conductor is Western; appeasing ancestors is traditional while putting a car tyre on the roof of a house is most probably both Western and traditional. In scenario 2, although the majority of the learners (60%) have given a scientific explanation why a place is struck several times by lightning (*the place is on a high place),* a significant number of the learners (34%) think that the explanation is traditional *(the owner of the place has powerful enemies or has not appeased his/her ancestors).* Similar conclusions can be made about scenarios 3.

Interpretive commentary

An analysis of the whole picture shows that the learners were being informed by both indigenous knowledge and science in their explanations of the nature of lightning, although the science explanation was dominant (CAT) over the indigenous knowledge explanations. Initially, at the individual learner level, the explanation was either indigenous knowledge or science and not both. In other words, the individuals were informed by the indigenous knowledge or by science. According to CAT, one of the two systems of thought was dominant. Later, even at individual level, the learners sought explanations of scenarios in both worldviews and that the indigenous knowledge explanations were being accepted by a very significant percentage of the learners. The learners were coming to terms with the possibility of living with several but not necessarily congruent explanations of natural phenomenon. Their views were becoming truly equipollent according to CAT.

Among the Xhosa people, one explanation of lightning is that it is a message from the ancestors. It is called *kuhambele umhlekazi. Kuhambele* means a visit while *umhlekazi* means honouring or respecting. Lightning would then be seen as a respected visit from the ancestors, who would have a message to and for the living. Only a traditional doctor called *igqrrha* can talk with the ancestors and get their message to the living. The message could be that the ancestors need some beer. Beer (*umqombothi)* is brewed to appease the ancestors. Sometimes a cow is also slaughtered to appease the aggrieved ancestors. Another traditional doctor called *ixhwele* would be called in to the affected homestead to do the prevention ceremony, a ceremony known as *ukuqinisa umzi (ukuqinisa* means to strengthen or protect while *umzi* means a homestead) or a cleansing ceremony to erase (*ukucima*) the effect of the lightning and prevent further lightning attacks.

This serves to illustrate that ancestors and traditional doctors play a very important role in the explanation of lightning among the Xhosa people. This explains the high percentage of learners (47% in total) who chose these options as explanations of how to prevent lightning attacks.

Black tyres on roofs of houses, as a way of protecting homesteads from lightning, chosen by 36% pre and 20% post, is a very common sight among the Xhosa people. There are other ways of protecting their homesteads that I learnt from the knowledge holders. One such method is to use a stick from a plant they call *umnquma* which is commonly found in their forests. Another way is to put the *umthathi* plant in pots on top of the roofs of their houses or hang the plant outside or inside the house. These plants are believed to be able to prevent lightning or to minimise its effects. While there may not be scientific explanations on how these methods work, the fact that they have been used for generations must mean that the methods work or that the people think that they work. As put very succinctly by one of the learners '*because many houses have survived using tyres'* which I translated to mean 'because it worked in many or in all cases.'

According to the learners, there are two reasons why lightning would strike a tall tree. The tree is closest to the source of the lightning. This is in line with scientific literature which says that tall objects such as skyscrapers, mountains and radio towers are more likely to be struck because of the narrow gap between the tall object and the oppositely charged cloud above. According to the learners, trees are also struck in order to protect people and animals from being struck since the lightning 'chooses' the tree instead of the person or animal. That a tree is sacrificed to save the lives of people and livestock is an explanation that would lie in the indigenous knowledge worldview in that a natural phenomenon 'chooses' to strike one object rather than the other perhaps directed by ancestors. If we accept this latter explanation, we can explain why indigenous people have lived "harmoniously with (their) bio-physical environments" (Ogunniyi, 2008b, p. 35). Not only did the indigenous people see their natural environment as a source for food, medicines etc. but they also saw the environment as a protector from natural elements such as floods (high ground acting as barriers), strong winds (trees acting as windbreak) and now, trees protecting them from lightning as well. This is why the people had to protect and respect their environment and use it sustainably.

The learners gave two reasons why one of the two boys was struck by lightning while the other boy with whom he was playing was not affected. The first reason was that the lightning was sent by an enemy to the boy. This explanation is coming from the indigenous knowledge worldview where there is a belief, amongst some indigenous people, that there are some people who have the power to create and control lightning and use it for their purposes, usually evil purposes. The second reason was that the boy who was struck happened to be in the path of the lightning. This is quite logical and could be informed by both worldviews. The difference, however, would be that indigenous people might want to know why the boy who was struck happened to be in the path of the lightning at that time and why not the other boy? Put differently, indigenous knowledge goes beyond scientific knowledge in that it seeks answers beyond human comprehension i.e. in the metaphysics realm.

While the scientific explanations dominate the traditional explanations (for example, 60% as compared to 34% in scenario 2; 75% as compared to 26% in scenario 3), the traditional explanations have made some very serious inroads in the minds of the learners as shown by a very significant number of the learners that have chosen those explanations. This could be taken as the major observation for this subsection of the research.

4.3.3 Learners' understanding of lightning and thunder: using statements on lightning.

4.3.3.1 Learners' reactions to statements on lightning.

The learners were given twenty one statements on the nature of lightning and thunder. They were asked to indicate whether they agreed or disagreed with those statements and to state why they agreed or disagreed. The table that follows shows the result of that survey.

Table 4.11: Learners' reactions to statements on lightning and thunder

Item	Statement	Agree (%)	Disagree (%)
1	Lightning is dangerous	100	0
2	Clouds become charged by rubbing with air	100	0
3	Clouds acquire a negative charge	100	0
4	Charge moves from cloud to ground	100	0
5	Movement of charge is lightning	80	20
6	The sound heard is thunder	50	50
7	There is need for protection from lightning	90	10
8	*Sangomas* can protect from lightning	70	30
9	Dangerous to stand under trees in a thunderstorm	100	0
10	Dangerous to play with water in a thunderstorm	90	10
11	Put out fires during a thunderstorm	70	30
12	Certain trees protect from lightning	60	40
13	Metal rods on houses protect from lightning	10	90
14	Lightning is natural	70	30
15	Lightning is man-made	56	44
16	IK helps me to understand lightning better	70	30
17	I can use Sc knowledge on lightning at home	90	10
18	I believe in Sc explanations more than in IK	67	33
19	I believe in IK explanations more than in Sc	20	80
20	I learn Sc explanation for exams	44	56
21	It is necessary to know both explanations	100	0
Total			
t-test		15.14	

critical t-value at $p \leq 0.05$ is 2.086. Since calculated t is greater than critical t the difference is highly statistically significant. This means that the learners strongly agreed or strongly disagreed with the statements.

The major observations about the feelings of the learners on these statements as revealed in the above table include:

All the learners agreed with the scientific explanations of lightning as given in statements 1 to 4. It is surprising, though, that there is some controversy on statements 5 and 6 which are also quite scientific.

The same learner would agree with contradictory statements. For example: the same learner would agree with both statement 14 (lightning is natural) and statement 15 (lightning is man-made).

Some statements were heavily 'contested'. This means that the learners were fairly distributed in these areas. Such areas include: certain plants can protect; lightning is man-made.

The learners seem to say, in statements 18 and 19, that they believed more in scientific explanations than in indigenous explanations. Their reasons are that: '*IK explanations not very clear; IK has not shown me the process'* while in science *'We did many experiments that convinced me; it can be explained clearly; it gives me full explanation.'*

The majority of the learners did not think that they learnt the scientific explanations of lightning (just) for examinations, despite the importance attached to examination results in this country. Their reasons were: '*To know more about it; to protect myself; exam could include IK explanation; can help in future.'*

All the learners felt that it was necessary to know the scientific and indigenous knowledge explanations of lightning. Their reasons were that: *'Have different interesting points; have some common points; helps to understand it better; to compare them; to balance knowledge; the two come up with a better way of knowing things.'*

The major findings that we can derive from this subsection that are of interest in this study are: the same learner agreed with contradictory statements; the learners believed more in scientific explanations than in indigenous explanations; the learners were of the opinion that they did not learn about lightning just for examination purposes but because that knowledge was useful in their lives; the learners felt that it was necessary to know both the scientific and indigenous knowledge explanations of lightning.

Interpretive commentary

The fact that the same learner would agree with contradictory statements and the observation that some learners thought that they were two types of lightning: the '*scientific lightning'* which they thought was natural and the '*man made lightning'* from evil people could be a result of the Xhosa people's belief that lightning could be a messenger from the ancestors (natural lightning) or that it could be a lightning bird sent by an evil person to his enemy. Clearly this is an indication that the learners accepted that lightning has several possible causes or explanations and that these explanations could be found in different worldviews. I took this to be a sign of equipollence on the part of the learner (Ogunniyi, 2004). The major thrust of this study was to help learners understand and appreciate that natural phenomena such as lightning could have several plausible and possible explanations. The observations made here seem to suggest that this objective was achieved by some of the learners.

That the learners believed more in scientific explanations than in indigenous explanations is understandable. Elsewhere in this thesis, I alluded to the fact that the learners were not happy when the community knowledge holder could not demonstrate the creation of lightning 'even on a small scale'. One can therefore understand the learners' frustration. Science tries to demonstrate what it believes in; indigenous knowledge is often shrouded in mystery. The learners were happy to see pieces of paper being attracted, metal leaves of an electroscope diverging and collapsing as they did experiments on static electricity. The learners seemed to say that they wanted similar experiences with indigenous knowledge. These learners are exposed to the scientific explanations at school which are given openly. When the learners go back home, they find that indigenous knowledge seems to be more guarded than scientific knowledge even in the home of the learner from an indigenous knowledge holder. I know of a person who was very good at treating (and preventing) snake bites using herbs. When he died, we discovered that he had not left that expertise with anybody, not even with his children.

All the learners felt that it was necessary to know the scientific and indigenous knowledge explanations of lightning because such explanations were better than the explanations from either knowledge system. One of the main objectives of this study was to help learners to appreciate that each of the two thought systems had something useful to offer and that combined, there could result in better understanding of natural phenomena. The reactions of the learners in this question seem to suggest that this objective was achieved by all the learners.

Lightning affects all of us, it is very dangerous. Its nature should be understood by all of us and not just by learners for examination purposes. This seemed to have been the stance taken by these learners.

I feel gratified that the learners did not just take their experiences in this research as purely academic. They were able to see its value in their daily lives.

4.3.3.2 Learners' classification of statements on lightning.

The learners were given fourteen statements showing different people's views about lightning and thunder. They were asked to state whether each of those views was informed by school science, or by indigenous knowledge systems or by both. The learners had to support their answer by stating words in the statement that had influenced them to come to their conclusion. The major purpose of this activity was to find out why (evidence) a learner would classify a given knowledge claim as either scientific or indigenous or both.

Below are the statements.

1. During a thunderstorm, clouds and the ground gain negative and positive charges.
2. When the negative charges in the cloud become too great/huge for the cloud there is a discharge of energy from the cloud to the ground which we call lightning.
3. As the charge moves to the ground it displaces air molecules violently resulting in the sound we call thunder.
4. Lightning is a bird' which is thought to have a large and strong beak and long strong legs.
5. The lightning bird lays eggs and returns for its eggs now and again.
6. The lightning bird causes wounds with its strong beak.
7. Lightning is believed to be an important, honoured and respected messenger from the ancestors.
8. Those affected by the lightning know that they must have offended the ancestors and must repent and restore their relationship with the ancestors.
9. *Sangomas* are called in to the affected homes and people to perform cleansing rituals.
10. Thunder is an elderly mother sheep and her son is lightning. The son is short tempered and quickly destroys houses and property when angry. His mother would then raise her voice to control him but he is always too fast for his elderly mother.
11. Some people plant certain plants around their homesteads in order to protect themselves from lightning.
12. Some families use metal rods on their houses to protect themselves from lightning.
13. Some families consult *sangomas* for protection against lightning.
14. Some families put old car tyres on the roofs of their houses for protection against lightning.

Table 4.12: Learners' ideas about lightning and thunder

Statements informed by scientific knowledge	**Statements informed by indigenous knowledge**	**Statements informed by both worldviews**
1. *Negative and positive charges*	*2. Discharges energy (lightning has a lot of power)*	2. *Discharges energy*
2. *Negative charges; discharges energy*	4 *Chimunga; umpundulu; lightning bird; evil people; harm enemies; thunder rows; lightning flashes*	4. *thunder rows; lightning flashes*
3. *charge*	5. *Lightning bird; returns now and again.*	5. *returns now and again.*
4. *Thunder rows; lightning flashes*	6.. *Lightning bird; causes wounds*	6.
5. *Returns now and again (can strike the same place several times)*	*7. Kuhambele umhlekazi; messenger from ancestors; from high levels (Ancestors live high up there).*	7. *from high levels*
6. *Causes wounds*	8. *Offended ancestors; repent and restore relationship with ancestors*	10. *Quick; slow; destroys houses*
7. *From high levels (from the sky/clouds)*	9. *Sangomas;cleansing rituals*	11 *Certain plants prevent lightning*
10. *Quick (lightning is fast); slow (thunder is slow); destroys houses and property.*	10. *Quick (lightning is fast); slow (thunder is slow); destroys houses and property. folk lore about mother sheep and her son*	
11. *Certain plants prevent lightning*	11. *Certain plants prevent lightning*	
12. *Metal rods*	13. *Sangomas can protect*	
	14 Car tyres on the roof	

Below the statement and in italics are the words that were used by the learners to classify the statements. In brackets is the learners' understanding of the words in the statement.

There was unanimous agreement on some statements. For example, all the learners classified statements 1, 3, and 12 as views informed by science while statements 8, 9, 13, and 14 as views informed by indigenous knowledge. There was a lot of controversy on the other statements. Some learners placed some of the remaining statements under science while other learners placed the same statements under indigenous knowledge and yet others placed them under both.

Interpretive commentary

That some statements were uncontested and classified as either scientific or as indigenous and yet other statements would be indigenous to some learners and scientific to other learners or both indigenous and scientific to yet others could be an indication that the learners were now searching for answers about the nature of lightning in both worldviews. They were borrowing from the two knowledge systems. This could be a sign that the learners had realised and accepted that lightning could have several possible explanations coming from different thought systems. The fact that the learners identified several explanations about lightning which they thought belonged to both knowledge systems could be a confirmation of the conclusion that the level of understanding lightning that these learners now demonstrated at this point in the study was quite enhanced.

These observations could be a signal that the learners could live comfortably with both of these positions, that these different positions about the same phenomenon could coexist in the minds and hearts of the learners. This is what Aikenhead & Jegede (1999) called the secured collateral learning which refers to a situation where the conflicting schemata consciously and consistently interact and the conflict is resolved in some manner and which Ogunniyi (2000, 2004, 2007a) describes as the equipollent contiguity category which the author explains as a situation where the learner holds in his/her mind and heart two different explanations of a phenomenon without cognitive conflict.

4.3.4 Learners' understanding of lightning and thunder on reflection.

At the end of the intervention programme, learners were asked to reflect on and express their views on what they thought about lightning before and after the intervention programme. *(See Appendix 13 for details).* The responses of some of the learners are displayed in the following table and are discussed in detail as exemplars of what the learners felt.

Table 4.13: Learners' pre-post views about lightning

Learner identity	Pre intervention views	Post intervention views	Observations and interpretive comments
7	'*lightning is caused by God'.* Learner 13 echoes the same sentiments when she says '*I thought it was when God is telling us something which we should know.'*	*'lightning is caused by complex phenomena';.* By 'complex phenomena' I thought that the learner meant that the 'causes of lightning are difficult to understand.' *'lightning is unpredictable even scientists do not understand it well'* (13)	These learners, initially, are saying that lightning is caused by a supernatural power (God). Learner 13 adds another dimension when she says: 'God has a message for us' when He sends lightning. After the intervention programme, the learners maintain that causes of lightning are 'complex' and 'difficult to understand.'
8	*'lightning is dangerous and I must protect myself against it'.* Learner 1 echoed the same view when he said *'lightning is very dangerous.'*	'*lightning is fast and hot.'*	The initial view about lightning of learner 8 is probably based on her experiences within her community. She could have witnessed or heard about the destruction that lightning can cause. She could also have seen the various methods used by the local people to protect themselves and their property from lightning. Later on the learner adds to her repertoire of knowledge about lightning when she says *'it is fast and hot'.* The intervention programme has not made her to shift her original position. It has simply made her more knowledgeable about lightning. According to CAT, this is the emergent category where new ideas are added to the already existing ideas.
9	*'I thought it was only caused by the scarying weather. I was clueless about it.'*	*'lightning could be created by witches and could strike people several times.'*	By 'scarying' weather, the learner meant 'scaring' or 'scary' which I took to mean thick dark clouds accompanied with scary calmness; 'the calmness before a storm'. I remember that as a young boy herding cattle I knew the meaning of such weather and ran home as fast as I could. That weather is associated with heavy rains and thunderstorms (a lot of lightning).This learner must have had similar experiences. His second statement is a bit puzzling. Does it mean that although he knew the weather conditions associated with lightning he did not know the cause of lightning or that lightning has several possible causes which he did not know then? His later statement seems to suggest that he now knew that lightning has other causes even when there is no 'scarying weather'. Witch doctors are believed to be able to create lightning with little more than a single cloud.
16	*'Lightning comes from the clouds.'*	*'Lightning comes from the clouds but can also be sent by witch doctors.'*	The learner now accepts that there could be more than one explanation of lightning and that those explanations could come from both science and indigenous knowledge systems. This seems to be an example of CAT's equipollent category where two different views can co-exist harmoniously in the mind of a person.

From the above table, the learners seemed to be saying that:

- It is difficult to know exactly the causes of lightning. Learner 13 puts it succinctly when she says *'it is caused by complex phenomena'* and that '*even scientists do not understand it well.'*
- Lightning probably has several possible explanations which could lie in the domain of science or of indigenous knowledge or of both.
- A combination of indigenous knowledge systems and other knowledge systems could help elucidate the nature of this complex natural phenomenon.

Interpretive commentary

The observation that '*God is telling us something that we should know'* when there is lightning and the belief among the Xhosa people that lightning is a message from the ancestors are very similar. Both God and ancestors are supernatural beings (although not of equal standing) who are believed to be capable of doing or causing things or events which mortal human beings cannot easily comprehend. It seems that these learners and the Xhosa people in general, are agreeing that lightning is caused by supernatural powers which may be difficult to explain. The four bizarre stories about lightning which I used during the intervention programme could have convinced them that there was more to lightning than the natural movement of negative charges from clouds through space to a positively charged object on earth. In other words, the learners came to a very important observation and conclusion which is that as mortal human beings there are certain things, events or phenomena occurring in our environments that we may never fully understand.

4.3.5 Learners' understanding of static electricity.

Activities on static electricity were done after the learners had gone through a series of activities on argumentation. This was because I wanted the learners to use what they had learned about argumentation to negotiate their understanding of static electricity and lightning.

The details of these activities on static electricity are found in lesson 7 under data collection procedures in chapter 3 and in Appendix 10. In brief, learners did a number of activities to illustrate the concept and laws of static electricity. Although the activities were done in groups, learners were required to answer the questions related to each activity individually and then later on, to compare and discuss their answers with those of the other group members. Finally there was the whole research team discussion. It was during this session that I would deliberately and consciously probe the given observations and explanations in order to deepen, broaden, and improve the quality of the argumentation process and the level of understanding of the concepts under discussion.

4.3.5.1 Neutral objects such as pens, rulers etc. are brought near light objects such as pieces of paper.

The groups described this observations as follows: '*nothing happens'*; '*no attraction'*; '*the pieces of paper were not attracted.'*

Three of the four groups could not explain what they had observed. The fourth group said: *'the ruler has not been rubbed.'* I wanted to know by what the ruler should have been rubbed and what would have happened if the ruler had been rubbed. (Although I present the two questions together here, the second question was only asked after the first had been answered). The group said the ruler should be rubbed with any piece of cloth and that once that is done, the ruler would pick up the pieces of paper. It was quite clear that this group or some of its members had experience in these experiments where rubbed objects pick up light objects. I decided not to ask, at this stage, how and why a rubbed object could pick up pieces of paper.

4.3.5.2 Rubbed pen/comb/ruler (charged objects) and pieces of paper are brought near each other.

The groups expressed this observations as follows: '*pieces of paper were attracted to the pen'*; *'pieces of paper jumped to the pen'*; *'pieces of paper clung to the pen.'* None of these groups mentioned that the pen was attracted by the pieces of paper. This is understandable because the learners actually saw (empirical evidence) the papers jumping to the pen and not the pen moving towards the papers (inferred from the law of static electricity that says that oppositely charged objects attract each other). I, however, challenged them to say if they thought the pen had also been attracted to the pieces of paper. The group felt that '*No, the pen was not attracted'* because '*the pen is a big object, it cannot be attracted by a small object such as a small piece of paper.'*

Only 2 of the 4 groups could offer an explanation of their observation which was that '*the pen was charged by rubbing and so could attract the papers'*. I asked how the rubbing caused the pen to be charged. One group said it was because of the friction. Another group said it was because rubbing produces heat (empirical evidence) which causes the charge (inference, not observable). As can be seen, none of the learners could really explain how rubbing charged the objects. I decided to explain the charging process later after more activities. (In all these activities, I decided not to give the learners information too early or information that they could discover for themselves with more activities).

When I asked how the charged pen attracted the papers, none was able to explain that the papers were also charged because of the nearness of the charged pen (charging by induction or charging by polarisation). To the learners it was only the pen that got charged. So, to them a charged object (the pen) can attract a neutral object (the papers). I decided to leave it like this until after further activities that would show them the correct answer to the question. I wanted to know if the piece of cloth was also charged during the rubbing. There was much debate and much disagreement on this. The next activity would answer this question. None of the groups could offer any reason for their positions. In other words, at this level, the learners were simply giving their opinions without any supporting evidence.

4.3.5.3 The piece of cloth that was used for rubbing objects is brought near the pieces of paper

All the groups stated that they had observed that the piece of cloth attracted the light objects just as the rubbed pen had done. The learners were then able to conclude that the cloth must have been charged as well. It was now easy to establish that when a pen is rubbed with a piece of cloth, both the pen and the cloth become charged.

4.3.5.4 Bringing charged objects near a charged balloon.

A charged balloon was made to hang from a tripod stand. A charged ruler was brought near the charged balloon. The learners were asked to make their observations. The cloth that had charged the ruler was brought near the charged balloon. The learners were asked to make their observations. It was noted that the balloon moved away from the ruler while it moved towards the piece of cloth. Through a question and answer session we were able to establish the following:

- The balloon had the same charge since the same balloon used for both experiments (with the ruler and with the piece of cloth) had been charged with the same cloth.
- Since in one case there was attraction (the charged cloth and the charged balloon) and repulsion in the other case (the charged ruler and the charged balloon), it seems

reasonable to assume that the ruler and the piece of cloth have different charges. It was at this stage that I introduced the following concepts:

- ✓ There are two types of charges: the positive and negative charges. I also mentioned the work of Benjamin Franklin (1706-1790), the American politician and inventor, who coined the concepts of positive and negative charges.
- ✓ All materials are made up of atoms. All atoms are made up of positive protons and negative electrons. In an uncharged material, the number of protons is equal to the number of electrons and that these particles are evenly distributed in that material.
- ✓ When objects rub against each other, one of the objects loses electrons to the other object. The object that loses electrons becomes positively charged because it has excess protons while the object that gains electrons becomes negatively charged because it has excess electrons.
- ✓ When charged objects are brought together, they either attract each other if their charges are of different types or they repel each other if their charges are of the same type. In short, like charges repel each other; unlike charges attract each other.

At this point, I asked the learners to reflect on some of the earlier activities we had done and give more informed explanations of what they had observed. The following is the result of that reflection.

Objects that had not been rubbed together did not attract pieces of paper.

The learners were able to conclude that the ruler and the papers had not been charged *'because they had not been rubbed together.'* This is why they could not attract each other. I introduced the term '*neutral'* to describe objects that were not charged. A neutral object was explained as an object where the number of protons and electrons in its atoms was the same and where these particles were evenly distributed in the object. The learners were able to conclude that 'neutral objects do not attract each other.' In Grade 11, these learners will be introduced to Newton's law of universal gravitation which will make them to revise the conclusion that neutral objects do not attract each other.

A charged body (ruler or cloth) attracted pieces of paper.

The learners came to the conclusion that the ‘pieces of paper must have been charged also for them to be attracted by the charged object and that the charge on the paper must be different from that of the charged object to which the paper is attracted’ since ‘unlike charges attract each other’. This conclusion did not come up easily. There was a lot of debate on this. Group 1 wanted to know if it was not possible for a charged object to attract a neutral object. This is a difficult question to answer. Unfortunately, some Physics books do not help either. They actually confuse the learner. For example, Nelkon (1975, p. 546) writes that “attraction is not a sure test of a charge. Repulsion is the only sure test” since a charged object can attract an uncharged object. Pople (1996, p.232) says “A charged object will attract any uncharged object close to it.”

The consensus was that objects had to have different charges for them to attract each other. Group 4 wanted to know how the same pieces of paper could be attracted by both the ruler and by the cloth which ‘we saw were oppositely charged’. It was this question that prompted me to explain the process of charging by induction at this stage.

A positively charged object induces a negative charge in the object near it by repelling protons (like charges repel each other) and attracting electrons (unlike charges attract each other) of the nearby object.

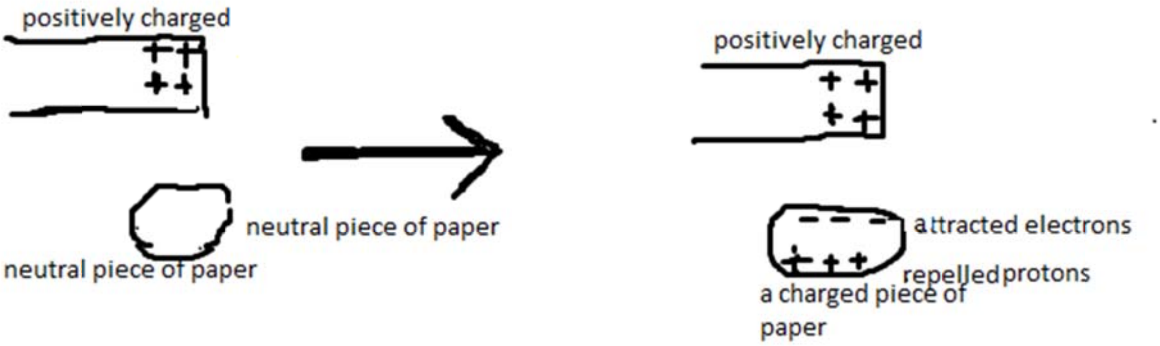

Figure 4.1: Inducing a negative charge on a piece of paper

A negatively charged object induces a positive charge in the object near it by repelling electrons and attracting protons of the nearby object.

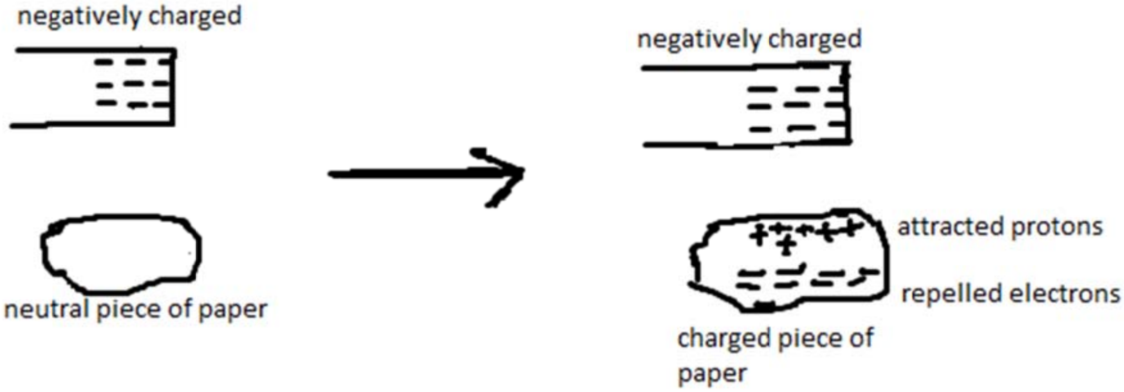

Figure 4.2: Inducing a positive charge on a piece of paper

This means that the pieces of paper got different charges when the ruler and the cloth were brought near it, respectively. This explains why the two differently charged objects attracted the pieces of paper.

I took this opportunity to mention that lightning, which was our main focus in this study and to which we would turn fairly soon, is a result of charging by induction. I did not explain anything further. I just wanted to arouse their interest in future activities.

One of the learners wanted to know whether the charge on the ruler was positive or negative and how we could tell. To answer this question I had to refer to the Triboelectric series which lists materials in the order they become electrically charged. Those at the top of the list become positively charged if rubbed with those at the bottom and vice versa. The following shows part of that list: (positively charged) - glass-human hair-nylon-wool-silk-paper-cotton-plastic-rubber (negatively charged). This means that if a rubber balloon is rubbed with a woollen cloth, the rubber balloon becomes negatively charged while the woollen cloth becomes positively charged. In our example, the plastic ruler was negatively charged, so was the rubber balloon, while the cloth (cotton or wool) was positively charged. This means that like charges (the ruler and the balloon) repel each other while unlike charges (the balloon and the cloth) attract each other.

I took this opportunity to explain to them that what is presented as facts in science lessons and science books are mental pictures of some scientists and that while some people believe in those mental pictures not everybody does. As a result, some people come up with their own explanations on the same phenomenon which are not necessarily wrong just as scientific explanations are not necessarily correct.

4.3.5.5 Charging an electroscope

We started this activity by identifying, describing, and explaining the structure of the simple electroscope we used. Our electroscope was made up of a metal cap to which was attached a metal rod or stem at the end of which were two metal leaves. Most of the metal rod and the two metal leaves were enclosed in a transparent glass container which was closed tightly. The metal rod and the neck of the container were separated by an insulator. The purpose of each part of the electroscope was discussed. For example, the container was draught-proof so that any movement of the leaves would not be attributed to wind and the container had to be transparent so that we could see what happened to the metal leaves.

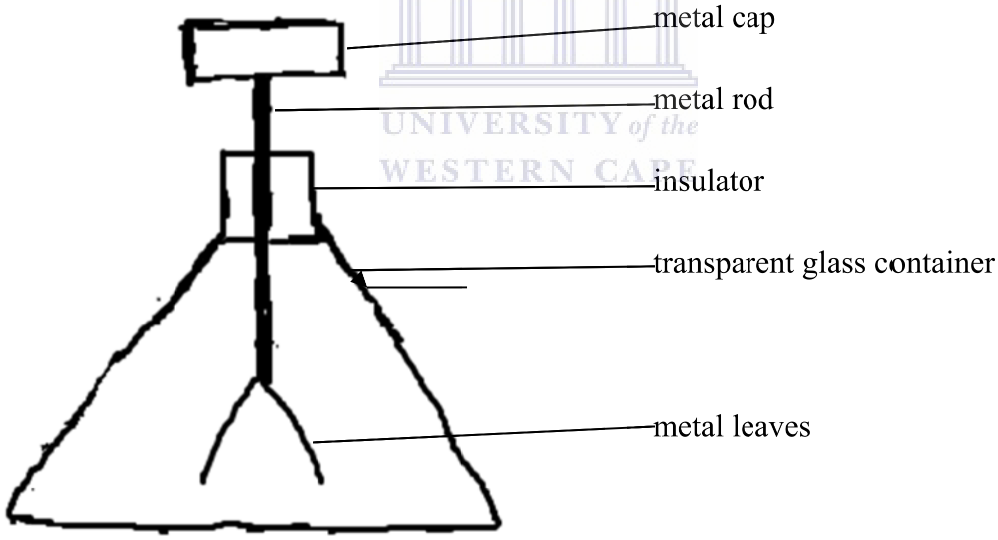

Figure 4.3: The structure of an electroscope

A polythene strip rubbed with a woollen cloth was brought near the metal cap and the learners were asked to state their observations and offer possible explanations.

All the groups reported that '*the metal leaves separated from each other'*; '*they moved away from each other*' *'they repelled each other.'* Again all the groups stated that this was because '*polythene strip was charged by rubbing'*; '*the metal cap must have got its charge from the charged polythene strip by induction'* and that the metal leaves must have got the same charge since *'like charges repel each other.'* These explanations came out fairly easily. The learners were using their previous observations and conclusions.

I asked them what they thought would be the charge on the metal cap if the polythene strip was negatively charged. Again all the groups quickly agreed that the cap must have been charged positively. *'The electrons on the metal cap were repelled by the electrons on the negative polythene strip.'* Then I asked them what they thought was the charge on the metal leaves. Two groups concluded that the leaves were negatively charged because *'the lower part of the electroscope got the repelled electrons when the protons were attracted to the surface of the metal cap.'* The other two groups said that the leaves were positively charged because *'the metal cap, the metal rod and the metal leaves are the same object. They would have the same positive charge as the metal cap'*. One of the learners in one of the first two groups wanted to know '*If the bottom part of the electroscope is also positively charged, where are the repelled electrons?'* The two groups that had said the metal leaves are positively charged could not answer this question. They then changed their position, accepting that the metal leaves were negatively charged.

4.3.5.6 Discharging the charged electroscope

A polythene strip rubbed with a woollen cloth was brought near the metal cap. With the polythene strip still close to the metal cap, a learner was asked to touch the metal cap with her finger. The learners were asked to state their observations and offer possible explanations.

The groups reported that '*the metal leaves came together'*; '*the metal leaves attract each other'*; '*the metal leaves touch each other.'* All the groups saw that the metal leaves collapsed. One group gave some explanation. The other three groups were unable to come up with any explanation.

One group gave the explanation said *'the two metal leaves had attracted each other*'. One learner in another group wanted to know where and how the two leaves got different charges so that they could attract each other. Clearly this learner was using the law of static electricity that says 'unlike charges attract each other.' The group that had offered the attraction explanation was unable to answer that question. None of the learners could answer that question.

I suggested to the learners that perhaps the metal leaves had lost their charge. They wanted to know how that could have happened. I suggested to the class '*at the beginning, when the leaves were not charged, they were together. Now they are together again. Could this not mean that the leaves are no longer charged?'* Not all the learners seemed happy with that explanation though although they could not offer an alternative explanation. I wanted to know how the leaves could have lost their charge. Most of the learners felt that it had to do with the finger that had touched the metal cap but they could not figure out exactly how the finger could make the leaves to lose their charge. I had to explain to them the process of earthing or grounding the electroscope. The explanation that I gave was that the excess electrons on the metal leaves escaped from the leaves to the earth via the human body because the human body was a good conductor of electricity since the human body has electrolytes in the form of body fluids such as blood.

Some of the learners were able to connect this with electrical shocks that people get when they handle faulty electrical appliances. Some of the learners were not convinced with my explanation, they wanted to know why the human body would attract electrons that were further down the electroscope and not attract protons that were nearer the finger. I explained that electrons were lighter and find it easier to move than protons. Some also wanted to know why '*we were not shocked if the charge went through our bodies.'* I explained that the charge that went through the body from the electroscope was very small. It could not cause a shock. At the end of it all, I thought I had not been able to really convince the sceptics.

The above descriptions and observations seem to suggest that during the intervention programme, as the programme progressed, the learners were now using observations and conclusions they had made in earlier activities to learn the major concepts about static electricity. These concepts included: objects become charged by rubbing (friction) or by induction; that there are two types of charges: the positive and the negative; and that like charges repel each other while unlike charges attract each other. In other words, through argumentation, the learners were able to construct the major concepts related to this topic and to correct misconceptions that they had before the programme.

Interpretive commentary

This discussion centres on the knowledge about static electricity that the learners were able to construct. The discussion will not repeat what was said in section 4.1 about the level of argumentation demonstrated by the learners.

Initially, the learners demonstrated lack of knowledge or misconceptions about static electricity.

Their lack of knowledge was demonstrated by the learners' inability to explain certain aspects of static electricity such as why a neutral object could not attract pieces of paper and how rubbing charged the objects.

One of the misconceptions shown by the learners was that 'a charged body can attract an uncharged body. As we have seen above, this is a difficult misconception to deal with since some books confuse rather illuminate the issue.

Another misconception was that all the learners thought that when a charged pen was brought near pieces of paper, it was only the papers that moved towards the pen and that the pen did not move towards the papers. Put differently, the learners did not think that the papers exerted any force of attraction on the pen. This is understandable because the learners actually saw the papers jumping to the pen and not the pen moving towards the papers. And yet another misconception was that the metal cap of an electroscope gains the same type of charge as the metal leaves *'because they are the same object.'* Through argumentation, as we saw above, these misconceptions were corrected.

4.3.6 Learners' responses on the achievement test on lightning and thunder.

This subsection reports the learners' level of performance in Section A and Section B of Appendix 11. Both sections had questions that had either correct or incorrect answers. All the questions in both sections were on static electricity.

4.3.6.1 Supplying correct missing words to complete given statements on static electricity, lightning and thunder. (See Section A of Appendix 11).

Section A was on basic concepts about static electricity and lightning. The answers to the questions were short (one word) and either right or wrong. This part of the test was administered before and after the intervention programme.

Table 4.14: Learners' pre-post performance in a test on lightning

Learner	Pre-test (%)	Post-test (%)
1	08	65
2	24	88
3	10	65
4	30	94
5	31	71
6	36	100
7	21	82
8	20	76
9	18	71
10	23	71
11	17	83
12	15	67
13	18	73
14	09	72
15	11	80
16	26	90
Total	317	1248
Mean	19.81	78
t-test	4.45	

N = 16

Before the intervention programme the highest mark was 36 % and the lowest mark was 8% and the average mark was 19.81%. This compares with the lowest mark of 65% and the highest mark of 100% and an average mark of 78% after the intervention programme.

A t-test statistic was calculated to determine whether or not there was a significant difference between the performance of the learners before and after the intervention programme.

The critical t value at $p \leq 0.05$ is 2.086 hence the difference is highly statistically significant. Since calculated t is greater than critical t-value, H_0 is rejected. This means that the learners performed significantly better in the achievement test on lightning after the intervention programme than before the programme.

From both the percentages and the t-test value, it can be concluded that the majority of these learners had grasped, very well, the basic concepts on static electricity and lightning as a result of the intervention programme.

4.3.6.2 Answering questions based on activities on static electricity. (See Section B of Appendix 11).

The learners had already done activities on static electricity. In this section, I wanted to find out how much the learners remembered about the activities they had done on static electricity. The questions demanded that the learners state what they had observed during the activities and explain those observations. The answers were either right or wrong.

The lowest mark was 41% while the highest mark was 100%. The average mark for Section B was 64%, a much lower mark than in Section A. I found that the greatest challenge the learners faced was giving an explanation of their observations. I also got the impression that it was more of a problem of inability to express themselves than a lack of knowledge. Still, I find an average mark of 64% an indicator of a very satisfactory grasp of concepts related to static electricity that shows a significant gain in knowledge by the learners as compared to the period before the intervention programme when, generally, the learners would give more wrong answers than correct answers as demonstrated during the activities on static electricity.

Summary

For this research question, the major finding is that the majority of the learners now seemed to accept that the nature of lightning could have more than one possible explanation and that these explanations could come from both the science worldview and the indigenous knowledge worldview. While, for the learners, the scientific explanations still dominated the traditional explanations, the traditional explanations have found a place in the minds and hearts of the learners. Both observations stated here can only mean that the learners seemed to have accepted that both science and indigenous knowledge can offer legitimate explanations to the nature of lightning. This was a huge departure from their original position where in the questionnaire before the intervention programme no single learner gave an indigenous explanation of lightning. This could also mean that the intervention programme was producing some positive results in that it was opening up the minds of the learners to other views contrary to their original positions and that the learners were appreciating and accepting these new perceptions.

4.4 The challenges encountered when using argumentation to integrate contrasting worldviews on lightning.

This section highlights challenges related to the integration of contrasting worldviews through argumentation and attempts to show how this study tried to minimise them.

This study found that, despite the many years of contact with the West and with school science, and despite their young age, the learners involved in this study had a very remarkable repertoire of indigenous knowledge which resonated with the knowledge that I got from the community knowledge holders. The problem that the learners seemed to have was that, initially at least, they did not think much of the indigenous knowledge that they had. To them, indigenous knowledge was just a belief system for the rural poor people which was of no value in today's modern life. Any negative attitudes towards IK must be overcome first before meaningful integration can take place. Fortunately, as a result of this intervention programme, the learners began to appreciate the value of indigenous knowledge even in today's technology driven life.

There is need for materials on indigenous knowledge and on how to integrate this knowledge with science. Holtman (2008, p.2) talking about '*Indigenous knowledge systems and education: The South African perspective*' laments that

> The core facilitators and implementers of this curriculum, the teachers, are now in a position where they have to teach and facilitate IKS with very little material having been developed to support the teachers.

This was one of the major challenges that I met. There were no materials to fall back on. I had to be creative and innovative. The School of Mathematics and Science Education at the University of the Western Cape, South Africa, through the Science and Indigenous Knowledge Systems Project (SIKSP) is producing teaching and learning materials that can be used to integrate science and indigenous knowledge in science lessons in schools. I was privileged to access a few of these materials and make use of some of their suggestions. For example, I borrowed their idea of using stories to teach the nature of lightning.

My experience with DAI is that it requires a lot of preparation (e.g. putting in place, often from scratch, materials which would teach the learners both the argumentative skills and the science concepts and skills important for their examinations). It also requires a lot of concentration so that one can capture, accurately, as much of what happens and is said during the debating sessions as possible. This is essential because such information would then be used later, with the class, to polish up their argumentative skills and sharpen and deepen their understanding of science concepts. This is not easy.

For this study, I spent about 100 hours with the learners and the only science concept that the learners learnt which is important for their examination was *static electricity and lightning*.

At this rate, the teacher would fail to cover enough content needed by the learners for their examinations.

This study made the observation that, initially, the learners were preoccupied with their own points of view without responding to the opponents' arguments. The learners had to go through several discursive activities where scaffolding and prompting were used to help the learners to argue effectively. As a result, as we have already seen, the learners started to address and even challenge the opponent's argument. Explaining this problem, Kuhn (2010) makes an observation that

> It is not hard to believe that argumentative discourse occasions cognitive overload on the part of young adolescents. Even in the simplest case of dyadic discourse with a single interlocutor, the arguer must simultaneously process the other's contribution and anticipate his or her own response to it and do so successively over what may become an extended sequence of turn-taking. Moreover, each contribution to the discourse disappears as soon as it is spoken. Any representation of previous contributions must be constructed and maintained by the arguer, posing a further cognitive burden.

This means that there are several processes taking place, simultaneously, during an argumentative discourse which make the whole process of argumentation not easy. Kuhn & Udell (2003) quoting the research results of a study done by Felton & Kuhn (2001), observe that young people involved in argumentative discourses "focused largely on the arguments supporting their own position, at the expense of addressing the arguments of their opponents" (p. 1246). In other words, the arguers failed to address the opponent's arguments through counterarguments. The authors go on to say that "deep-level processing of the opponent's argument, in addition to articulating one's own argument---- may represent cognitive overload for the novice arguer" (p.1247). This was certainly the case with this group of learners especially at the beginning of this study.

The learners in this study were able to articulate their knowledge claims or positions fairly easily almost right from the beginning. They, however, had problems, especially at the beginning of the intervention programme, with defending their knowledge claims with adequate and appropriate evidence. Sometimes the learners would produce both the claim ('*medicine from sangomas does not expire'*) and the data ('*the medicine is collected from the forest when it is needed')* but fail to connect the two statements with an appropriate word such as '*because'*. These observations are supported by literature. Learners have difficulties in articulating and defending their knowledge claims (Sadler, 2004). They may fail to justify their claims even when presented with data sets (Newton, Driver & Osborne, 1999); fail to select appropriate data to use as evidence (McNeill & Krajcik, 2007 in Berland & McNeill, 2010); fail to link or coordinate the claim and the evidence (Kuhn, 1991); fail to use appropriate evidence (Sandoval, 2003); fail to provide sufficient evidence (Sandoval & Milliwood, 2005); fail to justify why they choose certain evidence and not the other to support their claims (Bell & Linn, 2000; McNeill, Lizotte, Krajcik & Marx, 2006 in Berland & McNeill, 2010).

I had feared, having been informed by the literature, that the learners would not embrace argumentation with authority in a classroom situation when their upbringing taught them not to question elders and those in authority. Ogunniyi and Hewson, (2008) posit that generally, adults in this part of the world (Southern Africa) normally expect children to be seen and not heard, and obedience is usually manifested in unquestioning acceptance of the views of elders and superiors, and especially of teachers. Elsewhere in this thesis, I mentioned that these learners were now demanding, from their colleagues and me, evidence for knowledge claims that we made. They would shout: 'Where is your evidence?' In other words, my experience with the learners who took part in this study is that if the researcher allows genuine discussions and shows sincere interest in the ideas coming from the research participants, the research participants open up and begin to engage in meaningful discourses with anybody, including with those in authority. Also, it is important to allow the research participants to discuss on their own, without too much or unnecessary interference from the researcher because "argumentation appeared to be more productive in the absence of the teacher with teacher presence (not necessarily intervention) having an inhibiting effect" (Naylor, Keogh & Downing, 2007, p. 37).

The learners involved in this study had problems in expressing themselves in English especially where scientific concepts were being discussed. They were given a lot of opportunities to talk, read and write in English. Very little emphasis was placed on the grammatical correctness of the sentences that they constructed. This gave the learners confidence to say what they wanted to say, even if their English was not really up to scratch. The groups were also allowed to use Xhosa wherever they felt they could express themselves better in that language. All this was done because of the centrality of language in argumentative discourses and in (science) knowledge construction as revealed by literature. Constructivists view learning as a process of knowledge construction through cognitive processes such as thinking (Erduran & Jim'enez-Aleixandre, 2008). The authors go on to say that cognitive processes are internal and are made public through language. This means that people will be able to know what is going on in the mind of the learner only when that learner expresses it in some form such as language. Clearly, if the learner is limited in terms of understanding the language of instruction or of the discipline or has difficulties in expressing his/her thoughts through language, the language becomes a barrier to their construction of scientific knowledge.

The results of this study show that only one learner (7% of the learner population) felt that he was more confused at the end of the programme than he had been at the beginning of the programme because he now did not know which thought system to follow. The dilemma expressed by this learner is quite understandable because it is not easy to negotiate and accommodate two contrasting worldviews. I had feared that the presentation of these two worldviews at the same time would confuse rather than illuminate the nature of lightning. Literature had warned me of that possibility. The presentation of plural explanatory theories confuses the students or that it leads to the development or strengthening of a belief in a scientifically incorrect idea (Osborne, Erduran & Simon, 2004). This is explicable because the general belief is that a science teacher should present a carefully crafted and persuasive and non-debatable argument for the scientific worldview (Osborne, 2001 in Osborne, Erduran & Simon, 2004). Presenting alternatives to the scientific explanation would naturally cause confusion. I was pleased that this did not seem to be the case for the majority of the learners that I worked with.

Developing the skill and ability to argue effectively is a long process – something that comes about only with recurrent opportunities to engage in argumentation across the curriculum and not just in a few science lessons (Osborne, Erduran & Simon, 2004). Because of the soundness of Osborne's et al. (2004) observation, I was not very sure the sort of impact the intervention programme would have on the learners given the limited time we had for the study. In our study, learners were involved in two hour debating and activity based sessions three times a week for four months. This means that the learners went through nearly one hundred hours of the intervention programme.

As has already been indicated earlier, the results of the study show significant gains in the art of arguing and in the level of understanding the two knowledge systems and the nature of lightning. It is my belief that if this instructional tool is used in all science lessons and in other subjects on the curriculum, more positive results would be realised. It may also be interesting to compare these results with the results from other studies. In their study, Zoller et al. (2000, 2002) in Osborne, Erduran & Simon (2004) found that one semester was too short a period to develop high order cognitive thinking and that a systematic longitudinal persistence is necessary to achieve significant outcomes. Zohar & Nemet (2002), however, claim that they found significant improvement after a relatively short intervention period on argumentation.

There was a lot of enthusiasm amongst the learners when we were discussing everyday topics such as whether learners should put on uniforms or not and socio-scientific issues such euthanasia. That enthusiasm was much less when we were discussing scientific concepts such as the causes of lightning. Literature collaborates this when it says that supporting and developing argumentation in a scientific context is significantly more difficult than enabling argumentation in a socio-scientific context (Osborne, Erduran & Simon, 2004). To minimise this challenge, we started by debating the everyday/common topics moving on to debating socio-scientific issues before discussing static electricity and lightning. This way it was hoped that by the time we came to debating scientific issues the learners would have become familiar with the argumentative discourse. Indeed, this approach seemed to have ameliorated the problem.

4.5 The benefits accrued when using argumentation to integrate contrasting worldviews on lightning.

Despite the identified challenges, this study is of the opinion that there are benefits that were accrued by integrating explanations of natural phenomena coming from apparently dissimilar thought systems. In this section benefits exhibited by this study will be discussed and compared to what literature says. Some of these benefits can really be seen as indicators of the impact of the intervention programme on the learners.

In my interactions with the elders in the community I worked in, I found, as Kawagley et al. (1998) discovered among the Yupiag natives in Alaska, Canada, that many elders want their young people to learn the traditional knowledge and skills that enabled their ancestors to survive for thousands of years, not just because it is part of their heritage but because that knowledge is still relevant to the life in the village today. The elders also want their young people to learn the scientific knowledge and skills of the world outside the village because that knowledge is also relevant to the lives of their children. Their message is clear: ‘Teach our children both worldviews’. Indeed, this realisation was one of the reasons why the Chief of the community and the community leaders allowed me to do this research in their area and with their children. To them, not only was I teaching their children the much needed science, I was also reviving their culture, thus killing two birds with one stone.

As has been said before, this group of learners demonstrated an impressive gamut of indigenous knowledge even before the intervention programme. In other words, these learners brought their own worldviews to the classroom. It would seem that how far and how much the learners would gain at school would be influenced, to a large extent, by the level of acknowledgement and use of these worldviews in the classroom and that any education system that is hostile to or unappreciative of the learners' worldviews is likely to alienate them.

Bang & Medin (2010) reject the assumption that the epistemologies that students come to school with, from their cultural experiences, are inferior or less productive compared with the one(s) the teachers (of science in our case) are trying to assist students in learning. The authors also reject the claims made by other authors (King & Kitchener, 1995; Srike & Posner, 1995 in Bang & Medin, 2010) that successful science education will require students to replace the personal, cultural based epistemologies they bring with them with an epistemology that is aligned with Western scientific epistemology. Instead they argue that recognising the significance of Native epistemologies may remove some of the problems with student navigation of ethnic and academic identities and put the students in the position of successful border crossing.

All the above revelations point at the importance and necessity of integrating school science and indigenous knowledge in the school curriculum.

Argumentation was central in this study. Learners had to support whatever they said with evidence and to supply evidence to support or refute other learners' points of view. It is therefore reasonable to attribute any benefits accrued by the learners in this study to the process of argumentation. Some of these benefits have already been discussed. Below are a few others.

A key goal of science education is to help learners seek evidence and reasons for their ideas and knowledge claims as this is thought to be important in helping them to refine their image of science, construct deeper meaning of the content knowledge (Driver et al. 2000). Argumentation shifts the focus of science learning from one of rote learning, memorisation, and regurgitation of facts to one of constructing and justifying knowledge claims as individuals move between presenting their own understanding of an issue, evaluating other people's understanding of the same issue and refining their own understanding of that issue in light of their discussions with others (Duschl, Schweingmber & Shouse, 2007 in Berland & McNeill, 2010).

This was clearly demonstrated when the learners were discussing the results of their experiments and activities on static electricity. Through argumentation, the learners were able to come up with scientific knowledge on static electricity, clear their original misconceptions and change their perceptions about static electricity and lightning. It is through dialogue that ideas are explored and generated (Billig, 1987). Billig believes that argumentation serves as a defence against orthodoxy. Without argumentation and the provision of evidence it would be very difficult , if not impossible, to convince a critic or sceptic that 'the Earth is a sphere and not flat' or that 'day and night are caused by a spinning Earth and not a moving Sun' (when everyday observations point to the contrary) or that 'a plastic ruler gains electrons from woollen pieces of cloth when the two are rubbed together but loses electrons when rubbed with a nylon piece of cloth' (when these electrons are invisible). It is no longer enough 'to know science' or to know any subject for that matter. "the focus should be on *how we know* what we know, and *why we believe* the beliefs of science to be superior or more fruitful than competing viewpoints" (Duschl & Osborne, 2002, p. 43) (italics in the original).

This study does not support the notion that Western science is superior to other viewpoints but accepts Duschl & Osborne's (2002) view that "a discourse of science requires the consideration of plural accounts of phenomena" (p. 42-43) where members of the dialoguing community are seen, treated and behave as equals and where they are "encouraged to question, to justify, and to evaluate their own, and others' reasoning" (p. 43). Also, as the students interact with each other, they quickly learn that a science class is a place for collaborative knowledge building with evidence and that this is much better than individual knowledge (Berland & McNeill, 2010). Interactive classroom arguments and dialogues can help learners and teachers to clear their doubts, acquire new attitudes and reasoning skills, gain new insights, make informed decisions and change their perceptions (Ebenezer, 1996; Erduran, 2006; Ogunniyi, 2007a).

In an effort to find out the feelings of the learners on the impact of the intervention programme, a questionnaire was designed to ask them to reflect on the entire programme. This questionnaire allowed the learners to express what they thought they had gained or learnt, if anything, from the programme. *(See Appendix 13).* The following are the results and interpretation of those results.

The learners' views on the impact of the argumentation-based intervention programme

The learners' overall assessment of the impact of the intervention programme is summarised in the following table.

Table 4.15: Learners' views about the argumentation-based instructional programme

Question/statement	**SA(%)**	**A (%)**	**D (%)**	**SD (%)**
Programme helped me	14	86	0	0
Programme did not help me	0	0	36	64
Programme confused me further	0	7	50	43
Programme allowed me to express my views	36	57	7	0
My opinion was listened to and valued	8	85	8	0
The sessions were lively, interesting and educative	50	50	0	0
I learned a great deal	23	77	0	0
Programme on argumentation will help me in life	38	46	15	0
Programme was worthwhile	14	71	14	0
Programme was a waste of my time	0	0	57	43

N = 16

The statistics in the table above show that the majority of the learners thought very highly of the intervention programme.

Learners were asked if they thought that indigenous knowledge should be taught in the schools. They were challenged to support their decisions with reasons. This question was also an indirect way of finding out if the learners had enjoyed our sessions on indigenous knowledge systems.

An overwhelming majority of the learners (92%) agreed that indigenous knowledge ought to be taught in schools. The reasons given by the learners for the inclusion of indigenous knowledge in the school curriculum include: '*because learners have forgotten about their culture and values'* (13); *'some of us are willing to know it'* (7); *'we want more learning'* (1); '*we want to be current about all these things'* (10); '*to help children understand indigenous knowledge'* (8); '*it is something we come across with every day and we must know about it'* (9); '*there are many things we could learn from indigenous'* (4). (the numbers in brackets indicate learner identity). The single learner who thought that indigenous knowledge should not be taught in schools felt that *'teachers may not know indigenous knowledge.'* By extension, this learner is saying that indigenous knowledge needs to be handled by experts in that field.

The reasons given by the learners for the inclusion of indigenous knowledge in the school curriculum could be summarised as: to revive their cultural heritage which is threatened with extinction as a result of colonisation and globalisation *('learners have forgotten about their culture and values');* for the sake of knowledge *('we want more learning');* and that it is relevant in the lives of the learners. *('it is something we come across with every day').* I find all these to be legitimate reasons for including indigenous knowledge in the school curriculum. I also found the reason for not including indigenous knowledge in the curriculum (*'teachers may not know indigenous knowledge')* to be very valid indeed. If indigenous knowledge is to be in cooperated into the school system and if it is to be taught effectively, then we will need teachers who have the necessary desire and expertise to do it, otherwise a shoddy job will be done. As Ingersoll (1999) puts it: it is a fairly well known, established and accepted fact that for teachers to be effective, they must have strong and appropriate formal training in the field in which they teach.

It was very gratifying that 93% of the learners did not find the programme confusing. This finding is very important for this research where two contrasting worldviews were presented at the same time. I had feared that this could easily lead to some confusion. Indeed the learner (8) who felt that the programme had confused him said '*Its because I don't know what I would follow.'* This reflects a very serious but understandable dilemma. The learner finds it difficult to choose between scientific and indigenous knowledge explanations of natural phenomena. Such learners can perhaps be placed under CAT's equipollent category where two competing thought systems co-exist and exert equal cognitive force on a person's beliefs. This learner could still have cognitive dissonance in his mind which makes it not quite equipollent. Practically, this learner is likely to borrow from either worldview when confronted with a dilemma that requires an explanation.

The 84% of the learners who felt that the programme on argumentation would help them in life could have been referring to the social and socio-scientific issues that they had debated which they had found very relevant in their daily lives.

4.6 Conclusion

The chapter has presented the collected data in the form of verbatim narratives from the learners showing their skills and knowledge before and after the argumentation-based instructional intervention programme. Tables were used to summarise the learners' individual and collective responses to questions on the activities that they did and on the questionnaires they completed. These narratives and tables were presented according to the research questions that the study wanted to address. Both quantitative and qualitative indicators in the form of frequencies, percentages and t test values and in the form of recurring themes and patterns were used to interpret the presented data. The chapter also tried to attach meaning to these results by relating them to the research questions and the related literature.

The next chapter summarises these research findings and expounds on the lessons learnt by both the learners and the researcher during the course of this study.

CHAPTER FIVE

SUMMARY, IMPLICATIONS AND REFLECTIONS

5.0 Introduction

This chapter highlights the major findings of this study as revealed in chapter 4. The implications of the findings for curriculum development and implementation and for future research will be discussed. The chapter also describes the major experiences that my learners and I had through this study.

5.1 Summary of major findings

The basic premise of this study was that when a learner is confronted with two contradictory explanations of the same phenomenon, there is cognitive dissonance in the learner as the learner tries to determine which of the two explanations is correct. An argumentation-based instructional intervention programme was created for and used on and by the Grade 10 learners in order to attempt to ameliorate this cognitive conflict. It would be preposterous to claim that the intervention programme helped the learners to determine the more correct explanation of lightning. It must also be mentioned that this was really never the purpose of the study. The purpose of the study was to assess the impact of the intervention programme on learners' ability to deal with contradictory explanations of natural phenomena coming from different worldviews.

To a large extent the intervention programme seemed to succeed in making the learners to doubt and question the often taken-for-granted and accepted scientific explanations of lightning as they came to realise that these scientific explanations were at best inadequate and at times difficult to accept. The learners began to appreciate that there must be other explanations of lightning outside the scientific worldview which should be used in conjunction with or in place of the scientific explanations in order to get a full and satisfactory explanation of this awesome natural phenomenon.

Specifically, the study sought to determine the possible effect of this intervention programme on Grade 10 learners' conceptions of the nature of lightning and thunder. The research wanted to find out the relative impact of the programme on the learners' ability to argue effectively; their level of understanding of the major tenets of the nature of science and IK and the nature of lightning and thunder; their ability to use the learned argumentation skills to negotiate, integrate and harmonise different explanations of the nature of lightning and thunder that originate from different worldviews. The study also highlighted the challenges encountered and benefits accrued while using argumentation to integrate contrasting explanations of natural phenomena coming from different thought systems. The major findings of the study will now be presented research question by research question.

5.1.1 Learners' level of argumentation

The ability of the majority of the learners to argue improved significantly as they went through many discursive situations and as the study progressed. They transformed from quarrelling to debating; from offering knowledge claims with no evidence or from giving inadequate and/or inappropriate evidence to support or refute a knowledge claim to stating clear claims that were accompanied by relevant and sufficient evidence; from being preoccupied with their own ideas and not listening to or being interested in what the other people were saying to responding to and even challenging the opponent's argument; from being egocentric to collaborating with group members to come up with a strong position in an argument; and from being adamant to revising and shifting from their original positions or claims in light of available and compelling evidence. There was clear evidence of progression from poor to improved and satisfactory argumentation skills. The above progression is in line with Kuhn's (2010) assertion that argumentation skills, just like conceptual knowledge, have their own learning progressions. I speculate that the variety and scope of the argumentation sessions coupled with scaffolding and prompting and the freedom of expression of ideas that characterised these sessions could have facilitated the progression in argumentation skills that we observed in the learners.

5.1.2 Learners' understanding of the major tenets of the two worldviews.

Most of the learners developed a deeper, wider and clearer understanding of the major tenets of both science and indigenous knowledge and appreciated the importance and complimentary roles of these worldviews in their everyday lives. The learners now appreciated the tentative and uncertain nature of science and the fact that it, at times, relies on non-scientific methodologies. The learners were convinced that science was not the panacea of humankind problems. In fact, science has failed to eradicate or may even have caused some of the ills bothering humankind today. The learners no longer saw indigenous knowledge as just a belief system which was not useful for today's modern life. They accepted that both thought systems were legitimate ways of knowing and explaining the natural world we live in. This was in sharp contrast to the learners' earlier or original positions where they hero worshipped science and belittled indigenous knowledge. It must, however, be remembered that this intervention programme was not about substituting one worldview (Western science) with another (indigenous knowledge) but rather that the two thought systems be used in science classrooms.

5.1.3 *Learners' level of understanding of the causes, dangers and prevention of lightning*

The majority of the learners were able to construct the major concepts related to the nature of lightning and to correct misconceptions that they had before the programme. The majority of the learners now seemed to accept that the nature of lightning was so complex that it could have more than one possible explanation and that these explanations could come from both the science worldview and the indigenous knowledge worldview. In other words, the majority of the learners now appeared to accept that both science and indigenous knowledge can offer legitimate explanations of the nature of lightning. This was a huge departure from their original position before the intervention programme where the learners did not think that indigenous knowledge explanations of lightning were valid and useful.

5.1.4 Challenges encountered when using argumentation to integrate contrasting worldviews.

Teaching integration through argumentation requires carefully chosen teaching-learning-support materials. Such materials are not yet available on the market. Using suggestions from literature, I had to create the materials that I used with my research participants. I borrowed the advice of using stories to teach the idea of possible causes of lightning from the materials that SIKSP was producing for teachers in the Western Cape of South Africa.

Getting the cooperation of the local communities, who are the custodians of indigenous knowledge, was not easy. A lot of indigenous knowledge has been misappropriated, abused and commercialised by people masquerading as researchers. Naturally, people would want to protect their knowledge and resources from such unscrupulous people. I had to convince the Chief of the community and the community leaders of the importance of the research before I could be allowed to access indigenous knowledge from the community indigenous knowledge holders.

The following challenges related to the learners themselves were encountered. Initially the learners' conception of an argument was that it was a quarrel in which one team had to win. It took time to wean them from this mind-set and to make them appreciate the collaborative nature and function of argumentation. Again initially, learners found it difficult to find and articulate appropriate and adequate evidence to support or refute a knowledge claim. Some of the learners had language difficulties resulting in them struggling to express their knowledge claims and evidence. Initially learners had a negative attitude towards indigenous knowledge. They did not think much of it. To them indigenous knowledge was neither relevant nor useful to modern life.

The following table illustrates some of the challenges related to the learners' mind-set.

Table 5.1: Some challenges associated with DAI

Existing mind-set	Desired mind-set	The gap
Knowledge comes from those in authority such as books and teachers.	Knowledge is co-constructed by the learners as they interact with each other under the guidance of their teacher.	The learners would expect answers from the teacher when asked a question. Learners would feel that they were not 'qualified' to make meaningful contributions during lessons.
Knowledge claims are either right or wrong. The dichotomy of knowledge.	Knowledge claims are debatable. There is need to support or refute knowledge claims with evidence.	At the end of the debate, learners would expect a definite position. They would be uncomfortable with issues that are not 'resolved' or left loose.

Exposure to many argumentation-based activities and the valuing of learners' contributions during debate demonstrated by other learners and by the teacher helped the learners to change their mind-sets.

Related to the first gap in the table was the following observation: I also sensed that some of the learners would be reluctant to say something for fear of making grammatical errors or of saying something that would not be accepted by others. They were very conscious of what the other learners or the teacher would say about what they would have said and how they would have said it. (This fear of making errors in front of other learners was witnessed in the other lessons that I taught at this school and not just in our debating sessions). It was emphasised to the learners that as human beings we all make errors and that we learn from, and not laugh about, those errors and that even in the statements with those errors, it was usually possible to learn something useful.

These are genuine challenges which were exhibited by the learners at the beginning of the intervention programme but became less and less as the learners got involved in many discursive situations.

There was always the possibility of confusing the learners further by presenting contrasting worldviews to them at the same time. Fortunately, only one learner expressed this understandable confusion at the end of the intervention programme.

5.1.5 Benefits that seemed to accrue as a result of using argumentation to integrate contrasting worldviews.

The learners were quite enthusiastic during the debating sessions. Sometimes they were so engrossed in the discussion that we did not notice the passage of time. Sometimes it became difficult and unfair to stop them. They simply wanted to go on with their discussions. I cannot think of a teaching method that I have used that generated as much interest in learners as these discussions.

The learners were thrilled when they realised that what they knew before, from their communities, which they had thought to be of no value to their school work, was now being valued and used in their science lessons. Suddenly their home knowledge assumed a dignified status. The metamorphosis that seemed to have occurred in the learners in terms of their skill of argumentation, their knowledge base of science and of the nature of lightning and their ability to change and shift their original positions, their thinking and their knowledge claims could only have happened because of the use of argumentation. I am not sure if any other method could achieve these remarkable outcomes in such a short period of time of four months only. As Erduran & Jime'nez-Aleixandre (2008, p. 12) observe, argumentation "helps students learn things that are hard to learn except through argumentation."

The by-products of this study which these learners will use in their everyday life include: how to argue effectively and not quarrel; the importance of team work, team spirit, collaboration; the importance of valuing other people's views even where these are different from one's own; the importance of changing one's views in light of clear compelling evidence. It is hoped that this intervention programme was a genesis of the growth or production, out of these learners, of a citizen who is critical of his/her and of other people's actions and ideas and not a blind follower of the crowd; a citizen who is sensitive and appreciative of and receptive to good ideas from others.

Many months after our last argumentation-based discussion session, I still hear the learners shouting to each other: "Where is your evidence"? It seems that the learners will cherish these memories for a long time to come. If this is so, and there is no reason to think that this is not so, then every learner must be afforded the opportunity to go through this amazing experience. One also hopes that the learners will be able to use the knowledge and skills they learnt in these sessions in real life situations.

As a way of determining whether the learners thought they had benefitted from this programme, the learners were asked, at the end of the intervention programme, a number of questions.

For example, the learners were asked if they thought that indigenous knowledge should be taught in the schools. An overwhelming majority of the learners (92%) agreed that indigenous knowledge ought to be taught in schools. Clearly this majority must have enjoyed our sessions on indigenous knowledge and perhaps more so because of the input of the community knowledge holder.

From an academic point of view, an inclusion of indigenous knowledge on the school curriculum would place indigenous knowledge on a right footing in the academia where it would be allowed to compete with other knowledge systems for academic space (Dei, 2000 in Siseho, 2009 and Kuhn, 1970).

5.2 Implications of major findings

The research findings of this study seem to point at some positive results of an argumentation-based instructional model of teaching but also raise some questions that require further investigation. This sub-section highlights the implications of these research results in terms of curriculum planning and implementation and in terms of further research.

5.2.1 Implications for curriculum development and instructional practices

The research results suggest that an argumentation-based instructional model of teaching can help the learners to:

- Develop effective argumentation skills which they could use in learning concepts in science and perhaps in other subject areas and in life in general.
- Develop a deeper and broadened understanding of a scientific concept.
- Develop skills to negotiate and harmonise contrasting explanations of a natural phenomenon coming from different worldviews.

The research results also seem to indicate that the learners who come to the schools already have an impressive repertoire of indigenous knowledge that the school cannot or should not ignore because such home knowledge affects the learning of the students.

If this is so, then, there are a number of implications for policy, curriculum development and instructional practices.

To a very large extent, this study was an attempt to determine the relative impact of implementing the South African government policy of integrating science and indigenous knowledge and the use of argumentation in the classroom as espoused by the Department of Education in *Learning Outcome 3 Assessment Standard 1* of Physical Sciences at FET level which reads in part '*to evaluate knowledge claims: recognise, discuss and compare the scientific value of knowledge claims in indigenous knowledge systems and explain the acceptance of different claims.*'

The results of this study have shown that, even after a relatively short period of exposure to integration and argumentation, learners can navigate, negotiate and harmonise apparently discordant explanations about natural phenomena that they receive from different worldviews and that in that process, their understanding of the natural phenomenon is enhanced. From this observation, one comes to the conclusion that if this policy was implemented in all science lessons and in all learning areas, the results would be phenomenal and extraordinary. In a nutshell, this study recommends the full implementation, in the schools, of the policy of integration through argumentation.

My experience during this study is that it is not easy to implement the policy. To begin with, one needs the cooperation of the community knowledge holders in order to get authentic indigenous knowledge to work with and use in one's lessons and in order to ask for the knowledge holders' input in one's lessons. As was shown earlier on in subsection 5.1.4 above, that cooperation is not easy to get. I had to go through the community Chief to access the community knowledge holders and their knowledge.

Secondly, to implement the policy one needs expertise. One must know IK and science, how to integrate science and IK, and how to plan and use DAI lessons. Do the teachers have the prerequisite expertise? To what extent are pre-service and in-service teacher education courses supportive and informative of IKS, IK-science integration, and strategies that could be used to integrate the two systems? (Our school got B.ED students specialising in science from a local university from 2009 to 2012. These students did not seem conversant with learning outcomes and assessment standards, let alone learning outcome 3). To what extent do the teachers in the schools receive mentoring, monitoring, supervision, and guidance on the integration of the two systems? Are there practical suggestions from the Department of Education in South Africa on how the two systems could be integrated? How familiar are teachers and their supervisors with instructional methods such as argumentation?

The teachers were/are schooled in Western science and hence are more familiar with that worldview than with IKS. Most of these teachers were/are taught that science is superior to indigenous knowledge or that indigenous knowledge is of no value to modern life. Such teachers would need a complete new mind-set, a complete paradigm shift. To me, this is probably one of the most difficult adjustments that would be required in the Department of Education. We all know how difficult it is for people to change especially if the change requires a re-examination of one's belief system and/or requires the acquisition of new skills and means more work.

Are teachers committed to IKS? Do the teachers subscribe to it? Many people, even some indigenous people, view indigenous knowledge in the negative. This was certainly the view of the learners who were involved in this study at the beginning of the intervention programme.

There is a lot of literature that seems to suggest that, for various reasons, teachers find it difficult to integrate the two systems (Nichol & Robinson, 2000; Ogawa, 1995; Ogunniyi, 2006, 2007a). In addition, it is a fairly well known, established and accepted fact that for teachers to be effective they must have strong academic skills (Ehrenberg & Brewer, 1994), appropriate formal training in the field in which they teach (Ingersoll, 1999), and several years of teaching experience (Murname & Phillips, 1981). Do the teachers in question have these qualities?

If the answer to any of these questions is in the negative, then the Department of Education would have to invest heavily to produce the required personnel with the requisite expertise to implement the policy or to monitor and help those who are trying to implement the policy. The work of SIKSP at UWC of training teachers to implement a science-IK curriculum in the South African schools is commendable. This initiative should help overcome some of the challenges raised above but it needs to be done on a wider scale and not just in the Western Cape Province.

One needs books to refer to and materials to use with the learners. All these are not easily available. Holtman (2008, p.2) talking about '*Indigenous knowledge systems and education: The South African perspective*' laments that

> The core facilitators and implementers of this curriculum, the teachers, are now in a position where they have to teach and facilitate IKS with very little material having been developed to support the teachers.

This then calls for one to be extremely creative. One must always read and think in order to produce materials that can be used in the lessons. It requires a lot of time and ingenuity. This is not easy. The Department would have to invest heavily in the production of the much needed resources. The School of Mathematics and Science Education at the University of the Western Cape, South Africa, through the Science and Indigenous Knowledge Systems Project (SIKSP) is producing teaching and learning materials that can be used to integrate science and indigenous knowledge in science lessons in schools. While these materials should go a long way in minimising the challenge of relevant materials, the project needs the support and involvement of the entire range of relevant stakeholders, especially other institutions of higher learning who are training teachers and the Department of Science and Technology.

Are today's learners knowledgeable of IKS? How can teachers ascertain the authenticity and accuracy of the IKS brought to class by the learners? This study found that, despite the many years of contact with Western Education and Western science, and despite their young age, the learners involved in this study had a very remarkable repertoire of indigenous knowledge which resonated with the knowledge that I got from the community knowledge holders. The big question, however, is: Are today's learners committed to IKS? Any negative attitudes towards IK must be overcome first before meaningful integration can take place. The problem that the learners seemed to have was that, initially at least, they did not think much of the indigenous knowledge that they had. They looked down upon that knowledge. To them, indigenous knowledge was just a belief system for the rural poor people that is of no value in today's modern life. Fortunately, as a result of this intervention programme, the learners began to appreciate the value of indigenous knowledge even in today's technology driven life.

There are other constraints such as the learners' problems with language and the fact that they may not be used to argumentation and may confuse argumentation with quarrelling. These are genuine concerns but my experience during this study is that the learners are very receptive and accommodative of new ideas and of new ways of doing things. When the learners were given the opportunity to freely discuss issues and when I supported their efforts through scaffolding and prompting, they were ready to 'go'. The learners were very quick in assuming their new roles of knowledge producers from their usual role of knowledge consumers. My worry about the implementation of this policy is not about the learners, it is about the teachers and the Department of Education.

To what extent is the government of South Africa committed to the integration of IK and science? In 2004, the Department of Science and Technology in South Africa produced the *Indigenous Knowledge Systems Policy*. This policy document is very informative and should be useful in guiding the nation towards "the recognition, promotion, development, protection and affirmation of IKS" (p. 8). I, however, have my own misgivings. Is the policy document on integration clear and informative to the user system and to those who should monitor the system? What support systems did the government put in place to ensure success of the integration right at the beginning of the programme? These questions are pertinent because science and technology is increasingly being looked at as a way of enabling developing nations such as South Africa, to benefit from globalisation. Brown-Acquaye (2001) agrees with this sentiment when he contends that

> Presently, in most developing countries, science and technology are seriously considered as agents of development. Governments in the developing countries are faced with the Herculean task of eradicating disease, poverty, and hunger, and believe that their salvation depends on science and technology- and what science and technology, apart from the time-tested Western modern science (WMS), is up to this task? (p. 68).

Brown- Acquaye (2001, p. 69) continues to state that

> The dilemma of African governments (and I think this also at times applies to governments in most developing countries) is whether to employ tested, proved-to-be-effective WMS for the task of eradicating the poverty, disease, hunger, etc., or to rely on indigenous knowledge and technology whose results are left to chance.

To yet other people, including IK into the school curriculum is “retrogressive considering the present pace of global scientific and technological advancement” (Ogunsola-Bandele, 2009, p.54). Ogunniyi (2011) adds to this challenge by stating that there are gatekeepers of knowledge (people who have given themselves the task of determining what is and what is not legitimate knowledge) who oppose the inclusion of indigenous knowledge as a legitimate system of knowledge because they think that doing so is retrogressive and totally unwarranted in this day and age of globalisation and technological advancement.

Building capacity in science and technology becomes a priority (Rhea, 2002). In such a scenario, IKS would be pushed to the back seat again.

Ogunniyi (2007a, p. 2) identifies other challenges as follows:

New curricula demand new skills. In this case, argumentation and contextualisation in science discourses become important as compared to the teacher’s familiar mastery of science concepts. Educators may feel threatened by the new curriculum and choose to ignore it or pay lip service to it or they may fail to meet its demands. My experience with DAI is that it requires a lot of preparation (e.g. putting in place, often from scratch, materials which would teach the learners both the argumentative skills and the science concepts and skills important for their examinations). It also requires a lot of concentration so that one can capture, accurately, as much of what happens and is said during the debating sessions as possible. This is essential because such information would then be used later, with the class, to polish up their argumentative skills and sharpen and deepen their understanding of science concepts. This is not easy.

How feasible is the inclusion of indigenous knowledge into an examination-driven curriculum as that which we find in South Africa? For this study, I spent about 100 hours with the learners and the only science concept that the learners learnt which is important for their examination was “static electricity and lightning’. At this rate, the teacher would fail to cover enough content needed by the learners for their examinations.

Teachers generally resent curricula that are imposed from above. South Africa used the top - bottom approach to introduce the NCS and CAPS. Such curricula usually suffer ‘tissue rejection’.

5.2.2 Implications for future studies

In a way, this study opened a Pandora box in that it raised a number of questions that remain unanswered. These questions include the following:

- In this study, one of the major objectives was to find out if argumentation could help in the negotiation and harmonisation of two contrasting worldviews. The answer seems to have been in the affirmative. This research also used socio-scientific issues for discussion and found this to be very fruitful. Where else could argumentation be used and produce the same positive results? For example, could it be used in politics? or in religion? Or in everyday conversations? The reason why this question is being asked is because this researcher is of the opinion that most conflicts in the home, at places of work, in the country and elsewhere are because people cannot communicate and argue effectively.
- What potential does argumentation instruction have for learners' awareness, knowledge building and belief revision regarding diverse natural phenomena on which they hold erroneous or inadequate ideas?
- This research was centred in Science Education, would it have the same positive results if applied in to other learning areas in the curriculum?
- One of the assumptions underlying the study is that if the learners were exposed to an argumentation-based instructional programme in science lessons and perhaps lessons in other learning areas, the results would be positive. Is this really so? Or would the learners get bored by an excessive use of that method?
- How can a teacher use this method and still cover the requisite content for examination purposes?
- How could examination questions be structured in a way that learners are encouraged to argue and support their claims without feeling intimidated?
- In what specific ways could institutions of higher learning and the Department of Education incorporate argumentation skills in their training programmes?

5.3 Reflections on the study

During this study, the learners and I gained a lot of interesting and useful experiences some of which I would like to share with the reader. These include:

The challenges associated with the use of the dialogical argumentation instruction (DAI) have already been discussed in subsection 5.1.4 above. They will not be repeated here.

Concepts related to static electricity and lightning that the learners acquired

The learners learnt the usual concepts related to static electricity and its relationship with lightning. Such concepts include charging and discharging objects; the two types of charges and how they come about; the effect of charged objects on each other; the causes, dangers and prevention of lightning. The learners could have got most of this knowledge through the ordinary science instruction methodologies but they learnt much more as a result of the argumentation-based instructional intervention programme used. For example: They learnt to question the orthodox, often unquestioned and un-interrogated explanations of natural phenomena given by the scientific worldview; they learnt that there are other plausible explanations of these natural phenomena and that it was naive to think that natural phenomena would have simple and single explanations originating from one worldview; they learnt to appreciate and value the explanations and observations that they have experienced from their local community.

These science lessons, therefore, went beyond the usual, bookish science and incorporated the learners' home experiences, thus achieving many goals at the same time. One goal was knowledge construction and assimilation; the other goal was expansion and elaboration of that constructed knowledge; yet another goal was a shift in knowledge held by learners either from purely indigenous or from purely scientific to an embracement of both; the learners also began to have a positive self- concept in that they saw that the knowledge that they had before coming to school, which they may have thought to be useless/unimportant knowledge, was suddenly elevated to be equal or complimentary to scientific knowledge. This seems vital for a group of people, such as indigenous people, who can quite easily lose their identity and self-respect by aping other people's (Western) worldviews.

The role of opposition and counter argumentation in knowledge construction, skills development and conceptual change

Opposition, dispute or disagreement is used here to mean rejecting or undermining ideas advanced by self in solitary discourse or those advanced by others in social discourse. This study accepted Leitao's (2000) view that opposition is a phenomenon that occurs interpersonally (between people) and intrapersonally (within a person, in solitary discourse).

Opposition brings the truth of an advanced claim into question either by dismissing the claim through just denying or rejecting it or "by making a statement that potentially reverses what that claim comprises" (Leitao, 2000, p. 345 – 346). In argumentation, there could be counter-opposition which Leitao (2000) describes as an attempt by "the proponents to restore the strength of their original claims by making them more explicit and often by adding further justification and explanation" (p. 341). In other words, through opposition and counter opposition, arguers produce clearer and better sustained arguments.

Opposition and counter argumentation have both positive and negative effects on the people involved in it (Leitao, 2000). The positive impact of opposition, which we witnessed amongst many of the learners who took part in this study, was that the learners shifted their views about the meaning of argumentation (from argumentation as quarrelling and fighting to argumentation as a reasoned discourse); changed their views about science and indigenous knowledge (from hero worshipping science and demonising indigenous knowledge to accepting the two thought systems as different but legitimate ways of explaining the world around us); transformed and expanded their knowledge about lightning and thunder. Leitao (2000, p. 333) argues that "the experience of being opposed releases processes of belief reappraisal that enable people to move on from old (already existing) to new perspectives on a topic."

Bernas, 1999; Forman, et al. 1998; van Eemeren & Grootendorst, 1994 and van Rees, 1994 all in Leitao (2000, p. 337) agree with the above when they state that "the experience of being opposed to conflicting views in argumentation leads to transformation and significant restructuring in participants' understanding of a topic." In other words, opposition creates conditions for new perspectives on knowledge to emerge within the arguer. "People review their positions, and sometimes revise them, as a consequence of having contemplated opposition" Leitao, 2000, p. 354). Without opposition this conceptual change may not occur.
On the other hand, Leitao (2000) quoting Lord, Ross & Lepper, 1979 and Kuhn, 1991 feels that examining opposite sides of a question, may result in the polarisation of the two contrasting points of view. To me, this means that the learners who are exposed to opposition would become more opposed than before because their differences become deeply sharpened and entrenched because of the counterarguments from their opponents. I suppose that this is possible. However, I did not witness this in the group I worked with.

The role of joint thinking and collaboration in knowledge construction, skills development and conceptual change

The learners were taught to work together in their small groups and come up with an agreed position, a consensus which they would present to other groups and defend. This group of learners were able to, through collaborative work, build strong cases for argument and develop greater understanding of a concept. I also believe that this practice taught them valuable social skills such as listening to others, tolerance and acceptance of other people's views, the need to give and take (compromise), and the importance and value of team work in knowledge construction. Miller (1987) in Leitao (2000) posits that the people who are involved in argumentation must find, together as a team, an answer to the disputed question. To do this, the author suggests that the arguers must coordinate their contributions in a way that enables them to come up with a set of collectively valid statements accepted by all the participants in the discussion. They can only do this if they work together as a team.

In general, collaboration demonstrated the following benefits: helped learners in the construction of joint or shared understanding or meaning; challenged their own thoughts and those of others; clarified their thinking; helped to convince others; resolved differences; evaluated and revised their understanding of lightning.

Other lessons we learnt during this study were that:

- It is possible to help learners to appreciate and begin to understand explanations of natural phenomena coming from different worldviews if these learners are allowed to debate issues amongst themselves and to support their knowledge claims or refute other people's knowledge claims with reason or with evidence. Their encounter with controversial and debatable issues related to lightning and thunder, during their debating sessions, helped the learners to understand this natural (or is it supernatural?) phenomenon better.
- The results demonstrate important changes in the learners in terms of how they treated each other's views and use these views for their personal mental growth and development. The learners began to appreciate their opponent's ideas and used them to change their own original positions and knowledge claims. I believe that this skill should be very helpful to them in their lives during and well after their school days. This appreciation of other people's views was in sharp contrast to their original

egocentric tendencies to want to be heard and have only their ideas accepted by others.

- Through these debates the learners quickly realised that dogmatic statements do not convince audiences but arguments supported by appropriate and adequate evidence do. They were able to see the big difference between debating and quarrelling. The learners were made to realise that most of the conflicts in their homes and in the world today are a result of people failing to argue and communicate with each other effectively.
- If this is what was achieved after exposing the learners to only four months of an argumentation-based instructional intervention programme, one can only speculate on the impact of this methodology if it were used throughout the life of the learner at school in all science lessons and in other lessons.
- One also wonders the kind of results we could have obtained if indigenous research methodologies had been used given the assumption that there is more than one way to acquire knowledge (Smith, 2006 and Chilisa, 2012). Could the results have been more illuminating?

5.4 Conclusion

While some significant challenges were encountered and although some of these challenges remained unresolved, the results of the study seem to have shown and demonstrated a number of benefits of learning environments that allow and support learners' negotiation and navigation of different worldviews and epistemologies through argumentation. The results are encouraging in that they seem to show that the learners' skills in argumentation and their knowledge base on science, indigenous knowledge and the nature of lightning improved significantly as a result of this intervention programme.

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APPENDICES

APPENDIX 1: LETTER OF INVITATION TO JOIN RESEARCH TEAM

Dear colleague

In response to the emerging multi-cultural classrooms, the world over, the new South African curriculum requires educators to integrate school science with Indigenous Knowledge Systems (IKS). This is to make school science more relevant to learners than was the case with the old (apartheid) curriculum. The purpose of this study is to assist learners to integrate IKS with school science in their science lessons through an argumentation-based intervention programme.

I write to invite you to join my research team. I am a part-time student with the University of the Western Cape (UWC). There at UWC a national research project known as the Science and IKS Project (SIKSP) has trained several teams of educators on how to integrate IKS with school science. We want to do the same thing here in the Eastern Cape by using an argumentation-based instructional model similar to what SIKSP is using to enhance Grade 10 learners' understanding of natural phenomena. Our focus in this research is on lightning and the rainbow.

Background

Until the last decade of the last century, indigenous knowledge was side-lined, marginalised or even demonised by the West. The belief, which is purely Eurocentric, was that 'Western science' was the only legitimate and authentic way of knowing and explaining natural phenomena. Today, however, many people acknowledge that indigenous knowledge is a viable, legitimate and authentic way of knowing and explaining natural phenomena.

A call has therefore been made by many previously colonised nations to integrate science and IK in science lessons. In South Africa, Learning Outcome 3 in Physical Sciences reads in part: The Nature of Science and its relationships with Technology, Society and the Environment: The learner is expected to **identify and critically evaluate scientific knowledge claims; recognizing, discussing and comparing the scientific value of knowledge claims in indigenous knowledge systems and explain the acceptance of different claims.** Quite clearly the outcome is recommending integration of the two knowledge systems. But this implies bringing the two thought systems together in a dialogical argumentation and discursive classroom setting. In such a setting, learners can argue and express themselves freely without any intimidation. It is also in such a classroom setting that learners can talk freely about their cultural beliefs regarding various natural phenomena.

Odora-Hoppers (2002, p.16) contends that the two knowledge systems are "complimentary in their strengths and weaknesses, combined they can achieve what neither would". There is a lot of literature that points to the fact that there are a number of social and pedagogical benefits to the learners that accrue when the two worldviews are integrated in science lessons. For example, Ogunniyi (2004, p. 303) posits that "science education programmes that give a place to learners' indigenous knowledge systems are more likely to succeed …than those which cast aspersions and disdainful gaze at learners' traditional cultures".

Although various scholars have in recent years espoused the benefits of a discursive classroom in terms of providing learners the opportunity to express their views freely, clear their doubts and even change their views (e.g. Erduran et al, 2004; Simon, et al, 2006, Ogunniyi, 2007a & b) this approach of teaching is not a common feature of most classrooms in South Africa.

This study will design a teaching and learning programme on lightning (which forms part of the National Curriculum Statement content) during which views of both science and IK on lightning will be discussed using the argumentation instructional method. The argumentation instructional method is a method of teaching which trains learners to substantiate their knowledge claims with appropriate and adequate empirical and /or theoretical evidence. It is hoped that this study will:

- Show and convince the learners that their indigenous knowledge is important for their school science and that they have a rich heritage in that knowledge which they must be very proud of rather than being ashamed of.
- Improve the learners' understanding of lightning and thunder by combining knowledge from two worldviews.
- Help the learner to undertake a form of cognitive border crossing between indigenous knowledge and science and vice versa without being confused. In other words, the two thought systems are able co-exist in the mind of the learner which Ogunniyi (2007a) calls an equipollent mental state.

- Improve the learners' ability to debate, discuss, defend and argue not only issues about lightning and the rainbow but other issues such as abortion, sports and drugs, HIV and AIDS, euthanasia, genetic modified organisms, plastic surgery, etc.
- Convince other science educators in South Africa and elsewhere of the benefits to learners of integrating science and IK through argumentation.

The code of research ethics will be adhered to throughout the research and the research will be used for academic purposes only.

For this research I figure that I will need a research team made up of:

- A local person who is conversant with the local languages and the necessary protocols, a respectable person who can interact with community/traditional leaders and the knowledge holders with relative ease.
- A Xhosa language speaker and a teacher who is not only able to interpret what is said in Xhosa into English and vice versa, but who can unlock the 'hidden and subtle' meanings and ramifications of what is being said in the local language.
- A historian who will help by filling in gaps in the data collected and giving the data its historical importance/significance.
- Two Xhosa speaking science experts and teachers at FET level who will help in interpreting the learners' attempts to integrate, through argumentation, Western science and IKS on lightning and the rainbow. They will also examine the research instruments to ensure that these are valid and reliable.
- An expert in English who will help in identifying learners who will not be inhibited by their limited language skills and who will determine the appropriate language level to be used in the research instruments.

Your specific contributions will be explained to you once you have indicated your willingness to help by becoming part of the research team. I would want you to know that as a member of the research team, you are in partnership with me and therefore you should feel ownership of the research process.

I plan to do the actual field work from early 2011. For the rest of this year I will:

- Get permission to involve the learners in the research from the relevant authorities.

- Collect information on indigenous explanations on causes, dangers and prevention of lightning and the formation and significance of the rainbow.
- Put in place the **research team,** select and appoint the **research participants**, construct the **research instruments**.

Thank you, dear colleague, for your anticipated help in this research.

Yours sincerely,

Partson Virira Moyo

5 October 2010

APPENDIX 2: AN EXAMPLE OF THE LETTER WRITTEN TO SEEK PERMISSION FROM THE RELEVANT STAKEHOLDERS TO CARRY OUT THE RESEARCH

Gobizembe High School

P. O. Box, 240

ALICE

5700

6 September 2010

The Principal

Gobizembe High School

Dear Madam,

REQUEST FOR PERMISSION TO INVOLVE SOME GRADE 10 LEARNERS IN RESEARCH AT YOUR SCHOOL

I am a part-time student with the University of the Western Cape. I teach Natural Sciences and Physical Sciences at your school.

I am interested in investigating the relative impact of an argumentation-based instructional intervention on Grade 10 learners' conceptions of lightning and thunder.

Background

Until the last decade of the last century, indigenous knowledge was side lined, marginalised or even demonised by the West. The belief, which is purely Eurocentric, was that 'Western science' was the only legitimate and authentic way of knowing and explaining natural phenomena. Today, however, many people acknowledge that indigenous knowledge is a viable, legitimate and authentic way of knowing and explaining natural phenomena.

A call has therefore been made by many previously colonised nations to integrate science and IK in science lessons. In South Africa, Learning Outcome 3 in Physical Sciences reads in part: The Nature of Science and its relationships with Technology, Society and the Environment: The learner is expected to **identify and critically evaluate scientific knowledge claims; recognising, discussing and comparing the scientific value of knowledge claims in indigenous knowledge systems and explain the acceptance of different claims.** Quite clearly the outcome is recommending integration of the two knowledge systems and argumentation in science lessons.

Odora-Hoppers (2002, p.16) contends that the two knowledge systems are “complimentary in their strengths and weaknesses, combined they can achieve what neither would”. There is a lot of literature that points to the fact that there are a number of social and pedagogical benefits to the learners that accrue when the two world views are integrated in science lessons. For example, Ogunniyi (2004, p. 303) posits that “science education programmes that give a place to learners’ indigenous knowledge systems are more likely to succeed------ than those which cast aspersions and disdainful gaze at learners’ traditional cultures”.

I am planning to design a teaching and learning programme on lightning (which forms part of the National Curriculum Statement content) during which views of both science and IK on lightning will be discussed using the argumentation instructional method. The argumentation instructional method is a method of teaching which trains learners to substantiate their knowledge claims with appropriate and adequate empirical and/or theoretical evidence. It is hoped that this study will:

- Show and convince the learners that their indigenous knowledge is important for their school science and that they have a rich heritage in that knowledge which they must be very proud of rather than being ashamed of.
- Improve the learners’ understanding of lightning and thunder by combining knowledge from two worldviews.
- Help the learner to border cross from indigenous knowledge to science and vice versa without being confused so that the two thought systems can co-exist in the mind and the heart of the learner equipollently.
- Improve the learners’ ability to debate, discuss, defend and argue issues that arise in ordinary life where various views are possible, such as, abortion, sports and drugs, euthanasia, genetic modified organisms, plastic surgery.

- Convince other science educators in South Africa and elsewhere of the benefits to learners of integrating science and IK through argumentation.

The code of research ethics will be adhered to throughout the research and the research will be used for academic purposes only.

Request

I write to kindly ask you to allow me to involve a group of Grade 10 learners in this study.

If granted permission, the research will commence at the beginning of 2011 and will last for about three months. The learners' school programme and activities will **not** be interfered with.

Thank you, in advance, for your anticipated assistance in this matter.

Yours sincerely,

Partson Virira Moyo

Persal 54867614

APPENDIX 3: EXPLANATION OF THE RESEARCH PROCESS TO THE RESEARCH PARTICIPANTS

Dear research participant,

- I am a student doing some research work that needs your assistance.
- My area of interest are the explanations of natural phenomena such as lightning and thunder as given by both 'Western science' (the science taught at school) and indigenous knowledge systems (the knowledge possessed by local indigenous people).
- The topics I have chosen are part of the National Curriculum Statement and so while you take part in this research you will be learning concepts that are important for your school work.
- You will be involved in a number of activities, individually but mostly in groups.
- These activities will be done outside the school programme. This will ensure that you are not disadvantaged in terms of your school work. This, however, means that we will have to create time outside the school hours to do the research.
- While they will be no material (monetary) benefits for any of us, you will be supplied with food and drinks during the research sessions since you would not be expected to work long hours on empty stomachs. We will also organise an outing to celebrate the successful completion of the research process.

Thank you for agreeing to take part in this research. I hope you are going to enjoy the whole process as much as I will.

Yours sincerely,

Partson Virira Moyo.

APPENDIX 4: MODUS OPERANDI AND GROUND RULES

Dear research participant,

During the process of our interactions, we will be guided by some modus operandi.

A modus operandi spells out clearly how members of a group will work together.

As we work together, it is important to remember the following:

- Western science and indigenous knowledge systems will be taken as two viable systems of thought that attempt to explain and predict natural phenomena without one being seen as superior or inferior to the other.
- During the discussions: Everybody will be free to make their thoughts known to others without any fear of intimidation or ridicule from the other group members or the researcher. Where one member of the group differs in opinion with another member, the procedure will be to advance evidence against the opposed point of view. The same would apply to those who agree with a point of view: we would want to know why they agree with that point of view. The major question that we should always keep in mind and answer is: What is your evidence to support what you are saying or to refute another person's point of view?
- No answer, no matter from whom, will be treated as wrong or right but we will expect a reasonable explanation to support each answer.
- Make your contributions no matter how small you may think those contributions are. Remember that what you think is small could prove significant to the group and that many small ideas build up to become big and important ideas.
- When anyone of you raises a question, I will allow group members to respond to the question first because it is quite possible that the explanation given by one of your own could be more convincing than my own explanation.
- It is quite in order and legitimate to change your earlier way of thinking if you find the opposing argument to be stronger than your own argument. There is nothing shameful or belittling about this shift in position. In fact it will be taken as a sign of being reasonable and mature on your part.

- You will be expected to listen attentively and not to disrupt those that would be presenting their case. Each of you will be given a fair opportunity to put across their point of view. You will be expected and in fact required, to speak and to listen. Both processes (speaking and listening) are important in argumentation.
- All of us are equal in this exercise.
- If there are any issues or questions that arise during the course of our interactions that need to be attended to, we should be free to raise these issues or questions so that they can be resolved very quickly before these issues derail the whole research process.
- Always remember and accept that you now belong to and own this research process and that this research process belongs to you.

Thank you

Partson Virira Moyo

APPENDIX 5: LESSONS ON ARGUMENTATION

(See Lessons 1 & 2 under data collection procedures in chapter 3)

Lesson 1: Teaching argumentation through debates [TATD]

At the individual level, assume that you are debating an issue with someone, anticipate, attend to, and counter the opponent's argument.

Begin to debate the issue as an individual and debate the same topic with a peer and then as a group

Debate on common controversial issues [DOCCI

You will be divided into two groups for this task. One group will be asked to support the given statement while the other group will be asked to oppose the statement. In your preparation for debate at individual or group level, you should anticipate the arguments of your opponents and prepare counter arguments in advance. The emphasis is not to win the argument but to reach consensus on the basis of solid and justifiable evidence. There are no winners or losers in these debates. The debate will take place at three levels that Ogunniyi & Kwofie (2011) called individual brainstorming or self-conversation or "intra-dialogical argumentation" level, group or "inter-dialogical argumentation" level and whole class or "trans-dialogical argumentation" level.

The important thing is that you should support your arguments with evidence and that you should look for this evidence in books, newspapers, the internet etc.

For this activity, only the topics in bold will be discussed in class. You should use the rest of the topics for practice as individuals or in your groups.

1. ***Learners should wear uniform to school.***
2. The use of plastic materials should be banned in the country.
3. ***The rich and the poor should pay different rates for electricity.***
4. The death penalty should be introduced in South Africa.
5. Female drivers are more careful than male drivers.

6. Science is more difficult than History.
7. Boys perform better in Mathematics and in Science than girls.

8. A learner who is good at Mathematics is also good at Science .

9. Science and not indigenous knowledge tells us the truth about the natural world.

10. Indigenous knowledge is full of myths. (Indigenous knowledge is knowledge held or known by the local people. A myth is something that many people believe in but which is not true.)

11. Medicines made by sangomas are more powerful than those prescribed by medical doctors.

The following is an example of what was done during the debating sessions.

TOPIC FOR DEBATE 1

Group	**Topic for debate**	**Date**
• A • C	• Learners should wear uniform to school. • Learners should not wear uniform to school.	14.09.11 14.09.11
• B • D	• The rich and the poor should pay different rates for services such as electricity. • The rich and the poor must pay the same rates for services such as electricity.	14.09.11 14.09.11

ACTIVITIES

1. **Time line:**

1.1 On 12 September 2011

Group members debate the topic in their respective groups and come up with a group debate line which consists of what to say and how to convince the opposing group members. The group chooses their spokesperson.

1.2 On 14 September 2011

- The actual debate and then
- Group members reflect on what they said and on what the opposing group said during the debate. They identify their own weaknesses

in their arguments and the strong points in the opposing group's arguments. The group members prepare a better debate against their opponents.

1.3 On 16 September 2011

- The final debate. The final show down.
- During this final debate, groups could accept the arguments given by the opposing group if they found the arguments convincing.

2. **Preparing for the debating sessions.**

Session 1: Preparing for the debate.

The group members supporting a certain position in the argument explore, evaluate and organise arguments to support their position as well as to anticipate their opponents' responses and then work out possible counterarguments to the opponents' counterarguments.

Session 2: The actual debate.

This is the actual debate where emphasis shall be on the students' ability to address, directly, each of the opponents' claims and to weaken those claims with counterarguments. Social collaboration within members of the team in constructing responses to the opposition is highly valued at this level of the debate.

Session 3: Reviewing and reflecting on what happened during the actual debate.

For each of their arguments, the group members identify the opponents' counterarguments and their own comeback argument. They must now identify their strong and weak moves during session 2 and come up with better and more effective comeback arguments. They address the following questions:

a) What did the other team say which you found weak? How are you going to make maximum use of that weakness?
b) What did you say that the other team found weak? How are you going to strengthen your argument? Or are you going to abandon that argument?
c) What did the other team say which you found reasonable enough to accept? [There is nothing wrong in accepting the compelling arguments of your opponents.]

The group members prepare a better debate against their opponents

Session 4: The final "showdown"

The opponents engage in another but more informed and refined debate.

Debate on controversial positions held by different people [DOCP]

For this activity you will be given a scenario where members of a family differ over an issue. You will be divided into two groups representing the two opposing groups in the family. In your group, you will then be required to advance reasons why you support that group of family members.

Scenario 1

A member of your family is suffering from an incurable disease and is terminally ill. He/she is on life saving machines and heavy doses of pain killers because the patient experiences unbearable pain. A team of medical experts has come to the conclusion that there is nothing they can do, medically, to help their patient. Some members of the family are suggesting that the doctors should remove the life-saving machines to allow their loved one to die and be spared from unbearable pain. Other members of the family feel that their loved one must be allowed to live for as long as the life-saving machines can allow it.

What evidence would you advance in support or against the removal of the life-saving machines?

Scenario 2

Thecla is very unhappy with her facial appearances. She thinks she is very ugly and behind her back she has heard both men and women at her place of work talking about and laughing at her ugliness. She has decided to have plastic surgery that would turn her into the beauty she has always wanted to be. Her mother thinks that Thecla must have plastic surgery but her father is against the plastic surgery.

What evidence would you advance in support of or against Thecla having plastic surgery?

Debate on explanations of common occurrences [DECO]

Study and debate each of the following scenarios in these short stories. Four possible explanations for each of these stories are given. Which explanation do you agree with? You need to debate each explanation in your group. Explain why you agree with that explanation. If you agree with more than one explanation, explain why you agree with each of those explanations. If you do not agree with any of the given explanations, give your own explanation of the scenario in the story and explain why you think your explanation is a good explanation.

2.1 Many fatal accidents occur at a certain place along a certain road.

The reason why the fatal accidents occur at this place is:

- This part of the road was poorly constructed.
- Those who died at this place due to previous accidents are causing the current accidents.
- The drivers of the vehicles that get involved in the accidents fall asleep when they get to this part of the road.
- That is God's will

2.2 Lightning strikes at a certain place year after year.

The reason why lightning always strikes at this place is because:

- The lightning is directed by a witchdoctor to that place.
- The lightning is directed by God to that place.
- Lightning is a hen which lays its eggs in one place.
- There must be something that is attracting the lightning at that place.

Lesson 2: Teaching, modelling and scaffolding good and effective arguments (See lesson 3 under Data collection procedures)

Activity 1: Defining terms.

The terms claim, data or evidence, counter claim and rebuttal were explicitly defined and exemplified following the suggestion from Herrenkohl et al (1999).

Activity 2: Why is argumentation important?

The importance/ purpose/ rationale of argumentation was explained following the suggestion from Kuhn et al (2000).

Activity 3: How to build and develop good and effective argument.

The class was taught how to build a good and effective argument. This was done in order to improve the learners' understanding of the nature of argument in general and of argument in a scientific context in particular. Osborne & Young, (1998) cited in Osborne, Erduran & Simon, (2004) maintain that students must be helped to practice articulating and defending scientifically valid ways of arguing. The aim was to enhance the quality of argumentation of the students about scientific issues.

To initiate and promote effective argument, Erduran (2006) and Osborne, Erduran & Simon (2004) suggest the use of the following strategies, which were used in this study:

- Generally, students were taught the importance of justifying or refuting claims using appropriate and adequate theoretical and / or empirical evidence and the importance of thinking of and coming up with counter claims. Students were encouraged to
- begin their claims with phrases such as 'My idea is---'; 'I think---'; 'I am of the opinion that---'; 'My argument is---' ;
- begin their data/ evidence with phrases such as 'My reasons for saying so are---'; 'The reason for my argument is---' .
- begin their counter claims with phrases such as ' An argument against your idea is---'; 'To oppose your idea I would say that---'.
- To facilitate and scaffold student argumentation prompts were used. Argumentation prompts are open ended questions designed to elicit justification of a claim. For example, listeners were encouraged to ask questions such as 'How do you know that what you are saying is true?'; 'What or where is your evidence?'; 'What reason do you have?'.
- To promote counter arguments the researcher asked questions such as 'How would you argue against that claim?'; 'What evidence would you provide to show him/her that

his/her idea is right or wrong?'; 'Can anyone think of something to say to oppose that?'. In other words, the researcher played the devil's advocate.

- Further questions included; 'What do you mean by that? Can you please explain further.' 'How does that fit in with what has just been said by---?' 'How did you figure that out?' 'Can you give us some examples of that?'
- Opposition and argumentation were encouraged by putting the participants into the positions of two groups of people who held different opinions on some socio-scientific issue. The participants were then told to defend those opposing positions.

Activity 4: Model the process of argumentation using concrete examples (Osborne, Erduran & Simon, 2004). This involved offering students examples of both weaker and stronger arguments, enabling discussion of the features that make one better than the other. These authors say that strong arguments draw on a wider range of evidence and include rebuttals of counter arguments while poor arguments rely on no or minimal use of data to justify or refute the claims. The researcher used some of the participants' earlier reactions/ responses in order to teach about good and poor arguments and evidence

Modelling and scaffolding good argumentation [MSGA]

Responses from the research participants during the various tasks and during their discussions were used to model good argumentation by showing why certain arguments are good while others are not.

APPENDIX 6: SCIENCE- IKS QUESTIONNAIRE [SIKSQ] (adapted from Onwu & Ogunniyi, 2006; Simon, Erduran & Osborne, 2006).

Read each of the following statements and decide whether you agree with the statement or not. Write 'Agree' or 'Disagree' at the end of the statement. Give reasons why you agree or disagree with the statement. What is your source of information? This means that you must tell us where you got the information that you used to agree or disagree with the statement and where you got your explanation. For source of information, choose from:

- science books and science lessons/science teachers
- or indigenous /local community knowledge
- or the Bible/other religious sources
- or my own personal feeling/view.

If you got your information from more than one source, state all the sources.

If you want to add anything to or subtract anything from any of the statements, feel free to do so in the space provided. Please note that there are no right or wrong answers. I just want to get your opinion and the reason for that opinion.

1. Science is based on facts only.
   Agree/Disagree---
   Reason(s)--

   Source of information--
   Any addition/subtraction--
   ----

2. Indigenous knowledge is based on beliefs only.
   Agree/Disagree---
   Reason(s)--

   Source of information--
   Addition/subtraction---

   ----

3. Scientists deal with research and investigations.
   Agree/Disagree--
   Reason(s)--

   Source of information---
   Any addition/subtraction---
   ----

4. Indigenous knowledge is based on experience only.
   Agree/Disagree--
   Reason(s)--

   Source of information---
   Any addition/subtraction---
   ----

5. Science is universal. This means that it is true for all people in the world.
   Agree/Disagree--
   Reason(s)--

   Source of information---
   Any addition/subtraction---
   ----

6. Indigenous knowledge is true only to that group of people with that knowledge.
   Agree/Disagree--
   Reason(s)--

   Source of information---
   Any addition/subtraction---
   ----

7. Science is tentative. This means that it does not always have sure answers.

Agree/Disagree--

Reason(s)--

Source of information---

Any addition/subtraction--

----

8. Indigenous knowledge is final.

Agree/Disagree--

Reason(s)--

Source of information---

Any addition/subtraction--

----

9. Science changes when new information is found.

Agree/Disagree--

Reason(s)--

Source of information---

Any addition/subtraction--

----

10. Indigenous knowledge never changes. It is the same from generation to generation.

Agree/Disagree--

Reason(s)--

Source of information---

Any addition/subtraction--

----

11. Science and indigenous knowledge are completely different from each other.

Agree/Disagree---

Reason(s)--

Source of information--

Any addition/subtraction---

----

12. Science and indigenous knowledge have certain elements (things) in common.

Agree/Disagree---

Reason(s)--

Source of information--

Any addition/subtraction---

----

13. Scientists are learned people. They have been to school to learn science.

Agree/Disagree---

Reason(s)--

Source of information--

Any addition/subtraction---

----

14. Indigenous knowledge experts are not learned people. They have not been to school to learn indigenous knowledge.

Agree/Disagree---

Reason(s)--

Source of information--

Any addition/subtraction---

----

15. Science is straight forward and easy to understand.

Agree/Disagree--

Reason(s)---

Source of information--

Any addition/subtraction---

----

16. Indigenous knowledge is mysterious and difficult to understand.

Agree/Disagree--

Reason(s)---

Source of information--

Any addition/subtraction---

----

17. A lot of indigenous knowledge has scientific or reasonable explanations.

Agree/Disagree--

Reason(s)---

Source of information--

Any addition/subtraction---

APPENDIX 7: ESSAY ON COMPARING SCIENCE AND INDIGENOUS KNOWLEDGE [ESIKS]

Write an essay on the following topic: 'My views about science and indigenous knowledge'. Use the following information and answer the questions that follow to write this essay.

Science and indigenous knowledge systems are two ways of explaining and predicting natural phenomena (happenings) such as lightning and thunder. Science is knowledge that was brought to us by the Westerners from outside our continent. Indigenous knowledge is knowledge that we get from our communities as we grow up. It refers to the beliefs and practices of the local people.

A scientist is an expert in science. An indigenous knowledge holder is an expert in indigenous knowledge. Such experts include: the wise men and women in the communities, the traditional herbalists, the fortune tellers, the weather predictors.

In this activity, you will be asked to state your views about each of the following ideas about science and indigenous knowledge.

1. Is science superior to indigenous knowledge or is indigenous knowledge superior to Western science or are they of the same status? Why do you say so?
2. Do scientists have goals and values? If so what are these goals and values? Do indigenous knowledge holders have goals and values? If so, what are these goals and values?
3. Who or what controls the activities of scientists? Who or what controls the activities of indigenous knowledge holders?
4. Are scientists willing to share their knowledge with outsiders? Are indigenous knowledge holders willing to share their knowledge with outsiders? Why do you say so?
5. Are scientists trained to do what they do? If so, by whom? Are indigenous knowledge holders trained to do what they do? If so, by whom?
6. Is the truthfulness of science verified or proved? If so, how, or by whom? Is the truthfulness of indigenous knowledge verified or proved? If so, how, or by whom?
7. Where or how do scientists get to know what they claim to know? Where or how do indigenous knowledge holders know what they claim to know?

8. Are there any similarities between science and indigenous knowledge? If so, give examples of such similarities.
9. Add any other relevant issues.

APPENDIX 8: TEACHING THE NATURE OF SCIENCE AND THE NATURE OF INDIGENOUS KNOWLEDGE: MAJOR TENETS AND MAJOR MYTHS

The major emphasis here was to highlight those aspects of science and indigenous knowledge that I thought to be relevant for my study and that learners at Grade 10 level could easily grasp.

Activity 1: What is science? The major tenets of science

The major messages to the learners here were that science

- uses certain types of processes and methods to generate and test knowledge (science facts, concepts, generalisations, theories and laws).
- requires that information that is generated must be supported with appropriate and adequate theoretical and/or empirical evidence or must be verifiable by others.
- is a way of knowing and interpreting experiences. It offers explanations of the observations about the world we live in that we make with our senses and with instruments that we have devised to sharpen our senses.

Activity 2: The history of science. How did it come about?

The major messages to the learners here were that

- Originally, science coming from the Latin word *scientia* meant knowledge.
- West means Western Europe and North America.
- Western modern science (WMS) is a very recent creation of a very few influential and powerful people whose main agenda was to exclude certain types of knowledge from their definition of science.
- The so called Western science is really a blend or 'concoction' of ideas from many parts of the world.
- Science is a body of knowledge put together by many people in different parts of the world over many years. Collaboration and patience are required when generating science knowledge.

Activity 3: The myths of science.

- Science is the panacea of all humankind woes. *We all know now that science and technology have caused a lot of humankind problems such as pollution and* *degradation of the environment, global warming, depletion of natural resources and that science has failed to solve many humankind problems some of which it could have caused such as poverty and certain disease such as AIDS.*

- Science knowledge is generated through the scientific method which involves stating and testing hypotheses. It involves the use of the human senses to observe phenomena (empiricism) and the quantification of what has been observed. Experiments are the principle route to scientific knowledge. *There are many examples in the scientific literature that show that many scientific discoveries were made through non-scientific methods such as common sense, intuition, creativity, serendipity (as in the case of Alexander Fleming's 'carelessness' that led to the discovery of penicillin; Kekule's dream that led to the discovery of the benzene ring, Oersted's accidental discovery of the relationship between an electric current and magnetism).*
- Science deals with facts, with truths. Only scientific explanations give a true account of reality. *Not only are there other explanations of reality outside science but in science itself we find different explanations of the same object or phenomenon. For example, for nearly two thousand years the scientific world believed that heavier objects fell towards the ground faster than light objects until this was proved wrong by Galileo.*

Activity 4: What is indigenous knowledge? What are its major tenets?

The following quotation was used to discuss the meaning and the major tenets of indigenous knowledge.

Kaniki & Mphahlele (2002, p. 3 - 4) define indigenous knowledge as

a cumulative body of knowledge generated and evolved over time, representing generations of creative thought and actions within individual societies in an ecosystem of continuous residence, in an effort to cope with an ever changing agro-ecological and socio-economic environment. It is the sum total of knowledge and skills possessed by people belonging to a particular geographical area, which enables them to benefit from their natural environment. Such knowledge and skills are shared over generations, and each new generation adds and adapts in response to changing circumstances and environmental conditions.

The major issues raised were that indigenous knowledge

- Is knowledge and skills possessed by a group of people belonging to a particular geographical environment.

- Is knowledge accumulated by many generations over time.
- Is a result of careful and meticulous observations and recordings of events in the socio-physical environment.
- Is knowledge that the people use to survive in and make use of in their environment.
- Is dynamic. It changes in response to changes in the environment.
- Is a way of knowing and interpreting experiences. It offers explanations of the observations about the world we live in that we make with our senses. It goes beyond the use of senses going into the realm of metaphysics and goes beyond explaining how events to why events happen.

Activity 5: Myths about indigenous knowledge

The following misconceptions about indigenous knowledge were highlighted: Indigenous knowledge

- system is just a belief system.
- is for the poor rural people.
- holders are not educated or trained in what they do.
- Is mysterious, superstitious, unreasonable, irrational.
- Is useless in today's technological world.

Activity 6: Comparing science and indigenous knowledge.

Using the above information, the learners identified similarities and differences between science and indigenous knowledge.

Expected answers include:

- Both systems seek to explain and predict natural phenomena.
- Science often ends at what happens and how does it happen. Indigenous knowledge often goes further and explains why it happens.
- While science relies on the human senses, indigenous knowledge goes beyond the physical and consults and uses the metaphysical.
- Science studies objects or events in isolation. Indigenous knowledge is holistic. It studies an object or event in its entirety and as it relates to other objects or events.
- Although they use different methods, they are both legitimate ways of studying, explaining, and predicting natural phenomena.

APPENDIX 9: INTERVIEW/ QUESTIONNAIRE TO COLLECT INDIGENOUS KNOWLEDGE ON LIGHTNING AND THUNDER [QIKLT]

This questionnaire was administered to learners and educators during the preliminary stages of the study in order to solicit general information on the causes, dangers and prevention of lightning and thunder.

Using the same questions, community leaders and community knowledge holders were interviewed to solicit information on the causes, dangers and prevention of lightning and thunder.

Message to the learners:

You are encouraged to use any source of information that you can find such as your parents, your community leaders, books, internet etc. You must feel ownership of the knowledge that you bring to the classroom and ownership of the whole research process. Later on, the study would want to find out how far and how much your initial and perhaps simplistic views about lightning and thunder get changed or modified or refined as a result of the programme you will go through. More involving activities, on lightning and thunder, for you, will come later in the study.

What do you know, have read or have heard about each of the following?

1. What causes lightning?

   ----

2. What are the dangers of lightning?

   ----

3 How can one protect oneself and his/her home and livestock from lightning?

APPENDIX 10: LESSONS ON STATIC ELECTRICIY AND LIGHTNING [LOSEL]

Lesson 1 Introducing the lessons to the research participants.

We will be doing some interesting and simple activities related to a topic called **static electricity.** The word **static** means **'no movement'**. This means that we will be talking about electricity that is not moving. The electricity we will talk about is different from the current electricity we know which comes into our homes, schools, hospitals, etc, from Eskom through wires. When static electricity is forced to move (we shall soon see what would force it to move), it will not move through wires but through space and in a zigzag (not straight) path. That should be interesting. Is it not?

I will now give you some time to think about what I have just said. Discuss what you are thinking with your neighbour. Do you feel excited or do you feel uncertain or do you feel intimidated? Why do feel like that?

We will be talking about neutral and charged objects, charges, forces called electrostatic forces, attraction, repulsion, lightning and thunder. These words may be new to you but static electricity is very common in our daily lives. Have you ever wondered how and why

- Your clothes produce a cracking sound and sparks of light when you take them off in a dark room.
- Your clothes cling to you when you put them on or when you remove them.
- Your TV screen or computer monitor collects dust very easily.
- Thin but strong plastic paper is used to seal food such as meat in a plastic container.
- From your science lessons, you should remember the intramolecular forces that bind atoms in molecules and the intermolecular forces that bind molecules in substances.

  All these and many more phenomena are related to static electricity.

You should be able to tell us where static electricity has affected you or affected somebody you know. For example, do you remember getting some 'electric shock' after touching something? Share your experiences with all of us.

Lesson 2 How can a neutral object be charged? What can a charged body do which a neutral body cannot do?

Activity 1: Explaining the meaning of a neutral object and a charged object. (This activity assumes that the research participants know the simple structure of an atom from their earlier grades science work and their earlier science lessons in grade 10).

Activity 2: Doing a series of simple experiments to charge neutral objects and use the charged objects to discover what they can do.

Requirements: These are materials that will be required in all the experiments on static electricity.

- Materials to be rubbed: plastic ruler, plastic comb, balloons, glass rod.
- Materials to rub with: pieces of woollen, silk, nylon cloth; participants' hair.
- Light-weight materials: small pieces of dry leaves, paper, feathers; a thin stream of water.
- Other materials: cotton thread, tripod stand

  (For these experiments to work well, the materials used should be dry and that the weather should also be dry. An explanation for this condition is given) (The different groups will use different but similar materials and compare their results. They can also experiment with other materials in addition to those supplied for these experiments).

For each of these activities and questions, begin with your own individual observation and explanation, listen to other people's explanations, compare and debate the various possible explanations, and then as a group, come up with an agreed explanation. We will follow the following format:

Stage 1: Individual work. Answer the questions as an individual. We want your **personal** opinion, thoughts and beliefs. Do not consult or help anybody.

Stage 2: Small group discussions and consensus. Share your answers with members of your group. Each member of the group must be heard. Discuss, debate the presented answers and come up with the group's agreed answer. This is the consensus.

Stage 3: Whole research team discussion. A member of each group shares the group position with the whole research team. Further discussion/debate takes place leading to a greater understanding of the issues under discussion.

Experiment 1: Bring a plastic ruler or comb near the small pieces of tissue paper. Repeat the experiment using the glass rod, the balloon and using the other lightweight materials. (Many different experiments can be done here)

- *What happens? Compare your results with those of other groups. Are they the same or are they different?*

Experiment 2: Rub the ruler or comb on a piece of nylon cloth or nylon jersey or your hair or sleeve of your shirt. Bring the rubbed ruler near pieces of tissue paper. Repeat this experiment using other materials. (Again many different experiments can be done here).

- *What happens? Compare your results with those of other groups. Are they the same or are they different?*
- *Explain what happens and why the results are different from those of experiment 1.*

Experiment 3: Bring the piece of cloth you rubbed the ruler or comb with near the pieces of tissue paper.

- *What happens? Compare your results with those of other groups. Are they the same or are they different?*
- *Explain what happens and why the results are different from those of experiment 1. Begin with your own individual explanation, listen to other people's explanations, compare and debate the various possible explanations, and then as a group, come up with an agreed explanation.*

Lesson 3: What happens when charged bodies are brought near each other?

Experiment 1: Charge two balloons or two rulers or two combs or two glass rods using the same type of cloth. Tie, with a cotton thread, one of the charged balloons and hang it on a retort stand. Tie the other charged balloon with a cotton thread and bring it next to the hanging balloon.

- *What happens? Compare your results with those of other groups. Are they the same or are they different?*

- *Explain what happens. Begin with your own individual explanation, listen to other people's explanations, compare and debate the various possible explanations, and then as a group, come up with an agreed explanation*

Experiment 2: Use one type of cloth to rub one balloon and another type of cloth to rub the second balloon. Repeat the rest of experiment 1.

- *What happens? Compare your results with those of other groups. Are they the same or are they different?*
- *Explain what happens. Begin with your own individual explanation, listen to other people's explanations, compare and debate the various possible explanations, and then as a group, come up with an agreed explanation*

Lesson 4: Putting together the results of the experiments in lessons 2 and 3 in order to come up with the laws of electrostatics.

- Use your results where you rubbed the plastic ruler, the plastic ball point pen and the plastic comb with a woollen or cotton cloth and where you rubbed the balloon and the glass rod with a silk cloth to complete the following table. The questions you are answering are ***'What happened when you brought the two charged objects close to each other when they were free to move?'; 'What conclusions can you make from the completed table?'*** *. Begin with your own individual conclusion, listen to other people's conclusions, compare and debate the various possible conclusions, and then as a group, come up with an agreed conclusion.*

Repeat the experiments if you want.

Material	Plastic ruler	Plastic ball point pen	Plastic comb	Balloon	Glass rod
Plastic ruler					
Plastic ball point pen					
Plastic comb					
Balloon					
Glass rod					

Lesson 5: Discussing and explaining the phenomenon of lightning

Introductory remarks: A thunderstorm with lightning and thunder can be a really frightening experience. Tell the others what you do when there is a thunderstorm. For example, do you rush into the house and cover yourself with blankets? Lightning strikes are very dangerous. Many South Africans are killed each year by lightning. For this reason, this is a topical and important issue at all levels of society.

What causes lightning? What are the dangers associated with lightning? How can we protect ourselves against lightning? People, all over the world, have tried to answer these questions. Unfortunately, these explanations differ from one group of people to another.

In this programme we will look at two such explanations, one from the science point of view and another from the indigenous knowledge point of view. We will **NOT** attempt to decide which of the two explanations is better than the other. We will attempt to understand each point of view and to see where the two explanations mirror each other and differ from each other. In fact the aim of these activities is to convince you that the knowledge that you have from your communities is as useful and valid as the knowledge you get from your school science lessons no matter how different this knowledge might appear to be.

We will begin with the scientific explanation.

Activity 1: Linking static electricity and lightning.

1. When you remove certain type of clothes in a dark room what do you notice? What do you hear and see?
2. The cracking sounds and the sparks of light are caused by the movement of electric charges.
3. Thunder and lightning are also caused by the movement of electric charges. Lightning is, in fact, a large number of negative electric charges (electrons) moving from the clouds to the earth.

Activity 2: What causes lightning?

During a storm, electric charges build up in the clouds as a result of friction between the moving clouds and the moving air. By induction, when the cloud accumulates a negative charge at its bottom side, the side closer to the ground, the ground becomes positively charged. When too much or enough charge has built up in the cloud, a huge electric charge moves through the air towards the ground. The movement of the charge from the cloud to the ground is called lightning. The charge moves through the air at very high speed, causing the air molecules in its path to be displaced quickly and roughly. This displacement of the air causes a sound that we call thunder.

Is this explanation the same as or different from the one you know? Where did you get the explanation that you know? Tell us what you know about the causes of lightning.

Activity 3: The dangers of lightning.

From your experience, from what you have read, heard or seen, what are the dangers of lightning? Work in groups and produce a report that we will use to come up with a comprehensive list of the dangers associated with lightning. Include stories you have heard; reports in the newspapers, the radio and television; and pictures of damaged properties.

Activity 4: How can we protect ourselves against lightning?

From your experience, from what you have read, heard or seen, how do people in your village protect themselves against lightning? Work in groups and produce a report that we will use to come up with a comprehensive list of how to prevent lightning. Include things you must do and those you must not do during a thunderstorm. Find out from the school, the clinic and other places how buildings have been protected from lightning. I will then give you what the Western science people say about how to prevent lightning. We will compare the two lists and see where they agree and where they may not agree.

Activity 5: What causes lightning? What are the dangers of lightning? How can people protect themselves from lightning?: A indigenous knowledge point of view.

- An invited community knowledge holder explained these ideas to the research participants. This expert was briefed before presenting the lesson in terms of what is expected of him, what would happen after his lesson delivery and that he should not be surprised or annoyed when the learners ask him questions. (culture might have it that the young believe, without question, what the elders say, but not in our science lessons).
- A question and answer session to seek further clarification from the knowledge holder.

Activity 6: What causes lightning? What are the dangers of lightning? How can people protect themselves from lightning? Comparing the explanations given by the two world views on causes, dangers and prevention of lightning

- In groups, the research participants identified similarities and differences between the Western science knowledge and indigenous knowledge on lightning using the information they obtained from the science and indigenous knowledge lessons.
- A class discussion was held to identify common points of similarities and differences between the western and the indigenous knowledge systems' explanations of the causes, dangers and prevention of lightning.

APPENDIX 11: ACHIEVEMENT TEST ON LIGHTNING AND THUNDER [ATLT]

There are six sections that make up this science achievement test on lightning and thunder. Except for Section A and Section B, there are no wrong or correct answers. I am just interested in your opinions and why you think so. Nobody fails or passes this test.

Section A: Complete each of the following sentences in these three paragraphs by using the most appropriate word.

a) The law of electrostatics states that like charges--------each other unlike charges ------ each other. This means that repulsion occurs between a positively charged body and a ---------- charged body or between a negatively charged body and a -------- charged body. Attraction occurs between a negatively charged body and a ------charged body or between a charged body and a -----body.

b) We describe an electric current as the movement or flow of an electric charge. That electric charge comes from the ---- in the atoms which have a ------- charge. They carry their charge when they move. When objects are charged, one object loses ------ while the other gains them. The object that gains them becomes -------charged while the one that loses them becomes ----charged.

c) Lightning is the movement of an electric charge from a --------- to another ---- or from the clouds to the ------------. When lightning moves through the air it causes air to ---------- and contract and this produces a sound called ---------. Lightning travels ------ than thunder this is why thunder is always ---------- after the lightning flash.

Section B: These questions are based on the activities that you did on static electricity. Answer each of them in the spaces provided.

1. What do you observe when you put a ruler rubbed with a piece of cloth near small pieces of paper?--
2. Explain the observation you made in 1 above---
3. Two balloons are rubbed with the same piece of cloth. What do you observe when the rubbed balloons are brought close together?---

4. Explain the observation you made in 3 above. ---------------------------------------
----
----
5. Two balloons are rubbed with different pieces of cloth e.g. cotton and silk. What do you observe when the rubbed balloons are brought close together?----
----
----
6. Explain the observation you made in 5 above. ---------------------------------------
----
----
7. A positively charged polythene strip is brought close to the metal cap of an electroscope. What do you observe?---
----
8. Explain the observation you made in 7 above. ---------------------------------------
----
----
9. With the positively charged polythene strip close to the metal cap, you touch the metal cap. What do you observe? --
----

10. Explain the observation you made in 9 above. ---------------------------------------
----
----
11. During a thunderstorm, the bottom part of the cloud becomes negatively charged. What causes the cloud to be charged?--------------------------------------
----
12. When the bottom part of the cloud is negatively charged, what kind of charge does the ground (earth) get?--
13. How does the ground get the kind of charge you mentioned in 12 above?-------
----

----
14. In a thunderstorm, what causes the lightning flash?---------------------------------
----
----

15. In a thunderstorm, what causes the thunderous sound?-----------------------------
----
----
16. Why is the flash of lightning seen before thunder is heard?------------------------
----
17. Give any three dangers of lightning.
a)---
----
b)---
----
c)---
----
18. Give any three ways you could use to protect yourself or your house from lightning.
a)---
----
b)--
----
c)---
----

19. Draw a fully labelled diagram to show and explain how
 19.1 an unprotected building can be struck by lightning
 19.2 a protected building may not be struck by lightning.

Section C: Read each of the following scenarios and the possible explanations of the scenario. Decide which explanation you agree with and explain why you agree with it. If you agree with more than one explanation, explain why you believe in each of those explanations. If you do not agree with any of those explanations, supply your own explanation and justify it. (Adapted from Liphoto, 2009)

Scenario 1:

Lightning struck Mr. Ndhlovu's house several times in one year. To protect his house, Mr. Ndlovu must

1.1 consult a traditional doctor

1.2 fix a metal conductor from the top of his house to the ground.

1.3 appease his ancestors by making a feast or brewing beer for them

1.4 put an old car tyre on top of his house

1.5 pray to God

1.6 own explanation---

Scenario 2

Lightning struck Mr. Ndhlovu's house several times in one year. The reason for this could be:

2.1 Mr. Ndhlovu has a powerful enemy who sends lightning to Mr. Ndhlovu's house.

2.2 Lightning is like a hen that lays its eggs, day after day, in one place.

2.3 Mr. Ndhlovu's house is probably built on a high ground.

2.4 Mr Ndlovu's ancestors want him to appease them.

2.5 own explanation---

Scenario 3

A boy who was struck and killed by lightning was found to have wounds all over his body. The reason for the wounds is

3.1 the boy was burnt by the lightning.

3.2 the boy was wounded by the bird of lightning

3.3 the wounds came from the power of the enemy who sent the lightning to the boy.

3.4 the boy had the wounds before he was struck by lightning.

3.5 own explanation---

Scenario 4

As I grew up, I was told not to play with water or to be near a water source during a thunderstorm. The explanation for this could be:

4.1 lightning likes water.

4.2 water is a good conductor of lightning.

4.3 lightning lives in water.

4.4 water attracts lightning.

4.5 own explanation---

Scenario 5

As I grew up I was told not to take shelter under a tall tree during a thunderstorm. The reason for this advice could be:

5.1 tall trees attract lightning

5.2 lightning lays eggs on tall trees

5.3 lightning lives in tall trees

5.4 lightning hates tall trees and wants to destroy them.

5.5 own explanation---

Scenario 6

The lightning flash is always seen first before the thunder is heard. What could be the reason for this?

6.1 lightning travels faster than thunder.

6.2 lightning is more angry and powerful than thunder.

6.3 lightning is an angry and fast boy while thunder is his slow mother trying to control him.

6.4 the lightning and the thunder occur at the same time.

6.5 own explanation--

Scenario7

Two people, Moni and Mana are walking during a thunderstorm. Moni is struck and killed by the lightning while Mana is not. A possible explanation for this is:

7.1 the lightning was sent by an evil man to Moni only.

7.2 Moni is taller than Mana

7.3 Mana has been protected against lightning by a traditional doctor.

7.4 Moni happened to be in the path of the lightning.

7.5 own explanation--

Section D: Using stories to learn more about the nature of lightning.

Incidents of lightning strikes appear regularly in the press. We also read about lightning strikes from books. Many incidences and stories about lightning are quite common in the communities from which we come. These stories can tell us a lot about the nature of lightning. Below are some such stories. Study them and work out what those stories tell you about the causes and nature of lightning.

We will go through the following stages for each story:

Stage 1: Individual work. Answer the questions on each story as an individual. We want your **personal** opinion, thoughts and beliefs. Do not consult or help anybody.

Stage 2: Small group discussions and consensus. Share your answers with members of your group. Each member of the group must be heard. Discuss, debate the presented answers and come up with the group's agreed answer. This is the consensus.

Stage 3: Whole research team discussion. A member of each group shares the group position with the whole research team. Further discussion/debate takes place leading to a greater understanding of the issues under discussion.

Background

Lightning is one of nature's awe inspiring and dangerous weather phenomena. [Awe means causing a feeling of respect, a feeling of being impressed and a feeling of fear. Phenomena are events in nature.] Lightning is associated with hot and dry conditions that are followed by a stormy weather. [Stormy weather is characterised by strong winds and heavy rain.] Lightning is a very destructive force that can set fire to and damage property; start bush and forest fires; disrupt communication and electronic systems; and injure or kill livestock and people.

Scientists do not yet fully understand the exact origin and nature of lightning. Most scientists agree that lightning is the movement of a huge negative charge from the bottom of a cloud to the ground which would have become positively charged by induction. [Induction is the process whereby the electrons on the bottom part of a cloud repel electrons on the surface of the earth, leaving the surface of the ground with a positive charge.]

STORY 1: A soccer referee is struck by lightning

The following account is based on an incident described in the *Daily Sun* of 4 February 2008. Study it and answer the questions that follow.

"I was suddenly surrounded by blinding white light. I was in great pain. I fell over but I do not remember anything else." These were the words of Kagiso (24), a soccer referee, who survived being struck by lightning. A bolt of lightning struck him while he was in charge of a soccer match at the local football pitch. His clothes were torn as if someone had used scissors to cut them. The unconscious referee was rushed to a nearby house and from there to the hospital. Although he cannot walk properly yet as his legs are still swollen and he has burns on his back and on his legs, he is much better now and is grateful that he is still alive. His mother insists that it was an attempt by a witch to kill her son. "Somebody wanted my son dead because he was the only one struck by lightning. That usually happens when the lightning has been sent by a powerful witch. The witch would want to use my 'dead' son for his evil purposes, " she said.

Spectators at the soccer match said that they had never seen anything like it before in their lives. The coach of one of the teams said, "It was just drizzling. We did not think it was anything serious, so we decided to continue with the game. The strange thing, though, is that it was raining in the area around the soccer field only." Kagiso remembers that he had wanted to stop the game when it started raining but the players and the match officials brushed him off saying that the rain would soon stop.

The questions

1. Who or what did Kagiso's mother believe had caused her son to be struck by lightning?---
   ----
   ----
2. What evidence or reason(s) did Kagiso's mother use to support her claim?--------------
   ----

   ----
3. Do you agree or disagree with the claim made by Kagiso's mother?--------------

4. Why do you agree or disagree with Kagiso's mother?-------------------------------------
   ----
   ----
5. If you do not agree with Kagiso's mother, give your own explanation why Kagiso was struck by lightning.---
   ----

   ----
6. Support your claim with reasons.---

   ----
7. What scientific explanation(s) can you offer to explain why Kagiso was struck by lightning?--
   ----

   ----

8. Additional questions
   a. Why was the referee taken to a house first before being taken to the hospital?------
      ----
      ----
   b. Would your explanation of the incident be different if the referee had been killed by the lightning? If so, what would it be? ---
      ----
      ----
   c. What is the significance, if any, of the following?
      i. 'It was just drizzling'.---

         ----
      ii. The players and the match officials refused to listen to the referee when he wanted to stop the match because of the rain.------------------------------------
         ----
         ----

iii. Why was he the only one in the path of the lightning?-------------------------
----

Now study the following related stories carefully and answer the questions that follow.

STORY 2: A man is followed and killed by lightning after a quarrel with another man.

This story is said to have taken place in a certain African village. Two men quarrelled at a beer party. One man, X, threatens the other man, Y, but does not specify the nature of the punishment. A few days later, Y's homestead is struck by lightning, burning a hut. The man is not at the homestead. He is at a beer party not far from his home. Although nobody is killed by the lightning those present are terrified by the intensity of and the damage caused by the lightning. The man sees smoke coming from his homestead and rushes back home. While on his way home another lightning bolt strikes the homestead where the man had gone for the beer party. Again, nobody is killed but people are terrified. Before the man reaches his home, yet another lightning bolt strikes the man and kills him.

The following related stories are taken from **Pople, S. (1996, p. 229). *Explaining Physics.*** According to this source, these stories happened in North America and to Westerners.

Story 3 (a): Major Summerford is wounded several times.

In 1918, during the First World War, Major Summerford was wounded, not by the enemy, but by a flash of lightning which knocked him off his horse and left him paralysed from the waist down. He was invalided out of the army, retired to Vancouver (Canada, North America) and took up fishing. In 1924, he was by a river with three fellow fishers when lightning hit the tree beneath which he was sitting and paralysed his right side. Within two years he had recovered sufficiently enough to be able to walk in the Vancouver Park, where, in the summer of 1930, during a sudden thunderstorm, he was struck again by lightning. This time he was permanently paralysed and died two years later. In 1934, there was a storm over Vancouver. Lightning struck the cemetery and shattered a tombstone. The tombstone was that of Major Summerford.

Story 3 (b): Ex-ranger earns a place in the *Guinness Book of Records.*

Ex-ranger, Roy C. Sullivan, of Virginia, United States of America, earned a place in the *Guinness Book of Records* as the only known man to have survived seven attacks by lightning. In 1942, lightning destroyed his big toe nail; in 1969 lightning took away his eyebrows; in 1970, lightning seared his left shoulder; in 1972 lightning set his hair on fire. At this point Sullivan decided to carry a container with water in his car as a precaution. But this did not help. In 1973, his newly grown hair caught fire again in a lightning strike. In 1977, he was taken to hospital with chest and stomach burns after being struck by lightning while fishing.

1. Do you find these stories
    - believable? or unbelievable? ---
    - explainable? or unexplainable/inexplicable/incomprehensible?--------------------
    - scary/frightening? or perturbing/ worrying? -----------------------------
    - boring? or interesting/exciting?---
    - what other feelings do these stories evoke in you?----------------------------------
      ----
      ----
2. Explain your feelings. Why do you feel like that?---

   ----
3. How do you explain what you have just read? Why was lightning attracted to Y, to Summerford and to Sullivan or why did Y, Summerford and Sullivan attract lightning?---
   ----

----

4. Are there objects or people who are more prone to lightning? Yes/No------------

   If so,

   - Which objects or people are more prone to lightning?------------------------------
     ----

   - Why are they more prone to lightning?--

     ----

5. In my culture we have several explanations related to lightning one of which is that lightning is a hen that lays eggs in one place day after day. This belief is based on the empirical observation that some places get more lightning strikes than others almost as if the lightning was a hen going to the same place to lay its eggs.

   Some people accept this explanation of lightning. Some do not.

   Do you accept this explanation of lightning? Yes/No --------------------------------

   Why/Why not?--

Section E: In this section you are given statements. Read each statement and decide whether you agree with it or not. Write ‘Agree’ or ‘Disagree’ after each statement. Give an explanation why you agree or disagree with the statement. Where you are asked for your source of information, this means that you must tell us where you got the information that you used to agree or disagree with the statement and where you got your explanation. For source of information, choose from:

- science books and science lessons/science teachers or
- indigenous /local community knowledge or

- the Bible/other religious sources or
- my own personal feeling/view or
- my own experience or
- the media (radio, television, newspaper etc.

If you got your information from more than one source, state all the sources.

1. Lightning can cause severe damage to people, other animals, buildings and property.

   Agree/Disagree ---

   Explanation or reason for your answer ---

   Source of information ---

   ----

2. Clouds, containing tiny water droplets, become charged as air and the clouds move relative to each other (against each other).

   Agree/Disagree ---

   Explanation or reason for your answer ---

   Source of information ---

   ----

3. When a cloud accumulates a negative charge at its bottom side (the side nearer the ground), the ground becomes positively charged.

   Agree/Disagree ---

   Explanation or reason for your answer ---

   Source of information ---

   ----

4. When the charge on the cloud becomes too large, a discharge of huge amounts of energy moves from the cloud to the ground.

Agree/Disagree ---

Explanation or reason for your answer --

Source of information --

----

5. The movement of a charge between the cloud and the ground is called lightning.

   Agree/Disagree ---

   Explanation or reason for your answer --

   Source of information --

   ----

6. When a charge moves through the air, it displaces air molecules of the atmosphere very quickly and roughly causing a sound we call thunder.

   Agree/Disagree ---

   Explanation or reason for your answer --

   Source of information --

   ----

7. It is necessary to protect yourself from lightning because it can kill you.

   Agree/Disagree ---

   Explanation or reason for your answer --

   Source of information --

   ----

8. *Sangomas* have means of protecting people and their property from lightning.

   Agree/Disagree ---

Explanation or reason for your answer -- --

Source of information --

----

9. It is dangerous to stand under a tall tree when there is a thunderstorm.

   Agree/Disagree --

   Explanation or reason for your answer ---

   Source of information --

   ----

10. It is dangerous to play with or in water when there is a thunderstorm.

    Agree/Disagree --

    Explanation or reason for your answer ---

    Source of information --

    ----

11. Put out fires, including cooking fires in the kitchen, when there is a thunderstorm.

    Agree/Disagree --

    Explanation or reason for your answer ---

    Source of information --

    ----

12. Buildings can be protected from lightning by planting certain trees around the buildings.

    Agree/Disagree --

    Explanation or reason for your answer ---

    Source of information --

    ----

13. Buildings can be protected from lightning by attaching a metal wire or rod on the building. The metal wire must extend from above the building to the ground.

Agree/Disagree --

Explanation or reason for your answer --

Source of information --

----

14. Lightning is a natural phenomenon. It is not caused by people.

Agree/Disagree --

Explanation or reason for your answer --

Source of information --

----

15. Lightning is caused by some evil people.

Agree/Disagree -------------------------------

Explanation or reason for your answer --

Source of information --

----

16. Using my indigenous knowledge or beliefs helps me to understand lightning and thunder better.

Agree/Disagree --

Explanation or reason for your answer ---

----

17. I can use what I learn in school science about lightning at home.

Agree/Disagree ---

Explanation or reason for your answer ---

----

18. When it comes to lightning and thunder, I believe in my science lessons more than in indigenous knowledge.

Agree/Disagree ---

Explanation or reason for your answer ---

----

19. When it comes to lightning and thunder, I believe in my indigenous knowledge more than in my science lessons.

Agree/Disagree ---

Explanation or reason for your answer ---

----

20. I just learn the scientific explanation of lightning and thunder in order to pass examinations.

Agree/Disagree ---

Explanation or reason for your answer ---

----

21. It is necessary to know both the scientific and indigenous explanations of lightning.

    Agree/Disagree ---

    Explanation or reason for your answer ---

Section F: Read the following article which is based on Kelder (2006) and my interactions with the Xhosa knowledge holders. It shows different people's views about lightning. Pick out from the article what you consider to be scientific explanations, indigenous knowledge explanations and a combination of the scientific and the indigenous knowledge explanations and produce a three column table as shown below. Just write the number of the explanation in the appropriate column. Indicate the word (s) from the statement that helped you to come to that conclusion.

1. During a thunderstorm, clouds and the ground gain negative and positive charges.
2. When the negative charges in the cloud become too great/ huge for the cloud there is a discharge of energy from the cloud to the ground which we call lightning.
3. As the charge moves to the ground it displaces air molecules violently resulting in the sound we call thunder.
4. Lightning is a bird called the 'lightning bird' known by the different names such as *chimunga* or *impundulu* which is thought to have a large and strong beak and long strong legs. The bird is believed to be employed by evil people to cause harm on their enemies. When it flaps its wings, thunder rows. When it spits, lightning flashes.
5. The lightning bird lays eggs and returns for its eggs now and again.
6. The lightning bird causes wounds with its strong beak.
7. Lightning is called *kuhambele umhlekazi,* which is believed to be an important messenger from the ancestors —an honoured, respected visit from high levels.
8. Those affected by the lightning know that they must have offended the ancestors and must repent and restore their relationship with the ancestors.
9. *Sangomas* are called in to the affected homes and people to perform cleansing rituals.
10. Thunder is an elderly mother sheep and her son is lightning. The son is short tempered and quickly destroys houses and property when angry. His mother would then raise her voice to control him but he is always too fast for his elderly mother.
11. Some people plant certain plants around their homesteads in order to protect themselves from lightning.
12. Some families use metal rods on their houses to protect themselves from lightning.

13. Other families employ *sangomas* to protect themselves.
14. Then we have other families that put old car tyres on the roofs of their houses to protect themselves from lightning.

Copy and complete the following table. Which aspects of the above article show the scientific explanations, the indigenous explanations and a combination of the two explanations? Which words in the statement helped you to come to your conclusion?

Scientific explanations		**Indigenous explanations**		**A combination of the two explanations.**	
Statement number	Supporting word(s)	Statement number	Supporting word(s)	Statement number	Supporting word(s)

APPENDIX 12: OBSERVATION SCHEDULES

During the lessons on static electricity and lightning

The following questions guided me as I observed the research participants go through the activities on static electricity, lightning and the formation of the rainbow.

- Do the learners understand the task they must perform?
- Are the learners able to perform the task they are asked to perform?
- Do the learners in a group and as a whole group work as a team, helping each other, collaborating with each other?
- Do the learners arrive at some conclusion after each activity and is the conclusion based on evidence obtained during the performance of the task?
- Do the learners question each other and question the researcher in order to seek clarification or to air their own views on issues?
- Is there evidence of growth among the research participants in terms of understanding of concepts as the programme progresses?

During group discussions where argumentation was the main focus.

Students' discussion statements were analysed and evaluated in order to determine whether the statements had or contained the following:

- Claims that were not explicitly stated but implied.
- Claims that were clearly stated but with no data or evidence to support the claim. (Zohar & Nemet, 2002; Osborne, Erduran, & Simon, 2004)
- Claims that were clearly stated and were accompanied by data/evidence.
- Statements that contained rebuttals of counter claims (Kuhn, 1991; Osborne, Erduran, & Simon, 2004)
- Opposition statements that were explicitly stated.
- Statements that were reinforced or elaborated by additional data.

APPENDIX 13: REFLECTIVE ESSAY

***Write an essay on 'What I gained and learned from this experience' or* 'My reflection on the programme I went through during this research: what I gained and learned from this experience'.**

Reflect on the programme that you have just gone through. Reflect on your previous and your current positions in terms of your knowledge of science and indigenous knowledge systems and of lightning. Tell us what you thought or knew before this experience and what you now think and know. Where you have changed, tell us what made you to change. Do this by answering the following questions:

1. Before this programme what were your views about each of the following?
   - science ---

   - Indigenous knowledge ---

   - lightning ---

     ----

2. At the end of the programme what are your views about each of the following?
   - science ---

   - Indigenous knowledge ---

   - lightning ---

     ----
3. Where your views about any of the above have changed, explain what made you to change your original views.---
   ----

----

4. The following statements relate to the sessions on argumentation that you had. State whether you **strongly agree** or **agree** or **disagree** or **strongly disagree** with each of the statements by putting a tick in the appropriate box. Where necessary give a brief explanation for your choice.

   - The sessions have helped me to understand science, indigenous knowledge, and lightning better.

Strongly agree	Agree	Disagree	Strongly Disagree

     Explanation ---

   - The sessions have not helped me to understand science, indigenous knowledge, and lightning.

Strongly agree	Agree	Disagree	Strongly Disagree

     Explanation ---

   - The sessions have confused me further.

Strongly agree	Agree	Disagree	Strongly Disagree

     Explanation ---

   - The sessions allowed me to express my views on issues under discussion.

Strongly agree	Agree	Disagree	Strongly Disagree

Explanation --

- My opinion was listened to and valued by other members of the group and by the researcher.

Strongly agree	Agree	Disagree	Strongly Disagree

Explanation --

- The sessions were lively, interesting and educative.

Strongly agree	Agree	Disagree	Strongly Disagree

Explanation --

- I learned a great deal from both other research participants and the researcher.

Strongly agree	Agree	Disagree	Strongly Disagree

Explanation --

- The sessions will help me to argue effectively in life on controversial issues such as plastic surgery, euthanasia, sports and drugs, abortion, capital punishment (the death sentence), corporal punishment in schools.

Strongly agree	Agree	Disagree	Strongly Disagree

Explanation --
----

5. The experience was worthwhile.

Strongly agree	Agree	Disagree	Strongly Disagree

Explanation --
----

6. The experience was a waste of my time.

Strongly agree	Agree	Disagree	Strongly Disagree

Explanation --
----

7. Should indigenous knowledge about natural phenomena such as lightning and thunder be taught in schools? Give reasons for your views on this.

Answer ---

Reason for your answer--

----

8. If indigenous knowledge about natural phenomena should be taught in schools, who do you think should teach it? Give reasons for your answer.

Answer --

Reason for your answer ---

APPENDIX 14: IMPROVING THE QUALITY OF THE RESEARCH INSTRUMENTS.[IQRI]

Dear colleague

I am doing research on the following topic: **The relative impact of an argumentation-based intervention programme on Grade 10 learners' conceptions of lightning and thunder.**

I plan to put in place an intervention programme based on argumentation that I hope will help learners to integrate, accommodate and harmonise different explanations of natural phenomena such as lightning and thunder that come from different worldviews such as science and Indigenous Knowledge (IK).

Kindly go through the attached research instruments and make your fair and honest assessment of each of the items making up the research instruments. I attach the following research instruments:

1. Questionnaires
2. Interview items
3. Achievement tests
4. Observation schedules
5. Lesson plans, activities and worksheets
6. Reflective essays

Your assessment should consider the following*: clarity of instructions, clarity of the task given, suitability of language used in terms of both its level and its sensitivity to cultural contexts, difficult level of the task, and the relevance of the task to the issues under discussion which are*: **science, IK, argumentation, lightning and thunder**

Please use the following rating scale: Award

- 5 points for a very appropriate item
- 4 points for an appropriate item
- 3 points for a satisfactory item
- 2 points for a poor item
- 1 point for an inappropriate item

- 0 points for a completely irrelevant item.

I welcome comments on the items you think are not good enough. Tell me how you think we could improve them.

Thank you for your assistance.

Partson Virira Moyo

Please indicate the following information about yourself which I may use for comparison purposes.

Male/Female-----------Experience in years in teaching Physical Sciences-----------

Please use the attached documents to rate the items on the research instruments.

RATING SCIENCE - IKS QUESTIONNAIRE [SIKSQ] ITEMS

Item	Rating	Suggestions on how to improve it
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		

14		
15		
16		
17		

RATING QUESTIONNAIRE ON IK ON LIGHTNING AND THUNDER [QIKLT] ITEMS

Item	Rating	Suggestions on how to improve it
1		
2		
3		

RATING QUESTIONNAIRE ON IK ON THE RAINBOW [QIKR] ITEMS

Item	Rating	Suggestions on how to improve it
1		
2		
3		
4		
5		
6		
7		

RATING ACHIEVEMENT TEST ON LIGHTNING AND THUNDER [ATLT] ITEMS

Rating Section A

Rate ------------

Suggestions on how to improve it --

Rating Section B

Item	Rating	Suggestions on how to improve it
Story 1		
Story 2		
Story 3		
Story 4		
Story 5		
Story 6		
Story 7		

Rating Section C

Item	Rating	Suggestions on how to improve it
1		
2		
3		
4		

5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		

Rating Section D

Rate ------------

Suggestions on how to improve it --

RATING ACHIEVEMENT TEST ON THE RAINBOW [ATR] ITEMS

Item	Rating	Suggestions on how to improve it
1		
2		
3		
4		
5		
6		

7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		

RATING OBSERVATION SCHEDULE ON STATIC ELECTRICITY AND THE RAINBOW LESSONS [OSLSELR] ITEMS

Item	Rating	Suggestions on how to improve it
1		
2		
3		
4		
5		
6		

RATING OBSERVATION SCHEDULES ON ARGUMENTATION DISCUSSIONS [OSGDA] ITEMS

Item	Rating	Suggestions on how to improve it
1		
2		
3		
4		
5		
6		

RATING LESSON PLANS ON TEACHING STATIC ELECTRICITY [LOSEL] ITEMS

Item	Rating	Suggestions on how to improve it
Lesson 1		
Lesson 2		
Lesson 3		
Lesson 4		
Lesson 5		

RATING LESSON PLANS ON TEACHING ARGUMENTATION [LOA] ITEMS

Item	Rating	Suggestions on how to improve it
Lesson 1		
Lesson 2		

RATING ESSAYS ITEMS

Rating the essay on science and IK [ESIK]

Rate ------------

Suggestions on how to improve it --

Rating the essay on what I gained [EWIG]

Rate ------------

Suggestions on how to improve it --
