Title: Exploring grades 11 learners' scientific and indigenous worldviews of selected phenomena relative to traditional expository and argumentation instruction

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DECLARATION

I declare that: "Exploring grades 11 learners' scientific and indigenous worldviews of selected phenomena relative to traditional expository and argumentation instruction" is my own work; that it has not been submitted before for any examinations or degree purposes in any other university, and that all sources I have used or quoted have been indicated and acknowledged by complete references.

CHRISTOPHER DIWU

SIGNED: ……………………………… DATE: July 2016

DEDICATION

In loving memory of Christopher Diwu

The man who gets the most out of life is not the one who has lived longest, but the one who has felt life most deeply. Although Christopher Diwu did not live to see the submission of his thesis, this is something he would have loved to see. Before suddenly passing on at the age of 52, Christopher Diwu penned a number of research publications in science education. He was known to be an outstanding emerging scholar and researcher, an inspirational pan-Africanist and a visionary whose intellectual drive, passion and commitment for the transformation of South African science education to the inclusion of indigenous knowledge system (IKS). This dissertation is dedicated to late Christopher Diwu, his bereaved and bravest family and friends.

On behalf of Chris Diwu's family and the entire Science and Indigenous Knowledge Systems Project (SIKSP) Family I want to express my sincere gratitude to Paul Iwuanyanwu who left his own work to see to it this draft thesis reaches the present form by reformatting the text and pictorials to a more readable and fluent form-Supervisor: Meshach Mobolaji Ogunniyi

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ABSTRACT

In response to the emerging multicultural classrooms in South Africa, the amended National Curriculum Statement (NCS) for grades R–12, in the light of current curriculum policy and the NCS (Grades 10–12), has proposed the inclusion of Indigenous Knowledge Systems (IKS) in the school science curriculum. Interfacing the two knowledge systems namely, science and IKS have implications for curriculum planning and instructional practices. This is more so if one considers the fact that both systems of thought are based on distinctively different ontological, epistemological, metaphysical and axiological assumptions.

In pursuance of the demand to integrate the two knowledge corpuses, this study sought to explore school science and indigenous worldviews of grades 11 and 12 learners exposed to Dialogical Argumentation Instruction (DAI) as well the Traditional Expository Instruction (TEI) on selected natural phenomena. The aim was to explore the scientific nature of the learners' indigenous knowledge (IK) presupposition in relation to those of school science and to determine their level of compatibility in terms of the content and pedagogical practices.

The rationale for the choice of selected phenomena across different school science topics was to interrogate to what extent IK was amenable to certain school science topics. Furthermore, the variation of the selected phenomena was also to determine how the learners' cognitive stances shifted as a result of the nature of a particular concept. The instructional materials have been designed to reflect as much as possible the learners' life-world experiences so as to elicit areas of commonality and differences between school science and their IK.

The study adopted method is a mixed-method where quantitative data is augmented with qualitative data. Four comparable schools were selected on a volunteer basis, with two being selected for DAI approach and the other two for the TEI approach. A pre-post-test quasi-experimental design for evaluating the intervention was employed for both groups. The DAI intervention was implemented through a Participatory Action Research (PAR) design while the TEI intervention followed the normal Pace-Setter Instruction (PSI) design. The TEI approach used the linear topic approach for making sure that teachers keep up with the time frames for completing the syllabus. On the other hand, the DAI approach linked similar concepts across different topics using argumentation to facilitate learners' interactions in making sense of the concepts in unfamiliar contexts.

The data were collected through classroom observations, learners' survey questionnaires, learner worksheets and interviews. The data collected were then critically analysed and discussed in terms of argumentation theories as espoused by Toulmin's (1958) Argumentation Pattern (TAP) which focused on logical arguments embraced by school science and the Contiguity Argumentation Theory (CAT) (Ogunniyi, 2002) which explains the contexts in which various border crossings occurred. In addition, Hempel's (1966) Bridge Principle (which provides the structure of internal principles inherent in scientific explanations) was used as the platform for connecting the two distinctly different worldviews.

The findings show that:

- The introduction of IK into school science lessons created much enthusiasm among the learners because they saw the relationship between their IK and school science.
- Since school science and IKS are premised on distinctly different worldview presuppositions, the TEI learners (i.e. those not exposed to the DAI) appeared to experience cognitive conflicts and a form of cultural violence in that their IK was relegated to the background of school science.
- Learners exposed to the DAI approach did not only enjoy IK in their lessons but also displayed higher thinking and reasoning patterns that enabled them to link effortlessly their IK with school science.
- As opposed to the TEI group which was able to cope with only simple linguistic concepts and personal everyday meanings, the DAI learners displayed eminently higher language proficiency and abstractions.
- Although the learners' attitudes towards some items on the nature of science (NOS) were similar, the attitudes of the DAI group learners seemed to be better than those in the TEI group learners with respect to IKS.
- The inclusion of IK to some extent seems to have moderated the negative effect of the school science on the learners' worldview as well as enhanced their self-image.

While the full summary of implications and recommendations are provided, a key summary of the implications of these findings seems to point to the role of IK in science teaching and how to enhance the learners' efficacy in finding cognitive connection between IK and school science. This also implies that teachers and other stakeholders (e.g. curriculum planners, subject advisers and textbook writers) are knowledgeable of NOS and the NOIKS and associated explanations to know how to connect the two worldviews. Finally, a typology that can serve as a guide for interrogating the nature of phenomena and their explanations is proposed as a way to facilitate the connection between school science and IK.

KEY WORDS:

- School science worldview
- Indigenous knowledge systems worldview
- Selected natural phenomena
- Toulmin argumentation pattern (TAP)
- Contiguity argumentation Theory (CAT)
- Internal and Bridge principle
- Nature of science and IKS
- Dialogical argumentation instruction- bridge principle
- Traditional expository pace-setter instruction
- Worldview presuppositions

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ABREVIATIONS USED IN THIS STUDY

DAI-Bridge	–	Dialogical Argumentation Instruction Bridge
TEPSI	-	Traditional Expository Pace-Setter Instruction
PSI design	-	Pace-Setter Instruction design
PAR design	-	Participatory Action Research design
IKS	-	Indigenous Knowledge Systems
IK	–	Indigenous Knowledge
CAT	–	Contiguity Argumentation Theory
TAP	–	Toulmin's Argumentation Pattern
CBC	-	Cognitive Border Crossing
SLBC	-	Socio-Linguistic Border Crossing
NOIKS	–	Nature of Indigenous Knowledge Systems
NOS	–	Nature of Science
IKWS	-	Indigenous Knowledge Systems Worldview
SSW	-	School Science Worldview
LTSM	–	Learning and Teaching Support Materials
LoLTA	–	Language of Learning, Teaching and Assessment
NCS	–	National Curriculum Statement
FGIS	–	Focus Group Interview Schedule
SIKSP	–	Science and Indigenous Knowledge Systems Project
SSI	–	Socio-Scientific Issues
WCED	–	Western Cape Department of Education
DBE	–	Department of Basic Education
NCS	–	National Curriculum Statement
TUNOS	-	Teacher Understanding of the Nature of Science
TUNOIKS	-	Teacher Understanding of the Nature of Indigenous Knowledge Systems

OPERATIONAL DEFINITIONS

Worldview – To Kearney (cited in Ogunniyi, et al, 1995) "A world is a culturally organized macro-thought: those dynamically interrelated assumptions of a people that determine much of their behaviour and decision making, as well as organizing much of their body of symbolic creations…and ethno-philosophy in general" (p. 818).

Science/IKS curriculum – This term refers to the new South African school science curriculum which was as a result of the inclusion of Specific Aims 3 which calls on teachers to integrate IKS within the school science syllabus (Department of Education (DoE), 2002).

Language of Instruction - The language in which teaching and the learning materials are presented in, in the classroom.

L**anguage of learning and teaching (LoLT)** – The official language used in learning, instruction and in which assessment of outcomes are carried out rather than referring only to English and Afrikaans as was the case during apartheid era (DoE, 1997).

Language in Education Policy (LiEP) – A government policy within South Africa's education system which was enacted to provide a framework for the promotion and protection of all languages used in the country (DoE, 1996).

Indigenous Knowledge Systems (IKS) – A system of thought peculiar to people of a local geographic location or socio-cultural environment (Ogunniyi, 2008, p. 6).

Preconceptions/Prior knowledge – Pre-existing information or prior understandings held by learners before instructions begin. These can either support or interfere with future understandings (Hayward, 2014).

Socio-cultural Critical Constructivism – Constructivism that takes cognizance of learners' socio-cultural environment and background.

National Curriculum Statement – A policy document setting guidelines for curriculum implementation for the Further Education and Training band of the education system in South Africa (DoE, 2002).

Assessment – A means of evaluating students' understanding or knowledge using a form of achievement test, questionnaires or interviewing process.

Conception – A mental idea or one's perception about the nature of a given subject matter.

Controversial scientific issues - According to Hayward (2014), 'controversial science issues are scientific topics, that by their nature create discussions, debates and questions because students are intrigued by these issues.' (p. 26).

Constructivism – refers to a number of related ideas in learning theory that share the notion that learners must develop or construct understanding based on their prior experiences and personal experiences with objects and other learners (Ward & McComas, 2014).

Discrepant phenomena - According to Baeder (2014), discrepant events or puzzling phenomena are events that appear to contradict the laws of nature or what students expect to occur…thus causing students to wonder why a particular event or phenomena occurred.' (p. 36).

Nature of Science (NOS) – All explicit or implicit underlying assumptions underpinning the epistemology of school science.

Nature of Indigenous Knowledge Systems (NOIKS) - All explicit or implicit underlying assumptions underpinning the epistemologies of indigenous knowledge systems.

Teacher efficacy - deals with the ease and confidence in which a teacher is able to implement a curricular innovation in the classroom.

Symbolic violence - is assumed to occur when a person use his/her authoritative position and ignores other peoples' views other than his/her own.

CHAPTER ONE
INTRODUCTION TO THE STUDY

1. 1 INTRODUCTION

As the world is becoming a global village, science classrooms are also becoming multicultural. This phenomenon has thus resulted in many countries redefining their science curricula to reflect the multiplicity of their science classrooms. However these curricula interventions are always met with a number of challenges as most teachers are trained in the western-Eurocentric science; thus familiar with that worldview than that of the learners coming from non-westernized socio-cultural backgrounds (Ogunniyi, 2007). For example, Aikenhead and Jegede (1999) have pointed out that the learners from non-westernized backgrounds tend to experience cognitive dissonance when their state of reality is at odds with that of school science.

After the first democratic election in South Africa in 1994, as a means of authenticating the learners' [students] experiences of school science, a new curriculum was enacted in 1997. One of the provisions of this New South African curriculum was the inclusion of IKS within the science curriculum. For South Africa, the rationale for the inclusion of IKS in the curriculum was largely premised on South Africa's socio-political history and the need to redress the past educational imbalances that resulted from 350 years of colonisation (DoE, 2002; Jansen & Christie, 1999; Le Grange, 2004; Odora-Hoppers, 2004; Ogunniyi, 2007). Furthermore, South African curriculum documents all highlight that IKS provides a learning experience that makes the learning of school science relevant to the learners' [students] socio-cultural backgrounds (DoE, 2002, 2009, & 2011).

While the rationale for the inclusion of IKS in the science curriculum is commendable, the implications of how the natures of the two thought systems of school science and IKS impact on the implementation are not clearly articulated within the curriculum documents. It is in this regard that this thesis sought to explore the opportunities and challenges associated with implementing an IK integrated science curriculum in the country. The thesis therefore investigated the scientific and indigenous knowledge worldviews of two groups of grade 11 learners' on selected scientific concepts. These groups were respectively exposed to the traditional expository instruction and the dialogical argumentation instruction.

This thesis is divided into five chapters where chapter 1 constitute the introduction to the study; chapter 2, the literature review; chapter 3, the methodology; chapter 4, data analysis and discussions while chapter 5 deals with the conclusions. Chapter 1 is divided into the introduction, the motivation for the study, background to the South African education system, the problem statement highlighting the challenges in integrating the mainstream school science with IKS, the purpose of the study, the research questions, and the delimitations to the study, the limitations and finally, the significance of the study. Chapter 2 focuses on the literature review which is divided into theoretical considerations, practical considerations and the theoretical framework underpinning the study. Chapter 3 deals with the methodology highlighting the research setting, sample selection procedures, research methods and designs, research instruments validation and concluded with ethical considerations. Chapter 4 deals with the presentation of results, analysis and discussions of the data and finally, with a summary of findings. Chapter 5 presents the conclusions, implications of the findings, limitations to the study and finally, with the recommendations coming out of the study.

1. 2 MOTIVATION FOR THIS STUDY

"Critical thinking is the process we use to reflect on, assess and justify our own assumption as well as others' ideas, work and actions" (Fogler, 1999).

Various scholars in various parts of the world have come to recognise that the underperformance by the majority of learners, especially those from non-westernised socio-cultural backgrounds, is largely due to the differences between their worldviews and that of school science (e.g. Aikenhead, 1996, 1997, 2001, Aikenhead & Jegede, 1999; Battiste, 2002; Cobern & Loving, 2000; Corsiglia & Snively, 2001; Diwu & Ogunniyi, 2012; Fakudze, 2004; Jegede & Aikenhead, 1999; Liphoto, 2005; Ninnes, 2000; Ogunniyi, 1988; Ogunniyi, Jegede, Ogawa, Yandila & Oladele, 1995; Ogunniyi, 2007; Ogunniyi & Hewson, 2008; Phelan, Davidson & Cao, 1991; Sutherland & Reg-Dennick, 2002).

The observation above has led many governments to call for the inclusion of learners' indigenous knowledge (IK) in the mainstream school science curriculum. As has been highlighted in the introduction, Fleer (1999) has argued, school science originated from a conglomeration of Indigenous Knowledges (IK) from all over the world, and for that reason, many governments have advocated the inclusion of IKS in their science curricula. The assumption was that such inclusion could help mitigate the suppressive and hegemonic influence of school science on learners' IK. To this effect some scholars (e.g., Corsiglia & Snively, 2001) have argued that IK does have elements of modern science which the latter has not yet come to recognise. The same argument has been used by many educational departments, including the South African Department of Education (DoE), to demand that the new science curriculum include IK. The new science curriculum statement argues further that a lot of valuable IK marginalized or lost during the period of colonization needs to be rediscovered and used for the socioeconomic development of South Africa (DoE, 2002). The key issues addressed in the new curriculum include the following:

- There is lot of scientific ideas within IKS that has been suppressed or lost and therefore need to be rediscovered and reexamined to determine its value for the present day South Africa (DoE, 2002; Le Grange, 2004; Ogunniyi, 2007).
- People (including scientists) tend to use different ways of thinking for different situations in their daily lives. At times they use "religious frameworks" while at other times they adopt "other ways of giving value to life and making choices" (DoE, 2002, p. 12) and that school learners think in terms of multiple worldviews where they cross the cultural borders from their homes to school and vice versa (Aikenhead and Jegede, 1999; DoE, 2002; Jegede & Aikenhead, 1999 Ogunniyi, 2007 and Onwu & Mosimege, 2004).

However, as Ogunniyi (2007) have pointed out, the calls for the integration of school science with IKS have for the larger part ignored the fact that the two systems of thought are largely incompatible with each other since they are premised on diverse epistemic, ontological, axiological and metaphysically beliefs. For instance, Onwu & Mosimege (2004) speaking from a South African context, lamented the fact that the efforts of integrating science and IKS failed to address "…the engaging tension perhaps, amongst learners in our schools, between indigenous and scientific ways of knowing with the possibility of each stimulating and supporting the other in our classroom contexts."(p. 1). In response to the latter statement by Onwu & Mosimege (2004), Ogunniyi (2004) stated that the failure is rather due to the call for the integration of IKS into the science curriculum having underrated the teachers' lack of training in as far as their awareness of, and understanding of the nature of both school science and IKS.

In view of the latter, other scholars such as Cobern & Loving (2001) have argued that, IKS would be better off if it were to be treated as a separate knowledge and not be integrated with school science. Cobern & Loving perhaps based their thinking on the fact that school science currently enjoys a prestigious position within the scientific community and putting it alongside IKS would see IKS being further relegated to the background; and thus labelled as an archaic form of knowledge. Similar to the views of Cobern & Loving, Finley (2009**)** and Onwu (2009) have both questioned the idea of giving school science and IKS equal status since they address different issues and play different roles. For the same reason they wonder if the two systems of thought should in fact be considered as complementary or competitive.

Based on the view of some scholars to integrate IKS with school science (e.g., Corsiglia & Snively, 2001), and others advocating that the two be treated separately (e.g., Cobern & Loving, 2001), the question about their complementarity or competitiveness persist (e.g., Finley, 2009; Onwu, 2009). It was in light of this that the study sought to explore the possibility of finding the connecting points between the two systems of thought. Finding such connecting points is important particularly in view of the claims that have been made about the cultural and educational value of IKS in terms of the assumed scientific content hidden in IKS (e.g., Aikenhead, 1996; Corsiglia & Snively, 2001; DoE, 2002; Le Grange, 2004; Ogunniyi, 1988; Ogunniyi & Ogawa; 2008). In this regard, Ogunsola-Bandele (2009) have urged teachers and educators to interrogate the scientific nature of claims made through IKS so as to raise the status of IKS within the scientific community. Emeagwali (2003) has also alluded to the latter statement when she stated that IKS should also undergo similar processes of verification as the western Eurocentric science.

However, with regard to finding connecting points or areas of compatibility or otherwise between school science and IKS the two systems must be able to 'talk' to each other (Fleer, 1999) and that they should be able to argue or converse on equal grounds where no one worldview is seen to be superior to the other (Ogunniyi & Ogawa, 2008). In other words, each system should be evaluated on its own terms (Battiste, 2002; Ogunniyi & Hewson, 2008).

Having acknowledged the merits of having both worldview systems of thought as being worthy of scholarly attention, a bridge mechanism that would facilitate the integration or interface of the two systems is proposed. In this regard, argumentation which takes cognisance of the nature of both worldview presuppositions has been adopted as the appropriate framework for this study. By its nature argumentation is an appropriate rhetorical tool for interrogating conflicting viewpoints and for reaching consensus based on valid reasons. The same process probably takes place at the micro-cognitive level where two conflicting worldviews are in need of conceptual abrogation (Ogunniyi, 2007a).

However, in view of the differences between the scientific and indigenous systems of thought, the value placed on both systems and the need to reconcile them, this study goes beyond the notions of border crossing which focus on explaining the differences between the two worldviews, suggesting a dichotomy between the two. Argumentation as used in this study looks at the underlying presuppositions that define each worldview and seeks to find connecting points which may render the two worldviews compatible with each other. As (Erduran, 2006) has pointed out, science learning is an argumentative exercise and a human construct and thus may also apply to IKS although its argumentation may take a different form.

For example Ogunniyi (1988) has argued that argumentation within the IKS corpus may be in form of proverbs, metaphors, idioms, drama, songs, graphics, storytelling, dance and other symbolic referents. To elaborate on IK, Battiste (2002) argues that IK is "often oral and symbolic, it is transmitted through the structure of Indigenous Languages (IL) and passed on to the next generation through modelling, practice, animation, rather than through written word" (p. 2). She further argued that IK has its own internal consistency and ways of knowing, thus cannot be fully comprehended using western science criteria as "it does not mirror classic Eurocentric orders of life" (ibid). The latter statement suggests that, not every aspect of IK will necessarily 'make sense' or subscribe to the normal logical sense as in school science.

In concluding this section, this study thus sought to explore learners' school science as well as indigenous worldviews using argumentation as a bridging mechanism on selected conceptions relating to some natural phenomena. In mitigating for the differences between school science and IKS, an argumentation framework consisting of Toulmin's (1958) Argumentation Pattern (TAP), Ogunniyi's (2002) Contiguity Argumentation Theory (CAT) and Hempel's (1966) Bridge Principle was found to be relevant for this study. As Battiste (2002) has argued, each worldview has its own internal consistency. In other words, every scientific explanation finds its relevance and rationality upon the understanding of the principles and beliefs that underpin the worldview that created its knowledge claims (Kelly, Carlsen & Cunningham, 1993; Ogunniyi & Ogawa, 2008).

Exploring diverse worldviews calls for an 'integrative paradigm shift' (Odora-Hoppers, 2009) in using critical thinking as a tool to reflect on, assessing and justifying of our own assumptions and others' ideas, work and actions regarding the problems we face in society (Fogler, 1999). In this regard, the adopted framework helped the researcher not only in exploring the underlying presuppositions peculiar to each thought system, but to also in constructing cognitive links between the two systems of thought.

1. 3 A BRIEF BACKGROUND TO THE APARTHEID SOUTH AFRICAN EDUCATION SYSTEM

Before discussing the South African school science content as well as the challenges it poses for its integration with IKS, it is apposite to first give a brief background to the thinking that influenced how the apartheid South African education system leading to the present science curriculum was designed.

As is the case worldwide, education systems are influenced by various worldviews and values. Christie (1991) points out that since education is not neutral, different people and societies have different aims for education premised on their diverse worldview systems. In the context of the nationalist-conservative traditions thought, various opinions and aims for education as cited in Christie (1991, p. 12 – 13) are as follows:

- As stated by le Roux in 1945, a National Party politician stated the following regarding Black people in South Africa, "We should not give the Natives any academic education. If we do, who is going to do the manual labour in the community?"
- Later, at the start of the introduction of Bantu Education, Hendriek Friederick Verwoerd who was Minister of Native Affairs in 1953 also stated that, "When I have control over native education, I will reform it so that natives will be taught from childhood that equality with Europeans is not for them."

The two excerpts above highlight the views of those who were in power in the pre 1994 era and hence the nature of the education system in South Africa. In line with the various views of the apartheid oppressors pre 1994, the South African education system was divided along racial, ethnic and demographic boundaries, with 19 separate education departments, schools and residential locations (Enderstein & Spargo, 1998). However, Cross (1992) points out that the schools crisis between 1976 and 1980 students'uprising had an effect of committing many social scientists to a more serious approach in studying education in South Africa. He further points out that the De Lange Report in July 1981 as well as the Human Sciences Research Council reports both identified apartheid as a cause of conflict in South Africa.

To this effect, as a result of political pressure and sanctions leveled against South Africa, the old apartheid regime decided to unban all political parties and released all political prisoners unconditionally. This was followed by the announcement of the 1994 first democratic elections which saw the Black populace being involved in elections for the very first time. In the meantime while planning the election, the apartheid government went into talks with the African National Congress (ANC) through forums such as the Congress for the Democratic South Africa (CODESA) 1 and 2 where the future of all the South Africans was discussed.

After 1994 all the 19 separated departments were combined into one educational system; where all learners were suddenly allowed to choose which school and area they may choose to study at. However, the school infrastructure differences, poverty levels of the different communities as well as the requirements from the more White effluent schools did not change. Now, even after 22 years of 'freedom' or the scrapping of apartheid on paper, very little has changed between schools that are predominantly White and those that are not. The only thing that is common in the new curriculum is the content to be taught which is examined at the end of the year involving every school-going child irrespective of their socio-cultural backgrounds. The critical issue here is that despite the new democratic dispensation not much has changed in terms of educational opportunities. As Cross (1992) further stresses, the nationalist-conservative school of thought dominated historical literature on education both before and after the consolidation of the apartheid system in education.

For instance, with few exceptions, White children still attend better resourced schools than the children of colour. Hence, the idea that children can attend any school they want is still a pipe dream. The consequence of this situation is that the children of colour generally underperform in science both in the national and international assessments (Reddy, 2006). Another issue of concern, under the guise of 'one curriculum for all' has been the conspicuous reduction of scientific concepts and generalizations in the present physical science curriculum.

The support for the latter can be illustrated by a reconstruction of a graph depicting the matric results between 1976 and 1982 by Shindler and Hartshorne, cited in Christie (1991).

Table 1.1: Matric results in South Africa from 1976 to 1982

Year	Matric candidates	University entrance passes
1976	6,000	2,000
1977	8,000	1,500
1978	6,000	2,500
1979	12,000	3,000
1980	30,000	3,000
1981	44,000	4,000
1982	54,000	4,000

Source: Reconstruction of matric results graph by Shindler and Hartshorne cited in Christie (1991,p. 121)

The table above shows that, between 1976 and 1978, the number of students reaching standard 10 or matric fluctuated between 6000 and 8000, thus averaging 7000 students. For the three years the corresponding number of students with university entrance matric passes were 2000 on average. From 1979 till 1982 the number of students reaching matric grew exponentially from 12000 to 54000 in just 4 years, suggesting more access to education. A close look at Table 1.1 shows that, despite the exponential increase in the number of students reaching matric in the four years, their performances in matric were somewhat very stagnant if not disastrous. In other words, if we take into consideration the large number of matric candidates in those years, we should have had a much significant increase of matric passes with university entrance as opposed to just 4000 students.

As alluded by Reddy (2006), the underperformances of students in science cannot be divorced from their general underperformances in the matric results as shown in table 1.1. In other words, the double figures of 4000 (for 1979 through to 1982) compared to the initial university entrance passes of 2000 during 1976 through to 1978 cannot be seen as an improvement when compared to the very large numbers of learners writing matric examinations during the 1979 to 1982 period. The trend for matric passes towards the future as observed in table 1.1 seem to suggest that, the streamlining of the syllabi to make it easy for students to reach matric will not in itself guarantee that more students will perform sufficiently at matric to gain university entrances.

From a personal experience, I have observed how the science syllabus has been stripped off some of its content in the name of 'old syllabus' or 'outdated content'. What this ultimately meant, was that, students were expected to grapple with some new scientific concepts without having first mastered prerequisite concepts. In some instances, many concepts are oversimplified to such an extent that misconception of brought into the content.

The first time I did my matric or standard 10 in 1979 was under the then, Department of Education and Training which was also under the Joint Matriculation Board (JMB) governing all the education departments in the country. At that period, I was doing higher grade Physical Science which had a total marks of 400 as compared to the 300 marks stipulated in new National Curriculum Statement. From one year to another, the Physical Science syllabus has been stripped of content to make space for various outcomes such as the division of content into the three learning outcomes or specific aims. These will be elaborated further in the following section describing the current physical science syllabus in the country.

1. 3. 1 The current physical science syllabus in South Africa

For the Further Education and Training (FET) phase (grades 10 to 12), physical science as **a** school subject is divided into Physics and Chemistry where Physics constitutes the first paper and Chemistry the second paper. The Examination Guidelines for grade 11 Physical Science provides the weighting of the prescribed content for the Physics section out of which the selected phenomena in this thesis are selected.

Table 1.2: Examination Guidelines for grade 11 Physics section

PAPER 1: PHYSICS FOCUS		
CONTENT	**TOPICS**	**MARKS**
1. Mechanics	**Vectors in two dimensions** (resultant of perpendicular vectors, resolution of a vector into its parallel and perpendicular components), **Newton's Laws and Application of Newton's Laws** (Newton's first, second and third laws and Newton's law of universal gravitation, different kinds of forces: weight, normal force, frictional force, applied (push, pull), tension (strings or cables), force	68

		diagrams, free body diagrams and application of Newton‘s laws (equilibrium and non-equilibrium) **27 hours**	
2.	**Waves, Sound & Light**	**Geometrical Optics** (Refraction, Snell‘s Law, Critical angles and total internal reflection), **2D & 3D Wave fronts** (Diffraction) **13 hours**	32
3.	**Electricity & Magnetism**	**Electrostatics** (Coulomb‘s Law, Electric field), **Electromagnetism** (Magnetic field associated with current-carrying wires, Faraday‘s Law), **Electric circuits** (Energy, Power) **20 hours**	50
	TOTAL		150

Source: Curriculum and Assessment Policy Statement, (DoE, 2012, p. 126)

Table 1.2 above show that, Mechanics account for 45%, Electricity and Magnetism for 33% while Waves, Sound and Light account for about 22%.

The Curriculum and Assessment Policy Statement (CAPS) published by the Department of Basic Education (DOE) stipulates the concepts that need to be taught as well as the term and time frame within which each topic should have been completed, thus serving as a pace setter for the completion of the syllabus. The CAPS document further provides four-level assessment taxonomy as a tool for formulating questions to gauge learners' cognitive abilities at various levels. The cognitive levels specified in a descending order are: level 4-evaluation and synthesis; level 3–analysis and application; level 2 – comprehension; and level 1 – recall of simple information. For Physics these cognitive levels are weighted at 10%, 40%, 35% and 15% respectively. These knowledge areas in turn, are divided into three specific aims namely: knowledge, investigations and socioscientific issues. A closer look of these aims would easily reveal that they deal with the cognitive, psycho-motor and the affective aspects of learning e.g. the application or relevance of science to society. This third aim forms the central concern of this study.

The underlying assumption of the third aim above is that for school science to be relevant it has to have a direct application to the society. This implies that all learners, regardless of their sociocultural backgrounds, should find science relevant to their daily lives, including their indigenous worldviews which shape their lives outside the school environment. It is in this connection that the third aim in the new science curriculum implores teachers to include learners' indigenous knowledge (IK) and practices in the science classroom context (e.g., see Corsiglia & Snively, 2001; DoE, 2002; Department of Basic Education, 2012; Emeagwali, 2003; Le Grange, 2004).

In order to incorporate school science knowledge and that of the learners' IK, specific aims 1 relating to understanding of school science knowledge has to be negotiated knowledge and supported by investigations (specific aims 2) that are amenable to both school science and IK. The concept of negotiated knowledge is not a new idea as it is premised on the major learning theories of Piagetian and Vygotskian constructivism where knowledge is either negotiated through some form of dialogical argumentation at various levels e.g., within one's self (intra-arguments) or within a group (inter-arguments) or across groups (intra-argumentation) (Ogunniyi, 2007) just as the science concepts in the areas highlighted in Table 1 above have been arrived at through the process of argumentation, negotiation and dialogue within the scientific community.

As a means to make learners ready to engage in scientific enquiry, 25% of school science teaching and learning is dedicated to practical work. This is done so that learners can learn the practical skills to handle equipment that they can use to verify some of the scientific claims that they are supposed to understand. In this regard, negotiations take place as learners attempt to make meanings between their apparent observations and actual results obtained through practical work. It is against the backdrop of their ability to analyze, synthesize and evaluate information (cognitive levels 3 & 4) that the learners can begin to argue effectively and thus be able to make decisions about important socio-scientific issues that concerns the society at large. The next section will elaborate briefly on this issue of integrating school science with learners' IK by alluding to some historical antecedents.

1.4 PROBLEM STATEMENT

In contrast to the apartheid era Bantu education, the New South African government formed in 1994 enacted a new South African curriculum in 1997. This curriculum called for the integration of learners' indigenous knowledges into the formal school science curriculum (DOE, 2002, 2003, 2009, 2011). The rationale for including IK in school was justified by the argument that the colonization of the South Africa for about 300 years had robbed the country of the IK that had sustained it for centuries and that this needs to be redressed (DOE, 2002; Jansen & Christie, 1999; Le Grange, 2004; Odora-Hoppers, 2004; & Ogunniyi, 2004, 2007a). The second reason given was that, there is valuable knowledge embedded within the country's indigenous knowledge systems (IKS) that needs to be rediscovered and utilized for the socioeconomic development of the country (Corsiglia & Snively, 2001; Department of Education, 2002; Le Grange, 2004). The third reason proffered the inclusion of IKS provides a learning experience that makes the learning of school science relevant to the learners' sociocultural backgrounds (DOE, 2002, 2009, & 2011).

Despite the scrapping of the Group Areas act of 1953 and lately, the commencement of the new democratic dispensation South Africa is still divided into nine provinces with some carrying the baggage of poor infrastructural facilities of the apartheid past. Some of the provinces are largely rural while others are urban, semi-rural or peri-urban. The issue of unemployment resulting in the influx of people from the rural to urban communities as well as the lack of proper infrastructures in the rural areas has led to the overcrowding especially the township schools. While still having the various provincial peculiarities and diverse education systems, there is one curriculum that everyone in every province should follow.

In some provinces the majority of schools are in the urban areas and in others mostly rural. Based on the various challenges already mentioned, the disparities in the kind and quality of education received by the learners still pose a great challenge for the provincial and national Education departments. The various training workshops in the various provinces in the country focus largely on training the teachers on how to plan the completion of the syllabus than the understanding of the content. Despite the disparities, however, the curriculum seems to be assessment-driven and all that matters is learners' achievement in the matriculation examination. This setting seems to be one of the major obstacles in the realization of the objective to make the curriculum socially and culturally relevant to the masses of most learners.

In addition to the issues above, the curriculum itself has been marred with various implementation challenges such as: the issue of teaching resource materials; teachers' poor preparation or unpreparedness, opposition by teachers and other key stakeholders to the top-down approach used in the implementation of the new curriculum, the demand to include learners' IK in science lessons, etc. Besides, most teachers are trained in Eurocentric scientific worldviews and thus familiar with only that worldview and many other associated challenges including: the lack of learning and teaching materials; the teaching and learning of science in a second or third language; under-representation of the learners' IK in the science textbooks; etc. e.g. Janseen & Christie, 1999; Ninnes, 2000; Ogunniyi, 2004, 2007a). As a result of the above, Aikenhead and Jegede (1999) have argued that learners from non-westernized backgrounds experience cognitive dissonance when their state of reality is at odds with that of school science.

However, it must be admitted that the curriculum demand for teachers to include IKS in their science teaching raises various challenges that need to be addressed. Doing this without due consideration for teacher training and available teaching and learning materials seem to underrate the enormity of the challenges. Among others, is the issue of incompatibility between the two knowledge systems and the differences in their epistemic, axiological, ontological and metaphysical belief is a concern. These differences in turn raise a number of crucial questions such as: (1) finding aspects of IK and school science that are compatible (Finley, 2009 & Onwu, 2009); and (2) finding instructional strategies that can create an intellectual space for a sort of dialogue to take place between the two thought systems to attain cognitive harmonization (Diwu & Ogunniyi, 2012; Ogunniyi, 2007a, Ogunniyi & Hewson, 2008; Ogunniyi & Ogawa, 2008).

As Battiste (2002) and Ogunniyi & Hewson (2008) have noted, both systems of thought should be evaluated and validated on their own terms and conditions. In addition, a bridge principle should be sought that would facilitate a form of dialectic discourse between the two. This implies finding appropriate instructional strategies that could help create the necessary environment for conceptual appropriation and integration of the two thought systems (Ogunniyi, 2007a). For example, in line with the stipulation for teachers to include IK within their teaching in science classrooms, Ogunsola-Bandele (2009) has argued that teachers have the responsibility not only to interrogate the nature of scientific arguments, but also within their learners' indigenous systems. How all this will be possible is at the heart of what will follow throughout this thesis.

1.4.1 The structure of the Physical Science syllabus

It is difficult to find a space in the present structure of the physical science syllabus or any place to insert IK-based concepts without dislocating whole structure (see Table 1.2). What one finds instead is a collocation of abstract science concepts expressed in a manner which is hard to connect to learners' socio-cultural backgrounds. According to Jegede (1996), these 'hierarchies are dichotomized as abstract-concrete, rational-emotional, symbolic-sensual, objective-subjective, quantitative-classificatory, simple-complex…' (p. 6). These, as has been highlighted by the assessment taxonomy for the South African science syllabus, categorizes knowledge to two levels of difficulty – low and high. Jegede argues further that at the low level of organization, knowledge is seen to be simple, concrete and classificatory while at the highest level it is seen to be complex, abstract and quantitative. In contrast, he argues that knowledge within an African IK-based perspective is very versatile to allow its use and application in as many contexts as possible.

Consequently, a close look at the cognitive levels specified in the structure of Table 1.2 seem to show an undesirable unintended outcome. For example, cognitive level 2 – comprehension and cognitive level 3 – analysis and application are both weighted at 35% and 40%. On the other hand, cognitive level 1 – recall of simple information is weighted at 15 % while cognitive level 4 – evaluation and synthesis is weighted at 10%.

The above allocations suggests that cognitive level 2 and 3 are given more prominence. Ironically, the linear topic oriented structure of Table 1.2 does not seem to be in line with the aims of making sure that learners can attain to optimal performance in terms of the attainment of cognitive levels 2 (comprehension) and 3 (analysis and application). In order to achieve the latter, quoting Sutton, Dlodlo asserts that, the words a learner choose must 'be necessarily be interpretive instruments of understanding' (Dlodlo, 1999, p. 323). For example, one of the challenges concerning the integration of diverse worldviews is the compartmentalization of school science as if there are no alternative ways. This is also echoed by Ninnes (2000) who argues that IK is very much underrepresented within the school science textbooks. In his view, very little or no school science exemplars of scientific concepts relate to the learners' IK.

The topic approach used in the Physical Science syllabus effectively means that learners will have to go over the same concepts each time they start a new topic as dictated by say, moving from mechanics to electricity. For example, in mechanics the concept of force is expressed differently from that of electromotive force produced by a cell or a battery. While these distinctions help in the organization of knowledge and setting of the context for the concept, they, for most of the time restrict the learners' understanding of the concept to one context. For example, learners usually learn the different formulae for representing force by rote learning without understanding how the various quantities that make up the formula relate to one another. The force relationships between mass and acceleration are the most basic and understood ones while the force resulting from two charged particles or two large gravitational bodies or magnetic objects are difficult to comprehend. Besides the conceptual challenges associated with over-compartmentalization the various big ideas are taught and assessed as a bunch of incoherent informational items which learners are forced to learn by rote learning.

In other words, scientists develop models using one concepts in order to use the same concepts in unfamiliar contexts, thus the enhancement of comprehension as well as enhanced abilities for analysis and application of scientific concepts. This also enables scientists to be able to develop formulae of the same mathematical forms using different variables.

Below is a force field approach which exhibits a thematic approach where the concept of force can be dealt with in a holistic manner.

Table 1.3: The concept of force in various areas of physics are highlighted below

SECTION	TYPE OF FORCE (CAUSE)	MEDIUM & SOURCE	EFFECT
Mechanics: Force (F)	**Contacting forces:** F = ma, F = -Kx	**Body with mass M:** 1. By a Horizontal acting external force. 2. Connected to a spring field	Acceleration, velocity, de-acceleration or a balancing effect.
	Non-contacting forces: F = mg, F = (GMm)/r^2	**Body with mass M:** 1. Earth-body gravitational field 2. Earth-planet gravitational field	Gravitational acceleration, terminal velocity and gravitational attraction
Electrostatics Force (F) and	**Non-Contacting forces:**	**Particle with charge q:** 1. Between two charges	Attraction or repulsion

Force (V)	$F=(Kq_1q_2)/r^2$		between charges
	Non-Contacting and contacting forces: V = IR & V = qC	**Particle with charge q:** 2. Electrical field in a cell 3. In an electrical conductor/capacitor	Flow of current or charge
Magnetism	Non-contacting forces:		

As have been highlighted in the closing section of the introduction of this chapter, the main challenge for ensuring that real integration of school science and IK is realized is the realization and acknowledgement that the two knowledge corpuses differ from each other. The key issue associated with the above is the need to understand the nature of science and IKS. While the integration of school science and IKS is now accepted within the South African education system, a number of concerns are still being raised. The various curriculum modifications between 1997 and the 2009 and even the introduction of the Curriculum and Assessment Policy Statement (CAPS) have not shown the need to find a plausible connection between school science and IKS (Ogunniyi & Ogawa, 2008). This issue leaves teachers in a dilemma as to how they could “help learners to make cognitive shifts between their personal beliefs (underpinned by metaphysical and anthropomorphic assumptions) and the scientific belief underpinned by a mechanistic worldview”(Ogunniyi, 2004, p. 291). Furthermore, the present science textbooks have very little or no IK-based content or even exemplars of IK-related instructional materials (Ninnes, 2002). This lack of contextualization of school science within the learners’ life-world experiences implies a lack of access for many indigenous learners (Campbell & Lubben, 2000).

1.4.2 Learners’ attitudes towards science

Many learners find school science a daunting school science leading many to opt to follow other careers not requiring it. Adding to this, many scholars (e.g. Harlen and Holroyd, 1997; Papanastasiou, C and Papanastasiou, E, 2004) have attributed learners’ generally poor attitudes towards school science to teachers’ inadequate subject and pedagogical content knowledge, the teaching of science in a second or third language parents’ negative predisposition towards science and the un-conducive learning environment (Ninnes, 2000).

According to Osborne (2003), “the concept of an attitude towards science is somewhat nebulous, often poorly articulated and not well understood” (p. 1049). In mitigating some of the challenges of poor attitudes to science Cajas (1999) and Olsher and Dreyfus (1999) have suggested the use of technology as a tool to connect school science with learners' everyday life, and that this could enhance their attitudes towards science. Osborne et al. (2003), have noted that learners' attitudes towards schools science have been researched as far back as the early 70s. Ramsden (2008, p. 130) has added that the majority of such studies are not well conceptualized in that they are riddled with:

> … poor design of instruments used to gather data and of individual response items within instruments, failure to address matters of reliability and validity appropriately, and inappropriate analysis and interpretation of data. Additionally, the lack of standardization in the wide range of instruments reported as a means of measuring 'attitudes' makes comparisons between studies problematic

In most studies that look at learners' attitudes towards science, the epistemic nature of the diverse knowledge systems is usually underrated. The closest that such studies have come has been to examine the role that multiple worldviews play in relation to the epistemic connectivity between tow distinctively different worldviews e.g. school science and learners' everyday knowledge (e.g. Dreyfus, 1999). While such studies highlight the role of making science learning more relevant to learners' everyday lifeworlds, they do not really highlight the fact that school science is premised on a different worldview (Ogunniyi, 2007a).

This study places the notion of multiple worldviews at the heart of the major challenges that make school science inaccessible to most of the non-mainstream learners worldwide. A plethora of studies have shown that non-mainstream learners tend to feel alienated in the science classroom especially because it neither appeals to their intellectual interest not coincide with their sociocultural contexts (e.g. Aikenhead and Jegede, 1999; Battiste, 2002; Cobern and Loving, 2000; Ninnes, 2000; Ogunniyi, Jegede, Ogawa, Yandila, & Oladele, 1995; Phelan, Davidson and Cao, 1991; Sutherland & Reg-Dennick, 2002). In view of this, several scholars have posited theories or hypotheses which could be used as a framework to connect school science with learners' worldviews. Some of these theoretical frameworks are presented in the next section.

1. 4. 3 The hegemonic power of English, the language used to mediate school science

The majority of South African learners (about 80%) do not speak English as their native language and yet they are forced to grapple with the highly technical English language used in science. While teachers make concerted attempts to explain the school science concepts to their learners in home language, English is still used as a standard language for assessment; thus stifling learners' creative thinking skills. While many might argue that the effect of language in acquiring scientific knowledge is minimum or peripheral, the opposite is really the truth. The technical language does not carry the same meaning as the one used in everyday talk or in the local languages of the learners (Kearsey & Turner, 1999; Rollnick & Fakudze, 2008; Scot et al, 2007; Sutherland & Dennick, 2002; B. L. Young, 1979). Teaching and assessing learners in their mother-tongue enables the elicitation of IKS embedded in their first languages so as to assist in their enculturation into the school science worldview.

It is also apposite to state that the understanding of school science goes beyond just the knowledge of English per se. It requires the specialized language of science which is foreign even to first language science. The technical language does not carry the same meaning as the one used in everyday talk or in the local languages of the learners (Kearsey & Turner, 1999; Rollnick & Fakudze, 2008; Scot et al, 2007; Sutherland & Dennick, 2002; Young, 1979). Secondly, science also carries abstract concepts which learners do not initially possess; hence they find it difficult to develop meaningful comprehension of science concepts (Olsher & Dreyfus, 1999). In conclusion, Dlodlo (1999) adds that, "The fact that science and technology in sub-Saharan Africa is not taught in indigenous languages means that no scientific idea can be formulated in an African language in the present education system (p. 323).

1. 4. 4 School science and indigenous knowledge systems

Similar to Young's (1979) claim about the 'exactness' of scientific terms in English can also be demonstrated with isiXhosa an indigenous language in South Africa. Also, the apparent shortfall of the latter for accommodating scientific terms, also applies to the English language as well. For example, taking just a few scientific concepts expressed in isiXhosa will suffice. The equivalent word for "fermentation" when translated into isiXhosa is called 'ukubila', when directly translated into English means "to boil". In scientific terms one may ask, "What has boiling to do with fermentation – a biochemical process involving microorganisms?" The answer simple is that in terms of physical chemistry, boiling occurs when vapour pressure of gaseous constituents of a liquid equals that of the atmospheric pressure; it has little to do with the perceptions of hotness or coldness. In the case of fermentation which releases carbon dioxide gas into the atmosphere, no gas would be released if the vapour pressure of carbon dioxide was not equal or more than the atmospheric pressure above the alcoholic beverage. In other words, alcohols have a low boiling point and thus will boil at lower temperatures.

In the case above, an indigenous language, isiXhosa has described, in a holistic way, a biochemical process as involving a physicochemical reaction as well. The IK-based concept of fermentation is consistent with the scientific concept that the boiling of a liquid substance does not need to occur at 100°C as in the case of water. Many liquids e.g. alcohols and spirits boil in very low temperatures. For the same reason, the African beer, Umqombothi, is also said in isiXhosa to be 'boiling' when fermenting. In this regard, one can see that school science as expressed through English can also have a very limited definition.

To give further examples, in isiXhosa the word 'Ukusela' means 'to drink water' while 'ukuphunga' is used for drinking something hot such as tea or coffee. Here, the English word 'to drink' does not make any distinctions between the two meanings attributed to the term, drinking in isiXhosa. For isiXhosa, the word 'ukuphunga' has IK embedded within it. The term 'ukuphunga' is derived from the word vapour (umphunga) which is attributed to something which can also be associated with the English word 'to sip'. In isiXhosa, the act of drinking hot tea or 'ukuphunga' implies the act of inhaling vapour (or sipping) revealing an understanding that hot liquids exhibits vapour or induces evaporation. On the other hand, the term 'to sip' seems to only suggest drinking of small amounts of the liquid at a time. The isiXhosa term 'ukuphunga' incorporates small intakes of liquid as in the context of the English definition as well as suggesting that the liquid is hot.

For germinated seeds which are used in making of malt, isiXhosa uses two different words. The one is 'imithombo' derived from the word 'source of life' or 'new life' and the other 'inkoduso' referring to the 'home-coming' of boys from the initiation school. In the amaXhosa culture, 'umfana' is regarded as a brand new man in the same way as 'intombi' a young women who has just undergone initiation which is called 'ukuthomba' which is analogous to 'germinate'. As can be seen in the above examples, science knowledge or experiences about natural phenomena is interwoven in the isiXhosa culture and myths. More of these examples will later be elaborated upon to vindicate the position for IKS embedded in indigenous languages. The examples above are in accordance with the notion posed by Corsiglia & Snively (2001) that IKS embedded in local languages such as isiXhosa, has knowledge which school science (expressed in English) has not yet come to understand or to recognize.

As (Nuno, 1998) has cautioned the scientific worldview might not necessarily coincide with that of the learners' socio-cultural environment or personal worldviews since 'the culture of a science classroom is an unfamiliar one' (Chiappetta, Koballa & Collette, 1998: p. 51). Many scientific explanations of natural phenomena for a non-western learner are likely to be in contradiction with those of his/her indigenous knowledge systems (IKS). For example, the indigenous and scientific explanations of the causes of certain natural phenomena e.g. lightning, thunder, diseases or disasters are quite different. The question within the indigenous perspective is not only about the natural factors but also who must have been responsible for their occurrence or why they occurred at all. The point here is that, interpretations of natural phenomena by learners from non-westernized worlds is usually in contrast to those of school science and this could result in learners' cognitive dissonances.

1. 4. 5 The hegemonic power of western Eurocentric worldview over others

The non-westernized IK is usually relegated to the background and regarded as superstitions or misconceptions that need to be corrected. In some instances where IK is allowed, it is only limited to or regarded as learners' prior knowledge in the same token as the threshold limit of Vygotsky's Zone of Proximal Development (ZPD) (Vygotsky, 1978) or Ausubel's platform for further learning (Ausubel, 1968). In the latter case, IK is seen as a strategy to appease non-western learners and to make them feel good about their cultures, but not believed to have the potential for providing them more insight into the science they are being taught at school. In contrast to school science, IK is often oral and symbolic and mediated through the indigenous languages. However, within the indigenous culture, music, dance, rituals, graphics, animations and mythology rather than written documents are used in the transmission of IK from one generation to the next. These modes of transmission are excluded and not facilitated within the school science classroom. The consequence is that learners learn a decontextualized science.

1. 4. 6 Preparing Teachers to Implement the Science-IK curriculum

The training that teachers receive in higher education does not prepare them adequately to implement a science-IKS curriculum in their classroom (Ogunniyi, 2004). Having been schooled solely in western science they tend to discountenance or denigrate the learners' indigenous worldviews (Ogunniyi et al, 1995); thus alienating them from the very culture in which they have been reared. The current education system in South Africa assumes that because the majority of teachers are speakers of local indigenous languages, they will be able to mediate and reconcile the learners' indigenous ways of thinking with that of the school science. Even if the teachers were able to do so, the assessment practices do not allow the integration of science and IK.

Teachers' awareness and understanding of the Nature of Science (NOS) and their learners' socio-cultural background play an important role in the teaching and learning of science. By simply regarding their learners' alternative conceptions as mere superstitions or misconceptions they miss the unique opportunity for dialogue and knowledge building (Feltham & Downs, 2002; Jegede, 1996). Nuno argues further that the use of the term 'misconception' is actually misleading in the sense that its use presupposes homogeneity of worldviews within science classrooms, a situation which is uncommon in today's multicultural science classrooms.

1. 5 PURPOSE OF THE STUDY

This study aimed at exploring grade 11 learners' understanding of certain selected natural phenomena before and after being exposed to an argumentation instructional model. In pursuance of this aim answers were sought to the following questions:

- What were the grade 11 learners' understanding of the selected natural phenomena before and after being exposed to traditional expository instruction and a dialogical argumentation instructional model?
- What are the relative effects of the teaching methods on their attitudes towards an integrated science-indigenous knowledge curriculum?

The study examined the understandings of grade 11 learners in four comparable townships schools in Cape Town on a set of selected phenomena before and after they had been exposed to the traditional expository instruction and the dialogical argumentation instruction modes of instruction for a period spanning 2 months. A related aim was to determine the effect of the two instructional strategies on their attitudes and dispositions towards an integrated science-IK.

1.6 THEORETICAL FRAMEWORK

This study is underpinned two argumentation theories namely, Toulmin's argumentation pattern (TAP) and Ogunniyi's (2007a) contiguity argumentation theory CAT. However, to put the study in the proper perspective, it is necessary to explore briefly learning theories that have been proposed to explain how learners navigate between their indigenous knowledge which they bring into the science classroom and school science to which they are exposed at school.

1.6.1 Border Crossing Theory

Aikenhead (1996) proposed four types of cognitive border crossings that a learner could undertake in navigating between the knowledge they bring to school and what they are taught at school in the science classroom. The four are: smooth- occurs when a learner's worldview is consonant with the scientific worldview; managed- occurs when a learner's worldview differs from the scientific worldview and consequently the need to accommodate the latter for that setting; hazardous- occurs when there are contradictions between the learner's worldview and the scientific worldview presented at school; impossible-occurs when the two worldviews are completely resulting in the learner resisting or developing a distaste for the latter.

1.6.2 Collateral Learning Theory

Jegede (1996) posits collateral theory As a means of support to the integrationist position, Jegede identifies four different forms of collateral learning used by learners to resolve the conflict the experience between their indigenous beliefs and science namely: parallel-the conflicting schemata are compartmentalized or held side by side without interacting with each other; secured-two conflicting schemata are constantly interacting and the conflict is resolved in some way; dependent-one schema challenges the other to the extent that the learner accommodates the new worldview without necessarily undergoing much change; and simultaneous- fits between parallel and dependent learning e.g. an occasion may arise when a schema may in fact facilitate the other because they share some commonalities .

Even though border crossing and collateral learning have attempted to identify the types of collateral learning that non-western learners undergo between home and school experiences on a daily basis they have not shown clearly how learners acquire or adopt them and for that reason (Ogunniyi, 1995) proposed the contiguity hypothesis (later modified to cognitive argumentation theory (Ogunniyi, 2007a).

1.6.3 Contiguity Argumentation Theory

Ogunniyi (1995) proposed the Contiguity Learning Hypothesis and later the Contiguity Argumentation Theory (CAT) (Ogunniyi, 2007a) which attempts to explain the perceptual shifts that learners undergo when moving from the home to the science classroom. CAT posits that 'thinking and reflection', a form of inner argumentation or self-conversation, is involved in cognitive border crossing or learning. Therefore, when a learner holding an indigenous worldview encounters school science a sort of dialogical argumentation ensues in an attempt to attain cognitive harmony. Besides, not only does learning involve cognitive processes it also involves both the psychomotor and affective processes as well i.e. learning is a holistic process (Ogunniyi, 2007a).

CAT recognizes five types of cognitive states that a learner could adopt in resolving conflicts arising from contextual changes. They are: dominant- the most dominant worldview in a given context; suppressed- the worldview that is subdued by the dominant one; assimilated- the worldview that is subjugated by dominant one; emergent- the worldview that is attained from a new experience; and equipollent-a worldview arising from two distinctly different worldviews (Ogunniyi, 2007a). The assumption underlying the new South African curriculum is that by integrating science and IK learners are likely to see the relevance of the former to their daily lives. However, the integration of school science and IK in the classroom warrants the use of new instructional strategies.

1.7 DELIMITATIONS

The study is restricted and only devoted to exploring selected natural phenomena exhibited in school science topics in grade 11. Only four comparable schools in an educational district within the Western Cape's Black township schools having similar demographic and socio-economic features were selected for the study. Physical Science focus areas explored in the surveys were Physics and Chemistry, although the interventions using the instructional strategies were only on Physics concepts.

1.8 LIMITATIONS

The school syllabus in the four schools is based on a pace-setter system which is geared towards helping teachers to keep up which the workload required to complete the syllabus. In this regard, it was difficult to decide upfront which concepts to deal with in the intervention. A survey questionnaire dealing with a number of concepts was administered so as to identify common concepts that could be assessed in the four schools. Furthermore, these administrative limitations dictated that an action research approach be used. This in turn meant that the two instructional strategies be employed for any concepts that needed to be taught at any particular time during the intervention period in this study.

1.9 SIGNIFICANCE OF THE STUDY

As science education is tending towards multiculturalism worldwide, this study has significance locally and internationally for classroom practices. In the context of curriculum reforms in South Africa from 1997 to 2012 (DoE, 1997, 2002, 2009, 2012), "…pre- and in-service teacher education programs must also assist teachers in implementing research findings in their classrooms." (Kyle, 1989, p. 3). In this regard, the significance of this study lies in its potential contribution in providing plausible mechanisms for mitigating the challenges posed by the ever-growing reality of science classrooms becoming multicultural. In light of this, the findings from this study could prove informative and useful in:

1 Providing empirical evidence in support of DAIM as a plausible instructional strategy for bridging and connecting school science with the IKS worldview presuppositions (Ogunniyi, 1988).

2 Establishing the learners' conceptions as an essential component in the teaching and learning process, such that the concept of 'knowledge' as a noun becomes 'a coming to know' experience which is a verb (Odora-Hoppers, 2004; Ogunniyi & Ogawa, 2008).

3 The characterisation of natural phenomena in terms of the complexity of their scientific explanations which can serve as predictors of the level of possible cognitive dissonances that learners from non-westernised backgrounds can experience (Aikenhead, 1996, Jegede, 1995; Aikenhead & Jegede, 1999). This characterisation has the potential of explaining the perceived compatibility and incompatibilities that are normally observed between school science and IKS.

4 Creating awareness among curriculum developers that the implementation of a Science – IKS curriculum, free of epistemological biases would go a long way in affirming learners' diversity with respect to developing their sense of identity as well as their diverse socio-cultural backgrounds (Kyle, 1989).

5 Showing and demonstrating the mechanism of the integration of IKS with school science and what complementary IKS content could be incorporated into school science (see, Finley, 2009; Onwu & Mosimege, 2004; Onwu, 2009).

6 Help in enhancing learners' and teachers' awareness of, and attitudes towards science and IK (Erduran, 2006).

7 Strengthening the position that, IKS is a reservoir of knowledge that the learners could use as a veritable platform to develop a robust worldview about what they learn from their communities as well as what they learn in school science (Corsiglia & Snively, 2001; Departement of Education, 2002; Emeagwali, 2003; Ogunsola-Bandele, 2009).

8 Help demystify the notion that limits IKS to learner prior knowledge, hence rendering IKS as a subculture of science.

9 Reducing the negative perception that, the infusion of IKS with science will result in the reduction of scientific rigor and quality.

10 Identifying links between the learners' socio-cultural language and the language as used in school science.

11 Providing additional data that researchers, educators, curriculum planners and other stake holders could find useful and informative in reaching informed decisions regarding the implementation of the Curriculum and Assessment Policy Statement (CAPS) in education.

CHAPTER TWO

LITERATURE REVIEW

2. 1 INTRODUCTION

According to Enderstein and Spargo (1998) the new South Africa is a multicultural society. Prior to 1994 the education system was based along racial; all of which were safeguarded by the then Group Areas Act which came to effect in 19… However, at the down of democracy in 1994, the Group Areas Act barring learners of different races from attending the same school was abolished. Furthermore, the 19 Departments of Education were combined into one Department of Education (DOE). As a result of this new political dispensation learners from diverse cultural groups now have access to the same educational system with one national inclusive curriculum. This theoretically was what the education policy formulated by the new democratic government envisaged but in practice the influence of the erstwhile apartheid system of education has not been completely wiped out to make this goal feasible (DOE, 1997).

This chapter explores both theoretical and practical issues surrounding the issues of teaching and learning science in the present South African multicultural classrooms. Specifically, the chapter examines:

- The views of scholars about the challenges of an inclusive curriculum which demands the integration of school science with learners' indigenous knowledge (IK) in the classroom.
- Research studies done to determine the relative effects of traditional and dialogical argumentation forms of instruction on grade 11 learners' conceptual understanding and attitudes towards science.

As indicated in chapter 1, the National Curriculum Statement published by the Department of Education (DOE, 2002) has adduced some reasons for imploring science teachers to integrate school science with learners' IK. Among others, it states that: (1) IK has been effectively used by the people living in South Africa for centuries to harness the potential of their environment for their socioeconomic development; (2) colonization is believed to have eroded that IK considerably and so it needs to be rediscovered and used; (3) IK embraces the wisdom that the people living in the area have used to conserve their environment as well as ensure their sustainability and survival; (4) the way science is taught or presented in the science textbooks seems to alienate the majority of indigenous learners from school science;

(5) western science tends to denigrate learners' IK and thus makes them to develop a negative attitude towards school science; and so on.

2.2.1 Nature of science

As indicated in chapter 1, the central focus of this study was to determine to what extent traditional expository instruction and dialogical argumentation instruction were able to enhance grade 11 learners' understanding of selected physical science concepts as well as mitigate the conflict between their indigenous knowledge and school science. But before exploring this it seemed apposite to examine the 'Nature of Science (NOS) and IKS, the level and feasibility of integrating the two systems of thought within the classroom before considering the instructional strategies suitable for their articulation (Abd-El-Khalick, 2000:p. 665; Ogunniyi, 2004, 2006, 2007a & b; Ogunniyi & Hewson, 2008, Ogunniyi & Ogawa, 2008).

It is also important to ameliorate the distorted notion about the two systems of thought in the extant literature (Aikenhead & Jegede, 1999; McComas, 1998). As Ogunniyi et al (1995) have argued, "…knowledge of what teachers and students bring into the class is critical in situating the teaching – learning process within a meaningful context." (p. 819). In other words, neglecting to contextualise school science within the learners' socio-cultural background can easily result in what Kuhn would call symbolic violence i.e. intimidating and alienating learners from science by imposing on them the school science worldview without respecting their cultural beliefs or worldview presuppositions (Ogunniyi & Ogawa, 2008).

2.2.2 Nature of indigenous knowledge

In contrast to the western worldview upon which school science is premised, the learners'socio-cultural backgrounds in non-Western worlds are more based on IKS although many of them might be surrounding and influenced by technological products. According to Odora-Hoppers (2004), in many traditional societies throughout the world IKS is known by different names and practiced under different circumstances. In other countries it is called 'Traditional Knowledge Systems' (TKS), 'Endogenous Knowledge Systems' (EKS) while in some other cases it is called 'Classical Knowledge Systems' (CKS) and South Africa so far has settled for IKS as the preferred term (Odora-Hoppers, 2004, p. 18).

Indigenous science is science knowledge or system of thought which has been systematically handed down both from one generation to another which is peculiar to a particular people living in a particular socio-cultural environment (Ogunniyi, 2007a; Ogunniyi & Ogawa, 2008; Snively & Corsiglia, 2001). In contrast to school science, IK is often oral and symbolic and mediated through Indigenous Languages (IL). Most African children grow up in a tradition of story-telling or folklore, rituals coupled with songs and dancing. Music, dance, rituals, animations and mythology rather than only the written code are used in the transmission of IK from one generation to the next.

For example, some clan names of isiXhosa speaking people are derived from the names of animals, birds, plants, certain objects within the environment and natural phenomena. In all these, specific knowledge and wisdom about socio-economic issues, natural phenomena, the environment as well as value systems and beliefs are embedded and hence forms of traditional libraries. With respect to food systems, Rollnick and Fakudze (2008, p. 3) assert that the knowledge retrieved has a terminology which " is embedded in cultural taboos and euphemism" and that in indigenous communities, language contains movement, progress and transformation – that is, nouns as objects emerge in a secondary way through the modification of verbs" (Odora-Hoppers, 2005, p. 6). In the amaXhosa tradition as well as in the |xam bushmen beliefs as related by Hollmann (2007) there is an anthropomorphic as well as an anthropocentric relationship between human and non-human objects. Language and thought are both articles of a worldview in which one is predisposed to. In this regard, the learners' IK and/or prior learning is articulated in the languages of the learners, which is predominantly one of the indigenous languages of South Africa (e.g. isiXhosa – in the context of this study).

2. 2. 3 Socio-cultural perspectives in learning school science

As has been highlighted in chapter 1, when the new South African government came into power in 1994, it enacted a new curriculum in 1997 which stresses the need to make school science relevant to the learners' life-world experiences e.g. by integrating school science with learners' indigenous knowledge. The National Curriculum Statement published by the Department of Education (DOE), in agreement with Aikenhead and Jegede (1999) and others, points out the fact that: "…one can assume learners in the Natural Sciences Learning Area think in terms of more than one worldview. Several times a week they cross from the culture of home, over the border into the culture of science, and then back again…" (DOE, 2002, p. 12).

2.3.Theories of Learning

The general consensus among scholars working in the area of cultural studies in science education is that the worldview prevalent in the learners' socio-cultural environment does influence how they respond to school science. In view of this, Aikenhead (1996) proposed Cultural Border Crossing (CBC) as a way to explain how learners cross the borders of the culture of home to that of school science. To Aikenhead, school science is a culture that has the potential for causing conflicts with the learners' indigenous beliefs. In the same vein, Jegede (cited by Ogunniyi, 2008) proposed the Collateral Learning Theory as another plausible mechanism to explain how learners harmonise the conflicts between their indigenous beliefs and school science. In an attempt to understand how learners navigate their way between home and school several theories have been proposed. However, only a few that are relevant to the study are briefly presented here. The gist of the theories in relation to this study would be elaborated upon later.

2.3.1 Border Crossing Theory

Aikenhead (1996) proposed four possible border crossing situations in which a learner can encounter while being exposed to school science from a non-school science background. These different aspects could challenge how learners view and experience school science, hence contributing to their attitudes and assimilation of science concepts. Accordingly, smooth border crossing results when a learner's sociocultural background on a particular topic is consonant with that of school science.

Examples where the learners' life worlds could be congruent or similar to that of school science could be those of time and seasons which depend on visual observations of the sun and stars in the sky. According to Aikenhead and Jegede (1999), the 'smoothness' of border crossing decreases with the degree of discomfort or cognitive conflict one experiences as a result of being exposed to the culture of a different worldview.

The second kind of border crossing is managed border crossing where there is a difference between the learner's worldview and that of science resulting in a need for accommodation. Manage border crossing does not explain how the management part can be recognised from a variety of scenarios. One can assume that the 'manageability 'could be as a result of the introduction of a new school science concept that is not compatible with that of school science in a non-challenging manner. In this regard, managed border crossing can be seen as a situation where the current worldview accommodates a new idea in an additive rather than in subtractive assimilation.

The third one is hazardous border crossing where there are contradictions between the learner's worldview and that of school science such that a lot of tension and cognitive conflict can ensue. This form of border crossing denotes a situation where the two worldviews are incompatible or seemingly contradicting each other. Hazardous border crossing does not draw a line between the situations where the two worldviews are not compatible, and yet run parallel to each other. A good example of hazardous border crossing can be viewed from a cultural perspective where some phenomena have dual explanatory models such as those of visible and invisible light as well as audible and inaudible sound. The two scenarios can be viewed as contradictory by learners in everyday contexts

The last and final form of border crossing is called impossible border crossing. It is called 'impossible' for the mere fact that the tension and cognitive conflict between the two worldviews is such that the learner will resist the learning of a new school science concept. There are various reasons that this could occur. In this case, Aikenhead and Jegede (1999) cites psychological pain as one reason that results in impossible border crossing. Aikenhead's categories of border crossing do not highlight situations where the two worldviews do not interface at all. One example can be exemplified in the issue of faith versus scientific testability. In this case, the two worldviews can either attract, repel or do nothing to each other depending on the individual learner's psychological, physiological or metaphysical predisposition.

Impossible border crossing as well as the previous hazardous border crossing are a cause of concern and robust debates in the field of the integration of school science and IKS. Examples of such concerns are raised by Cobern (2001), Onwu and Mosimege (2004), Onwu (2009) and Finley (2009). These debates centred on what aspect of IK should be included in the school science curriculum. Attached to the incorporation of IK into science raised further questions of whether to accord both worldviews the same status but the same or different roles.

In conclusion, cultural border crossing as espoused by Aikenhead and Jegede (1999) asserts that the success of in school science by learners from a culture diverse from that of school science will depend on: (a) the degree of cultural difference that students perceive between their life-world and their science classroom, (b) how effectively students move between their life-world culture and the culture of science or school science, and (c) the assistance students receive in making those transitions easier (p. 270). In the final analysis, incorporation of the proposed IK materials into the classroom have possibilities of creating the various border crossing situations mentioned above.

The gist of this theory is that learners on a daily basis undergo cognitive border crossing as they move from home to school and vice versa. Aikenhead (1996) identifies different types of border crossing exercise experienced by learners on a daily basis: smooth - when the culture at home is similar to that of the school; managed - although a learner's worldview differs from that of the school he/she manages to adapt as much as possible to what is deemed appropriate for each occasion; hazardous - the learner holds two conflicting worldviews which he/she is not able to resolve; impossible - the learner feels alienated from what is taught at school.

2.3.2 Collateral Learning Theory

Jegede (1996) posits collateral theory As a means of support to the integrationist position, Jegede identifies four different forms of collateral learning used by learners to resolve the conflict the experience between their indigenous beliefs and science namely: parallel-the conflicting schemata e.g. science and learner prior knowledge do not interact at all; secured-the conflicting schemata are continuously interacting and the conflict is resolved in some way; dependent-one schema challenges the other to the extent that the learner accommodates the former without radically modifying the extant schema; and simultaneous- fits between parallel and dependent learning; an occasion may arise when a schema in fact may facilitate another as a result of shared common elements. These types of learning are not assumed to be separate but points along a spectrum depicting the level of interaction (Ogunniyi, 2008).

2.3.3 Collateral Learning: A Cognitive Explanation of Border Crossing

Aikenhead and Jegede (1999) have argued that collateral and learning and border crossing are intricately related. The two authors summarized the relationship between the two learning theories as follows:

- Smooth border crossing and parallel, secured or no collateral learning.
- Managed border crossing and parallel, simultaneous, or secured collateral learning.

- Hazardous border crossing and either dependent or simultaneous collateral learning.
- Impossible border crossing and possibly dependent, if at all.

Even though border crossing collateral learning has identified the types of collateral learning that non-western learners undergo between home and school on a daily basis it has failed to describe or explain how he/she acquires them and for that reason (Ogunniyi, 1995) proposed the contiguity hypothesis (later modified to contiguity argumentation theory (CAT) (Ogunniyi, 2007a). I will provide more details about CAT later.

In addition to the learning theories above, the study benefited from two philosophical theories dealing with knowledge building and integration of knowledge systems namely, the Toulmin's (2003) Argumentation Pattern (TAP) and Hempel's (1966) internal and bridge principle.

2.3.4 The Internal and Bridge Principles

In order to understand the mechanisms of the cognitive processes which could facilitate the integration of science and IK in a learner's mind, Ogunniyi (2007a) has adopted and explicated Hempel's (1966) notion of internal and bridge principles involved in the formulation of a theory. The former relates to the basic entities and processes or "micro-cognitive phenomena" invoked by the generalizations (theories and laws) they are assumed to conform. The later indicate how the processes envisaged by such generalizations are related to actual empirical phenomena with which we are already familiar, and which the generalizations may then describe, explain or predict. In other words, the bridge principles help to connect certain aspects of the "micro-cognitive phenomena" with corresponding "macro-cognitive phenomena".

Another way to say this, is that the bridge principles help to connect the theoretically assumed entities and processes that are unobservable such as the processes of dialogical argumentation or intra-argumentation (e.g. thinking or self-conversation) with more or less directly observable learning behaviours such as conceptual, perceptual or attitudinal change (Ogunniyi, 1988, 2007a & b). Finally, in order to find a common ground or that cognitive site which Ogunniyi (1995) calls the contiguous site, the nature of explanations posed by both thought systems should be understood so that the so-called internal and bridge principles become applicable.

2.3.5 Toulmin Argumentation Pattern

TAP is a discursive and argumentation theory based on logical, deductive and inductive patterns within an argument in defence of a claim or conjecture. As put forward by Ogunniyi (2007a, 2008), Toulmin categorizes an argument in terms of claims, evidence (data), warrants, backings, qualifiers and rebuttals. In terms of the common science and IKS aspects, knowledge is made up claims which can be accepted or rejected depending on the nature of evidence or data supporting those claims. If there are no warrants to validate the evidence, then the claims could be refuted or modified using some qualifiers or conditions upon which the claims could hold valid. TAP frameworks work well within most school science curriculum because of its simplicity in analysing the validity of the science subject content.

An example of a scientific statement that would require TAP evaluation to gauge its accuracy or validity would be as follows: "The boiling point of water is 100 ^{0}C". A set of questions in evaluating this statement using TAP would be:

1. At what altitude was this measurement taken?
2. Is this pure water?

In scientific terms, these questions relate to the conditions that would provide the kind of data that can serve as evidence to the claim made by the statement. An unambiguous scientific statement that does not warrant questions would be: "The normal boiling point of pure water is 100 ^{0}C." In this case, 'normal' highlights that the measurement was taken at Standard temperature and Pressure (STP), which is at 1 Atm at sea level. In order for learners to master school science, they have to learn this language and be able to read scientific texts and be able to communicate in the same manner; otherwise their answers will be incorrect. This is a challenge even for learners who are English native language speakers and worse for those from non-westernised societies for whom the Language of Teaching, Learning and Assessment (LoLTA) is not their home or first language.

The weakness of TAP in this regard lies in fact that it does not capture the experiences of learners' from diverse IKS worldviews which are not necessarily underpinned by logical, deductive or inductive arguments, but "… encompasses science, technology, religion, language, philosophy, politics and other socio-economic systems" (Ogunniyi, 2007: p. 965). For scientific knowledge to be valid it must be justified by evidence or reason (Ogunniyi, 2008) and not all of the above pertaining to IKS can be supported by evidence or data. In this regard, TAP has had to be supplemented by other alternative argumentation frameworks that will attempt to capture the experiences of learners from socio-cultural backgrounds so as to enhance their access to; and school science capability and skills development.

2.3.6 Contiguity Argumentation Theory

Ogunniyi (1995) proposed the Contiguity Learning Hypothesis and later the Contiguity Argumentation Theory (Ogunniyi, 2007a) which attempts to explain the cognitive process that might help to explain the perceive border crossings. Essentially, CAT posits that conflicts that arise in a learner's mind as a result of contradictory ideas (e.g. school science and IK) is resolved through a psychological process involving accommodation, assimilation, appropriation, integrative reconciliation and adaptation (Ogunniyi, 1988, 1995, 2007a).

CAT construes 'thinking' as a form of inner argumentation, dialogue or self-conversation. Therefore, when a scientific worldview comes in contact with IK a sort of dialogical argumentation ensues in an attempt to attain cognitive harmony. Besides, not only does learning involve cognitive processes it is also an embodied experience. In other words, a person's entire body is involved in the process of learning. For example, a pianist may have forgotten a musical note but as he/she engages his/her musculature, e.g. by tapping the keyboard, full notes are remembered- a cognitive process, and so the whole music comes alive (Ogunniyi, 2007a). Within this framework there are five different forms of cognitive states that a learner could adopt in resolving the conflict between his/her indigenous knowledge and school science:

Dominant: The most prevailing or accepted argument or worldview in a given context.
Suppressed: A worldview that is subdued by the dominant one.
Assimilated: A worldview that is subsumed by a more dominant one.
Emergent: A worldview that arises from a new experience or insight.
Equipollent: Two or more co-existing but distinctly different worldviews exerting equal or comparable cognitive force on a person's worldview (Ogunniyi, 2007a).

The integration of school science and IKS in the classroom warrants the use of new instructional strategies i.e. instructional strategies that are compatible with both the scientific and indigenous knowledge worldviews which learners bring into the science classroom. The assumption underlying the new South African curriculum is that by integrating science and IK learners are likely to see the relevance of the former to their daily lives. As stated earlier, the study was underpinned by two argumentation theories namely, the Toulmin (2003) Argumentation Pattern (PAT) and the Contiguity Argumentation Pattern CAT).

2.3.7 Argumentation as a Rhetorical Instructional Tool

Argumentation, whether it is at the individual or group level, always entails a form of contentious conversation. Ogunniyi (2007a, 2011) goes further that each of us in the process of thinking is engaged in some form of dialogical argumentation within ourselves before taking any decision. Therefore argumentation is a very important part of any intellectual discourse. Argumentation plays an important role in creating opportunities for meaningful discourse, belief revision and for resolving conflicting viewpoints both within the scientific and the indigenous communities. Likewise, argumentation is effective for clearing people' doubts and for helping them to change their minds in the face of stronger arguments or new insights on a subject matter (e.g. Erduran, Simon & Osborne, 2004; Osborne, 2010; Simon, Erduran & Osborne, 2004; Osborne, 2010).

The dialogical argumentation instructional model (DAIM) which forms the central focus of this study is underpinned by two theoretical frameworks namely, the Toulmin Argumentation Pattern (TAP) (Toulmin, 2003) and the Contiguity Argumentation Theory (CAT) (Ogunniyi, 2007a). Essentially TAP consists of a claim- a statement awaiting confirmation; data or evidence; warrants or justification of the claim on the basis of the evidence; backings or underlying assumptions; qualifiers or conditions in which the claim is valid and rebuttals or a contradictory statements to the claim (e.g. Erduran, Simon & Osborne, 2004; Osborne, 2010; Simon & Johnson, 2008).

CAT consists of five main cognitive states brought about by contextual changes namely: dominant; suppressed; assimilated; emergent; and equipollent. These cognitive states are in a state of dynamic flux and may change from one form to another as the context (Author, 2004, 2007a). The cognitive categories of CAT are as follows:

Dominant: The most dominating worldview (scientific or otherwise) in a given context

Suppressed: The worldview that is subordinate to the dominant one.

Assimilated: The worldview that is absorbed by the dominant one.

Emergent: A worldview arises out of a new experience.

Equipollent: Two distinctly different worldviews exerting equal cognitive forces on a person's worldview

TAP has been used in a plethora of studies to determine the effect of argumentation instruction on teachers' instructional practices and learners' conceptual understanding (e.g. Erduran, Simon & Osborne, 2004; Osborne, 2010; Simon & Osborne, 2004; Simon & Johnson, 2008). However, CAT, being relatively new, has only been applied in fewer studies dealing with the integration of knowledge systems e.g. science and IK in a science classroom context (Diwu & Ogunniyi, 2012; Nhalevilo & Ogunniyi, 2014a & b; Ogunniyi, 2004, 2007a & b; Ogunniyi & Hewson, 2008).

2.3.8 Dialogical Argumentation Instruction (DAIM)

As stated earlier DAIM is underpinned by two theoretical constructs namely, Toulmin Argumentation Pattern (TAP and the Contiguity Argumentation Pattern (CAT). DAIM consists of hands-on cognitive tasks tackled first as individuals (intra-argumentation stage), in small groups (inter-argumentation stage) and finally in the whole group (trans-argumentation stage).

The intra-argumentation stage involved the process of e.g. brain-storming the tasks and finally filling in the answers in the worksheets. The inter-argumentation stage entailed an evaluation of the validity or otherwise of the conclusions reached by individual learners at the intra-argumentation stage and then carrying out further arguments and discussions before the group reached collaborative consensus on the task at hand. The trans-argumentation stage involved the presentation by each group's leader or representative on the decision reached on the various tasks to the whole group.

The researcher moved from group to group asking thought-provoking questions as well as sorting out incipient problems that might arise from time to time. It is also important to state that no group or the role played by the members was permanent. Each lesson usually had different leaders and the members played different roles from the one they performed previously (Fig 2.1).

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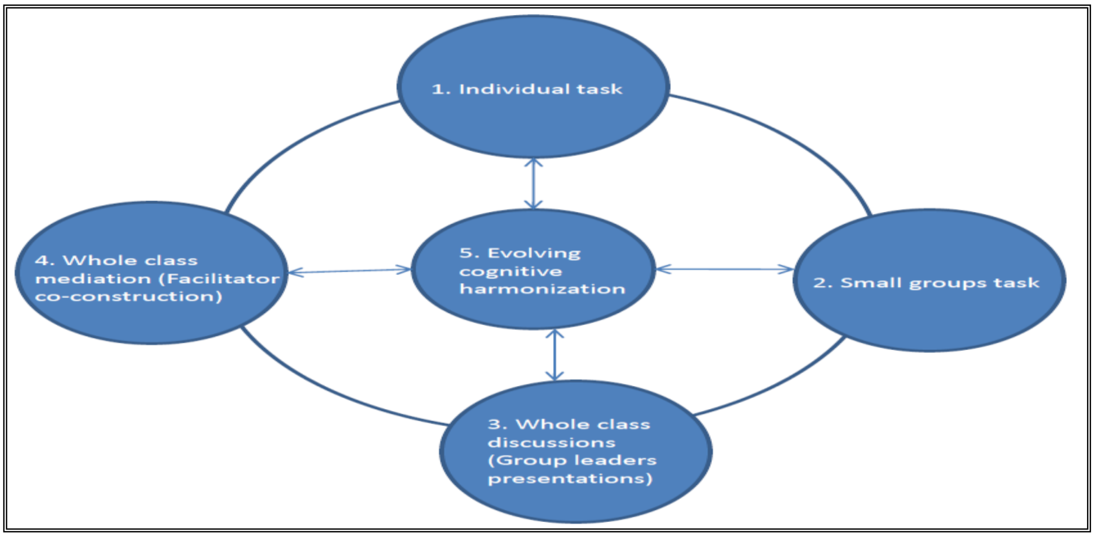

Fig.2.1. CAT-based dialogic argumentation instructional model (DAIM) (after Ogunniyi, 2009)

2. 4 PRACTICAL CONSIDERATIONS

According to Fleer (1999, 121), "In order for individuals to begin to appreciate meaning systems and the processes of knowledge construction in another culture, the two cultures must come together and exchange world views." This is the heart of this thesis; to go beyond the issue of identification of the various forms of border crossing and the differences between the two worldviews. The focus is to see how the two worldviews relate with each other and finding appropriate mechanisms as suggested by Fleer.

The reason for this focus as has been highlighted by Ogunniyi et al. (1995), is that several studies (e.g., Gunstone & White, 2000; Posner et al. 1982) from socio-cultural perspectives have revealed that, "alternative conceptions about natural phenomena are not easily replaceable by the scientific world view" (p. 819). Each worldview is a socially constructed entity which is engrained in the minds of those who are predisposed to it (Newton, Driver, & Osborne, 1999). They support this view by stating that:

> This perspective recognizes that observations are theory laden (Hanson 1958, Kuhn 1962) and, therefore, that it is impossible to ground claims for truth in observation alone…" (p. 554).

In addition, the evidence itself is open to interrogation, "both in terms of the way that it is framed conceptually and in terms of the trust that can be placed in its reliability" (ibid). Other scholars such as Simon et al. (2006) also argue that, "science education requires a focus on how evidence is used to construct explanations…" (p. 236) and that, " the teaching of argumentation through the use of appropriate activities and pedagogical strategies is, we would argue, a means of promoting epistemic, cognitive and social goals as well as enhancing students' conceptual understanding of science" (ibid).

However, achieving the latter thus require that teachers as well as learners be equipped with the knowledge about the nature of the two worldviews as well as the skills of how to engage in cognitive negotiations between the two worldviews. In this regard, Ogunniyi (2008, p. 11) summarizes this issue as follows:

> From socio-cultural and psychological perspectives interactive classroom arguments and dialogues can help teachers and students to clear their doubts, upgrade current knowledge, acquire new attitudes and reasoning skills, gain new insights, make informed decisions and even to change their perspectives...

But before we go ahead, it is apposite that the role of the learners' prior knowledge be addressed as various scholars have different views or see various roles for prior knowledge in the teaching and learning of school science.

2.4.1 The role of the learners' prior knowledge in teaching and learning of science

The extant literature is replete with studies that have looked into the learners' prior knowledge or learners' preconceptions which have argued that, if learning has to take place, then the learners' preconceptions must be assessed and taken into account in the process of teaching and learning (e.g. Ausubel, 1968; Campbell & Lubben, 200; Chiappetta et al. 1998; Enderstein & Spargo, 1998; Eshach & Schwartz, 2006; Hamza & Wickman, 2007; Hewson, 2010; Hewson & Hewson, 2003; Jegede, 1996; Mohapatra, 1991; Nuno, 1988; Yip, 2001).

According to Eshach and Schwartz (2006), identifying the learners' preconception is a necessary stage in increasing the teachers' awareness of the difficulties and barriers faced by their learners in understanding scientific phenomena. However, assessing the learners' prior knowledge or preconception is often done for various reasons. As Chiappetta et al. (1998) has alluded, the lack of success at school by learners from socio-cultural backgrounds was assumed to be as a result of their home backgrounds contributing to these misconceptions being less advanced than that of learners from western modern science backgrounds. As highlighted by Feltham & Downs (2002) and Jegede, (1996), to some scholars, the learners' prior knowledge is viewed as blockages in the path of scientific indoctrination, and thus needs a conceptual change approach to rid the learners of such misconceptions. In contrast to the latter view, Hamza & Wickman (2007) have argued that misconceptions do not hinder or constrain the development of learners' reasoning; instead, the learners reasoning develop in response to the contingencies of a specific situation. Furthermore, as noted by Posner et al. (1982) and Gunstone & White (2000), learners' preconceptions or prior knowledges are hard to change, if not impossible.

Instead of noting the latter, Keane (2007) has pointed out, that some constructivist scholars' interest in interrogating learners' preconceptions is for the purpose of driving and leading the learners to particular predetermined explanations – that is, towards the supposedly correct school science worldview interpretations of natural phenomena. As highlighted by the latter scholar, while the constructivist approaches accept that learners do not come into class as empty vessels, the content of these vessels is viewed as largely unscientific and thus need to be changed. As Ninnes (2000) also alluded, some scholars do not question the scientific constructivism of scientific knowledge, but rather attempts to use the learners' prior knowledge to develop more effective strategies for persuading learners to adopt the western scientists' social constructivism.

In contrast to the above, while school science is largely embedded within western Eurocentric worldviews, the learners' preconceptions from non-western traditions should be viewed as having unique scientific knowledge that is embedded with IKS frameworks, inclusive of belief systems, norms, values and attitudes (Aikenhead, 1996, Corsiglia and snively, 2001; Department of Education, 2002; Fakudze, 2004, 2008; Le Grange, 2004; Ninnes, 2000; Ogunniyi, 1988; Ogunniyi & Ogawa, 2008; Phelan et al, 1991; Sutherland and Dennick, 2002,). In an attempt to find a common place between the two worldviews of science and IKS, it should be noted that, the learners' IK-based ideas that may be viewed as unlinked or inconsistent with the school science worldview, may be linked for the learners from the learners' perspectives (Marin, Solano & Jiminez, 2001; Mohapatra, 1991).

According to Mohapatra (1991) these IKS framework is what contribute to "the single most important factor" (p. 431) of personal concepts which "…will be scientific to the same extent as is the knowledge acquired by pupils in the school" (p. 432), hence determining 'the quality' of how the learner constructs his/her knowledge (p. 431). As Wiseman (2011), the author of '59 seconds' succinctly puts it, "Our beliefs do not sit passively in our brains waiting to be confirmed or contradicted by incoming information. Instead, they play a key role in shaping how we see the world" (p. 8). The views expressed above are consistent with Contiguity Learning Hypothesis (CLH) which states that learners are able to hold two diametrically opposed worldviews without experiencing any cognitive conflict (Ogunniyi, 2008). In other words, from the learners' perspectives, IK and school science are not necessarily mutually exclusive of each other (Ogunniyi, 1988) as these distinctions may only exist in the minds of teachers.

In view of the latter statement, Ogawa has argued that, approaching science education from a multicultural approach is not sufficient, science education should be approached from a multi-science approach (Chiappetta et al, 1988, p. 50), where both school science and IK could engage each other on equal footing (Ogunniyi & Hewson, 2008). In this regard, scientific knowledge from this perspective should be a product of negotiated knowledge between the two worldviews (Fleer, 1999) such that learners may be in a position to understand the contexts and limitations of each knowledge system and learn to use it appropriately (Gunstone & White, 2000). In this regard, Eshach and Colleague (2006) suggested that, the teachers' awareness of the learners' preconception may help them to develop learning materials and environments that will assist the learners to refine their initial conceptions and to use them as anchors in the process of developing emergent and unique scientific knowledge (See also, Ninnes, 2000).

With regard to teaching and learning, Hamza & Wickman (2007) noted that, 'the concept of experience allows us to be generously inclusive in our description of a situation' (p. 145). In other words, they assert that the learners' preconceptions, whether from a school science or an IK perspective, they could at least initially and pre-analytically be assigned to the same level, thus allowing learners the opportunity to explore the various alternative solutions or explanations of a concept and how they may link to existing conceptions. In searching for the learners' preconceptions, it is possible that areas of commonality or contiguity may exist between the learners' preconceptions and the 'acceptable' school science conceptions of natural phenomena, hence their ability to make sense of the apparent distinct worldview knowledge bases. For instance, George is cited as questioning the learners' ability to switch from one worldview to another (Malcolm and Stears, 2005, p. 12). Accordingly, Malcolm and colleague (2005) also assert that, the relationship between parts of knowledge and their ways of knowing are essential parts of knowing. Not looking for these connection points would amount to reinforcing the hegemonic status of the school science worldview (Ogunniyi & Hewson, 2008) or promoting the dichotomisation of knowledges, thus leading to one knowledge system being viewed as inferior to the other.

In summing up, firstly, as has been amply argued in the paragraphs above, there is no need to look at constructivism from the perspective of seeing and viewing learners' preconceptions as possible interferences that may need a conceptual change or a substitution approach. Secondly, instead of the above, it would be beneficial to try to understand how learners seem to bridge the apparent worldviews as seen from an adult or teacher perspective. One way to do this would be to interrogate both the school science and IK worldview presuppositions as has been suggested by Emeagwali (2003) and furthermore look for the scientific evidence embedded within the learners' IK (Corsiglia & Snively, 2001; Ogunsola-Bandele, 2009). Finally, a mechanism of how diverse and distinctively different worldviews can be bridge together so as to find that contiguous site inherent between the two.

2.4.2 The role of language in the teaching and learning of school science

In similar ways that learners have to manage their border crossing from their indigenous worldviews into the school science worldview, they have to do so using their indigenous languages irrespective of whether the language of teaching and assessment is English. Learners learn new information by first making meaning of it by first doing internal translation into their own languages and then try express their understanding of it using the language of teaching and assessment. The reason for this phenomena is that the school science worldview together with its language of discourse are epistemologically different from indigenous languages since indigenous knowledge is transmitted in indigenous languages (Wababa & Diwu, 2010).

The implications for the above suggest that learners from non-western socio-cultural backgrounds have to transcend three cognitive degrees as opposed to those learners who are native speakers of the English language. In the first instance, non-western learners (using and indigenous language) have to first cross the linguistic border which is grammar-based to the language of teaching and assessment (depending on which language of the coloniser is applicable) and then again having to cross another linguistic border which is discourse oriented to the school science worldview. On the other hand, learners from westernised backgrounds especially those who are native speakers of English or any other westernised language only have to cross one linguistic border into the school science worldview which is itself a derivative of the western grammatical language (Diwu, 2010).

Regarding the relationship between language and science learning, Sutherland and Dennick (2002, p. 4) asserts that, "…cross-linguistic research shows that different meanings in different languages account for many common misconceptions, and there are some suggestions on how language influences learning." As the latter shows, challenges for border crossing from indigenous languages into western-Eurocentric languages and then into their corresponding coded school science language are unsurmountable. Since 1996, the Department of Basic Education in South Africa enacted the Language in Education Policy (LiEP, 1996) followed by the LiEP implementation plan in 1997 which never took ground. However, these policies were aimed at the recognition of other nine South African indigenous languages to be used in education

It was also hoped that by enacting the New Curriculum in 1997 which called for the inclusion of IKS in the school science curriculum, it would make it easy for the LiEP to be easily implemented. Alongside the LiEP implementation plan, bodies such as the Pan South African Language Board (PenSALB) were set up to look into the corpus and status planning of all other nine South African languages which are peripheral to teaching and learning.

On the other hands, teachers have continued to use their own indigenous languages as scaffolds in order to help the learners to at least understand what the language of teaching and assessment is trying to convey. Practices such as transliterations with meaningless clumsy-sounding vocabulary makes no scientific sense (Dlodlo, 1999; Wababa & Diwu, 2010) as they only provide a shielding effect for the lack of terminology in the target languages. In other cases direct translations emerge because some words/terms in the school science language do not readily translate into the same meaning in indigenous languages (Young, 1979). It is this regard, some scholars have proposed terminology development strategies that are based on indigenous knowledge worldviews – making sense of the African language etymologies and translating into English rather than the status quo where English is traditionally used as the source text.

2. 5 SUMMARY

The border crossing models discussed above have amply demonstrated how science learning is influenced by the socio-cultural background of the learners. These models as discussed in Aikenhead and Jegede (1999, p. 180) suggest that science teachers should be able to:

- Recognize or understand that the school science presently taught in schools is a cultural entity.
- Recognized that the of learners experience cultural border crossing when they move from their lifeworlds into those of the school science, hence understand that science learning is a cross-cultural event for the majority of learners.
- Identify and consider the various ways learners from socio-cultural backgrounds deal with cognitive conflict when interfaced with school science and how they use collateral learning to make sense of such conflicts.
- Help learners to negotiates their border crossings as well as the corresponding resulting cultural conflicts

As explicated in the above points, point 3 and point 4 respectively suggest that collateral learning as espoused by Jegede (1995) is able to explain the cognitive conflicts experienced by learners and thus teachers should also be able to help learners to cross these borders as smooth as possible. Whilst the border crossing explanations are very plausible and useful in elucidating the challenges or struggles that learners face in crossing cultural borders, they however underrate the teachers' lack of both the NOS as well as NOIKS. Furthermore, the border crossing models do not specify how the two thought systems of school and science can interact with each other (Fleer, 1999; Le Grange, 2004). Ogunniyi & Hewson (2008) have also added that, if the two thought systems have to effectively meet on a common ground, the two systems should be in a position to argue on equal footing.

In line with the latter statement Ogunniyi & Hewson (2008), Jegede (1997) has stated that, it is important for learners to be able to at least understand the alternative interpretations suggested by other learners even if they may not believe in them. For example, Ogawa argued that, when western science technological products were introduced in Japan, the Japanese only took the practical products of western science and its technology; but never their epistemologies (Ogunniyi et al., 1995).

In order for learners to understand alternative worldview interpretations as espoused by school science, learners must be able to argue and make decisions about what to believe or not. As such, school science itself has progressed and advance through argumentation (Erduran, 2006). Furthermore, Simon et al. (2006) points out that argumentation as an instructional tool and analytical tool comes by practice. As has been argued regarding the incorporation of IKS within the school science in South Africa, the curriculum documents such as DoE (2002), the 2009 Ministerial report on challenges facing the curriculum as well as the latest CAPS document (DoE (2011), do not explicitly specify what aspects of IKS should be incorporated into the curriculum. Furthermore, there is no guidance as to how learners should be engaged in argumentation in their attempt to making sense out of the two distinctively different worldviews. Again, as have been highlighted for the assumptions made for collateral learning, teachers are not well trained or conversant with both the NOS and NOIKS.

Connected to the need for the understanding of NOS and NOIKS as well as the need for argumentation on equal footing, argumentation as used in the school science perspective is premised on deductive monologue as well as on probabilistic forms of scientific explanations (Hempel, 1962, Ogunniyi, 2007) which are not compatible with the non-logical and metaphysical forms of logic as embraced by IKS (Ogunniyi, 2007). Based on the latter discrepancies, the forms of border crossing have been found to be deficient in terms of their instructional approach linking the two worldviews. For instance, Ogunniyi (2008) have noted that the border crossing models proposed have not yet explained how an individual learner's experience result in a particular form of border crossing, let alone stating why. Furthermore, he asserts that the border crossing theories have also fallen short in explaining the physiological as well as the psychological processes that result in either form of border crossing among learners exposed to school science.

Since argumentation is a mechanism by which the three worldviews of personal, science and IKS within the learners' cognitive structure are mediated, it would seem reasonable that argumentation be an over-arching learning theory for learners to cross from one worldview into another. Furthermore, this is more so that the physiological apparatus of learning and of emotional reasoning are also invoked through intra-arguments. However, as sub-strata of argumentation, effective argumentation would rely on knowledge of the nature of scientific explanations within each worldviews as well as the linguistic apparatus of the language of discourse in each worldview. In this regard, Hempel (1962, 1966) provides various explications of scientific explanations leading to his famous bridge principle (Fetzer, 2015). Based on these realisations, the Dialogical Argumentation Bridge (DA-Bridge) is constructed as a theoretical framework for this study.

CHAPTER THREE
METHODOLOGY OF THE STUDY

3. 1 INTRODUCTION

The focus of this chapter is to present the methods used in order to explore the scientific and Indigenous Knowledge (IK) that grade 11 learners bring into the science classroom as well as determine the effect of traditional and argumentation instruction on their understanding of selected scientific concepts.

In order to achieve the above, this chapter sought to identify:

1. The subjects for the study by describing the sample and their demographic locations.
2. The research methods employed in developing the research instruments, their evaluation and final development.
3. The research design followed.
4. The ethical considerations followed.

3. 1. 1 Research setting

The research was conducted in four predominantly Black township schools in Cape Town. All the schools are high schools include grades 8 to 9 – i.e. the General Education and Training (GET) band and the grades 10 to 12 – i.e. Further Education and Training (FET) band. Schools A and B are neighbouring schools located within the demographic location of a large township pseudo-named Kaliba whose main language is isiXhosa. Schools C and D on the other hand are located in a suburban area of Cape Town with learners speaking isiXhosa and a mixture of South African and other African languages.

Each of the schools is surrounding by three to four feeder primary schools. While Schools C and D are not model C school, they are slightly well resourced than the other two since they are Dinaledi schools which are specialising in science. While the majority of parents of learners in all the four schools have houses in the vicinity of Khayelitsha, the majority are children of migrant workers who have their permanent houses and their larger family members in the rural areas of South Africa which they often visit during the holidays.

The number of teachers in the four schools range between 40 and 45 depending on the enrolment. While in many cases there might be sufficient teachers at a school, the need for the surplus teachers is also necessitated by the insufficiency in the number of permanent staff for specific subjects (learning areas). For this reason the Department of Education usually offers schools the so-called "replacement teachers" for three months up to a year contracts depending on the reasons why a suitable teacher cannot be found. In other cases, where even the contract teachers are not sufficient and no teacher being able to be identified among the permanent staff members, the school usually has to provide the School Governing Body (SGB) posts with lower salaries to make up for the lack of specific teachers.

The organisational structure of each school has a Principal supported by two Deputy Principals, one for academic and another for administration. The deputy principals themselves are in charge of Heads of Departments (HODs) who themselves are in charge of coordinating the administrative affairs of subject teachers within their areas of specialisation. School A has 45 teachers and a maximum of 1500 learners giving a 1: 31 teacher to learner ratio. School B has 48 teachers and 1700 learners with a 1: 35 teacher to learner ratio. School C has 42 teachers and 1300 learners giving a 1: 31 teacher to learner ratio while school D has 40 teachers and a maximum of 1460 teachers with a learner ratio of about 1: 36.

3.1.2 Profile of the dialogical argumentation as well as the traditional instruction groups

The Dialogical Argumentation Instructional Model (DAIM) mentor (the researcher) is a 54 year old male teacher with 7 years Physical Science teaching experience. He has taught Physical Science from grades 10 to 12. As member of the Science and Indigenous Systems Project (SIKSP) based at the University of the Western Cape, he has undergone training on implementing a science curriculum using DAIM for four years. In this regard, he presented workshops where all the teachers in the study were involved engaged in strategies of how to develop socially and culturally relevant science lessons. As indicated earlier two teachers A and B volunteered to use the DAIM were both mentored by the researcher in their two respective classrooms.

Teacher A from the DAIM group is a 39 year old male teacher with only a year's teaching experience and who holds an Honors' degree in Physics. He teaches grade 10 and 11 Physical Science classes at School A. Teacher B, also from the DAIM group is a young 32 year old female teacher who has only taught for about three years. She holds a B.Sc. degree in Chemistry and a Post Graduate Certificate in Education (PGCE) which is a professional certificate for teachers from non-education faculties or departments who want to pursue careers in education. She teaches both grades 11 and 12.

Teacher C from the Traditional Expository Instruction (TEI) group is a 58 year old male teacher with 14 years Physical Science teaching experience at the General Education and Training (GET) band as well as the Further Education and Training (FET). He holds a Higher Diploma in Education (HDE) with a formal B.Sc. degree in Chemistry and Mathematics. At the time of the study he taught in a class with 37 learners and had been the Head of Department for about 6 years in the same school. In terms of his duties, he had to mentor other three teachers in his department who were teaching grades 8 and 9, grade 10 and grade 11 classes. In terms of language abilities, the teacher speaks English as well as IsiXhosa which is the learners' home and first language.

The second TEI Teacher D is a 38 year old female teacher with 6 years Physical Science teaching experience. She taught in School D from grades 10 to 12. She holds a B.Ed. degree as well as some ACE courses in physics and chemistry. As a result of many learners who failed in grade 11, her class for Physical Science is relatively smaller (about 27) than that of other three schools. However, she has a bigger load in her time as she also teaches about two other grade 11 classes. The teacher speaks English as well as Shona, a Zimbabwean native language.

3. 1. 3 The sample used in this study

Grade 11 has been purposively selected as an appropriate grade level for this study. Furthermore, as has been highlighted in the above section, four difference schools have been chosen from which four grade 11 cohorts came from. After the administration of a survey questionnaire on the learners' conceptions of selected scientific concepts at Grade 11, light, sound and electricity concepts were found to be common in terms of the learners' prior conceptions.

The choice of the grade 11 classes was chosen based on the following reasons:

- The NCS as well as the CAPS documents for the Further Education and Training (FET) band covers the same subject area of Physical Science which incorporates Physics as well as a Chemistry section.
- Grade 10 to 12 syllabus is coordinated with similar topics which have levels of difficulty commensurate with the grade concerned.
- Grade 11 in this regard, is the first year of the final matric examinations at grade 12, hence key concepts are started at this grade in preparation for the final year.
- Furthermore, since Grade 11 syllabus is close to that of Grade 12, it was felt appropriate for use in research so as not to distract the learners in their final matriculation year.
- All the four teachers had Grade 11 as one of the grades they teach.

Furthermore, the four schools were selected on the basis of volunteering from teachers who attended the pre-intervention workshops. Using different schools has been to mitigate against contaminations that are usually associated with intact classroom cohorts belonging to the same school. The other reason is premised on ethical issues that are related to unequal treatment of learners of the same grade in one school, thus either advantaging or disadvantaging the other.

A brief profile of the sample in the study is as follows:

1. The total sample of all learners from all four schools is 141 with 62 boys and 79 girls.
2. The DAIM group had 76 learners with a ratio of 31/45 boys to girls while the TEI group had 63 learners with a ratio of 29/34 boys to girls.
3. The DAIM group had 71 learners in age group of 15 to 20 years and 5 above 21 years of age while the TEI group had all their 63 learners within the age group of 15 to 20 years old and none above 20 years old.
4. In the DAIM group, 65 learners had their home language as isiXhosa, 10 as English and 1 other African language while the TEI group had 41 for isiXhosa, 18 for English and 4 other African languages.
5. In the DAIM group, 34 learners where born in the rural areas, 16 in a city and 26 in the poor townships of Cape Town while the TEI group had 14 of their learners born in the rural areas, 33 in the city of Cape Town and 16 in the poor townships of Cape Town.
6. In the DAIM group, 64 learners had permanent homes in the rural areas, 1 in a city and 11 in the poor townships of Cape Town while the TEI group had 24 with permanent homes in the rural areas, 24 in a city and 15 in the poor townships of Cape Town.

7. In terms of the frequency of visits by these learners to their respective rural homes, the DAIM group recorded 50 learners who visited their homes once a year, 14 twice a year and one learner who visited about four times in a year. On the other hand, as opposed to the DAIM group the TEI group recorded 24, 8 and 3 visits respectively.
8. In terms of the duration of visits by these learners to their respective rural homes, the DAIM group recorded 42 learners who spent 1to 3 weeks during a visit, 20 spending about 4 to 7 weeks, 3 for more than 8 weeks and 11 as never having visited the rural areas. On the other hand, the TEI group had 22 of its learners spending 1 to 3 weeks, 13 spending 4 to 7 weeks, none over 8 weeks and 28 learners as having never visited their rural homes.
9. The majority of the learners subscribe to the Christian faith although most still value their cultural practices.

A quick review of the demographic profile of the learners shows that School D is very different from the other three schools. For example, without going into much detail it can be clearly seen that learners from School D are predominantly neither non-isiXhosa nor English native language speakers while those in Schools A to C are predominantly isiXhosa native language speakers. Although the learners in Schools A to C were born in the rural areas they lived in Cape Town township because their parents had were migrant workers. To that effect, the learners indicated that they frequently visited their rural homes and stayed for durations ranging from one week up to seven weeks in a year. Contrary to these learners, the majority of learners from School D stated that they were born and lived in Cape Town and consequently they never visited the rural areas. In terms of home and first languages, the majority of learners from School D indicated that they spoke seSotho, but seemed but not rural seSotho speakers as they never visited rural homes and that they did not have homes in the rural areas. In terms of the above data, a full demographic profile which is the source for the above is presented in Appendix 3A.

In summary, the two groups of learners were similar with regard to:

1. All the learners reside in the same local community but in four different high schools.
2. Both groups received the same pre and post-test survey questionnaires.

3. All classes from the four schools belong to a mathematics, physical science and life science (biology) stream as determined by the Science-Focus schools in the local school district.
4. Both groups were taught the same topics using the integrated science-IK curriculum. Except for the apparent structural support in Dinaledi schools C and D, the learners themselves are comparable in terms of their enrolment status into the grade.

3.2 RESEARCH METHODS

This study employed both quantitative and qualitative research methods in the collection and analysis of data. Quantitative data were derived from the performance scores of the learners' understanding of Selected Concepts Questionnaire (SCQ) which incorporates the learners' biographical data, an attitudes to science section as well as the conceptions of selected phenomena section. Qualitative data were derived from the learners' written responses in the SCQ, Teachers Observation Schedules (TOS) as well as the Learners 'Reflective Diaries (LDR).

All the teachers involved in the study were part of two broader workshops which were administered prior to the invitations to participate in the interventions. Prior to the selection of the four schools, teachers belonging to two EMDC districts together with their curriculum advisers were invited to two workshops organised by the researcher to demonstrate some plausible strategies on how the learners' IK could be effectively incorporated into the mainstream school science syllabus. The second aspect of the workshop focussed on the mediation or teaching strategy for integrating school science and IKS. From the four teachers who took part in the interventions, two agreed to be part of the proposed DAIM mediation strategy. Two teachers from two Dinaledi schools were purposively chosen to be part of the TEI interventions. Coupled with the Dinaledi schools' infrastructural support, these teachers were more experienced than those chosen for the DAI group. As already highlighted, the DAIM teachers were however already part of the researcher's mentee teachers selected for the EMDC North's mentoring programme where the researcher was a mentor. In this regard, it made sense for the researcher to continue working with them on the DAIM approach.

In order to realise the above, a number of key concepts which were deemed to be part of the core syllabus of the Grade 12 final examination were selected from the Grade 11 syllabus (see. CAPS, 2011). In line with the objective of the study to explore the learners' indigenous as well as scientific worldview the test items of the instruments were designed as much as possible to reflect the learners' lifeworlds. Ninnes (2000) has lamented the fact that school science textbooks and test items further marginalise learners from non-Western settings due to them intentionally or otherwise presenting content exemplars than are only based on western science contexts.

In terms of the latter, the instruments were designed and exposed to face and construct validation by peers, experienced Physical Science teachers and teacher educators. The instruments were further trailed over a couple of weeks with colleagues on Saturday workshops wherein some pre-service, in-service and teacher educators attended. Furthermore, the researcher also trailed the instruments with learners in the schools where he was a teacher mentor as part of the Department of Education's mentoring programmes in the province. Finally, the materials were also pilot tested in two teacher workshops which were meant for introducing the research programme to the schools. Prior to the instruments being administered to the four schools, five raters were asked to rate the instruments in order to calculate the inter-rater reliability scores. All the raters where experienced teachers who are part of the Science and IKS Projects (SIKSP) and hence had been trained in the DAIM approach and had good content knowledge.

In order to select the specific scientific concepts used as 'selected concepts' for the study, 21 concepts which were part of the survey questionnaire were administered by the researcher as pre-test items to all the grade 11 learners from the four schools. The latter effort was also a means of establishing the comparability of the learners from the four schools. Since the four schools are intact their comparability needed to be assessed, hence data from them also needed assessment in terms of their levels of distributions of scores or rather equality of variances. In terms of the Kolmogorov-Smirnov normality test, the alpha level was set at 0.05 or 95% confidence limit with a null hypothesis stating that there will be no significant difference in the variances of the sample groups from the four schools. Having requested the test from SPSS, significant results of P less than 0.05 were obtained as can be seen in the Appendix 3B. However, Dawson and Trap (2004) also argue that the t-test is robust for samples that are above 30 subjects and which are comparably equal. The only exception to this observation is school D whose subjects are less than 30.

From the performance scores obtained, the reliability scores from the subjects' perspective were calculated. Coupled with the latter, the scores helped the researcher to analyse the learners' performance scores in relation to the nature of the concepts in which they were exposed. For exploring the nature of the learners' worldview presuppositions, three concepts were found to be key and common to all four schools.

Finally, as has been highlighted above, Schools A and B formed the DAIM cohort while Schools C and D constituted the TEI cohort. In other words, all the data for Schools A and B were combined together to give the DAIM data and the same was done for Schools C and D. In terms of the Learners' Reflection Diaries (LDR), special focus group learners were selected for this purposes from the two groups. The selection of group members was chosen on the basis on the prominent group leaders in the DAIM group and TEI group. The rationale for this approach is that group leaders tend to present the consensus of their groups on a subject matter. According to Fleer (1999, p. 128):

> …the common practice of interviewing children on a one-to-one basis has also been shown to yield very little indigenous data. However, when children are interviewed as a group, children's responses are much richer and more readily given.

3.2.1 Quantitative and qualitative research methods

A mix methods approach is a pragmatic research approach that allows the researcher to combine quantitative as well as qualitative approaches in ways that one technique can augment the other (Niglas, 2000). In support of the latter, Nunan (cited in Alexander, 2009, p. 3) points out that:

> […] in practical terms, qualitative and quantitative research are in many respects indistinguishable, and that researchers in no way follow the principles of a supposed paradigm without simultaneously assuming methods and values of the alternative paradigm.

In respect to the above, it becomes clear that there is no need to try and draw sharp demarcations between quantitative and qualitative research.

In line with the mixed method approach employed, quantitative research methods seeks to establish a causal relationship between independent variables and dependent variable (Ogunniyi, 1984). The instrument used in support of the above was the Selected Concepts Questionnaire (SCQ) incorporating an attitudes to science section as well as the conceptions of selected phenomena section. Contrary to the latter, qualitative research involves the collection and interrogation of experiential data rather than that which is based on empirical testability or numerical values (Ogunniyi, 2009). For the purpose of this study qualitative approach was used to augments and to give meaning to the quantitative data that was independently generated by the statistical techniques. Qualitative analysis was used to interrogate and to analyse the learners' written responses in terms of Toulmin's Argumentation Pattern (TAP) as well as Ogunniyi's Contiguity Argumentation Theory (CAT) as well as the extant literature achieved by selectively picking the emerging patterns as excerpts of cases for interrogation to validate the quantitative results.

3. 3 RESEARCH DESIGN

3. 3. 1 Quasi-experimental design – Pre and post-test stages

The purpose of true the experimental research is to describe 'the consequences of a direct intervention into the status quo' (Ogunniyi, 1992 p. 81). In the context of this study, the TEI and DAI teaching strategies can be regarded as the independent variables while the learners' performance scores can be regarded as the dependent variables.

However, the ideal situation on which a true- experimental research design is based is rarely found in social sciences as groups as usually selected purposively as was the case in this study. Normally, in a true experimental resign the groups are constituted through the process of randomization (Ogunniyi, 1992). In place of a true experimental the study adopted a quasi-experimental research design for the four comparable schools with intact classes. Two of the classes were exposed to DAI while the other two were exposed to TEI. As stated earlier the schools are in the same locality and experience similar conditions. Their comparability was later ascertained by comparing the pre-test scores of the experimental and control groups.

In summary, the quasi-experimental design used for this study is as follows:

O_1 XD O_2 (DAIM group)

O_3 XT O_4 (TEI group)

O1, O3 represents pre-intervention observations while O2, O4 represents the post-intervention observations. X represents the common IK integrated science lessons treatments for each school. XD represents the DAIM teaching method, XT representing the comparison representing TEI teaching approach.

3. 4 INSTRUMENTATION

3. 4. 1 Introduction

The design of the instruments and their respective test items were influenced largely by the title of this thesis and its objectives. In respect of the latter, the objectives underpinning the design of these instruments sought to explore the learners' indigenous worldviews on the selected phenomena and how such worldviews related with the school science worldview.

In order to explore and to interrogate the learners' indigenous and scientific worldviews, cognizance of the fact that almost all the learners in the study were second language English learners had to be taken into consideration This has been more so since, teaching learners about IKS is further complicated by the fact that most IK or IKS is easily understood using the learners ' home language which they use in their daily lives.

In view of the fact that the grade 11 learners involved in the study were second language learners, some difficult English words were accompanied by isiXhosa translated versions. This was done to ensure that misconceptions or alternative conceptions were not due to the language of instruction. According to Oyoo (2007, p. 231):

> An analysis of the language structures in the research instruments used in some studies of possible sources of students' misconceptions in learning science has revealed that language itself can be a profound variable in the understanding of science concepts even to those who learn in their first language.

In other situations a particular indigenous concepts was included in the test item where such a terms does not have a direct identifiable term in English. This consistent with the assertion by Dlodlo (1999) who has argued that learners' whose home language is not English may have difficulties in expressing some ideas which are innate to their indigenous languages. In support of the latter, Battiste (2000) argues that IK is "often oral and symbolic, it is transmitted through the structure of Indigenous Languages" (p. 2). All the above points to the realities that are associated with test instruments among subjects whose worldviews might be different to that of the test instrument designers. As Ogunniyi (2007) points out, school science and IKS worldview are premised on distinctively different epistemic, ontological, axiological and metaphysical beliefs.

On the basis of the above, the researcher having been trained in both the school science paradigms as well as IKS became more cognisance of the worldview differences. The training from the SIKSP project at the University of the Western Cape on how to integrate school science and IKS since 2008 reawakened the researchers' knowledge of IKS. This reawakening helped the researcher to develop culturally relevant items which the researcher viewed as having scientific validity. It was then hoped that the learners would identify with some of the IKS within the test items and somehow relate them to the science they learn in the classroom. It is in this context that some of the items in the instruments were largely phrased from an IKS perspective which incorporated IKS beliefs.

3.4.2 Instruments used in the study

A summary of the instruments used, measurement scales as well as interpretation methods used are presented in the table below.

Table 3.1: Instruments, their measurements scales and interpretation method

Instruments used	**Measurement scales used**	**Analytical interpretation**
Pre/post-test conceptions of the selected concepts	1. 4-point argumentation. 2. Worldview responses analysis	1. Quantitative T-tests. 2. TAP/CAT analysis.
Pre/post-test attitudes to science and NOSIKS.	1. 4-point argumentation. 2. CAT categories sub-scales.	1. Quantitative T-tests. 2. TAP/CAT analysis.

Classroom observations	Learners responses and excerpts	Qualitative.
Learners' reflective diaries.	Learners' reflective responses and excerpts presented.	Qualitative.

Selected Concepts Questionnaire (SCQ) which incorporates the learners' biographical data, an attitudes to science section as well as the conceptions of selected phenomena section. Qualitative data were derived from the learners' written responses in the SCQ, Teachers Observation Schedules (TOS) as well as the learners 'Reflective Diaries (LDR).

3.4.3 Selected concepts questionnaire

As have been highlighted, the Selected Conceptions Questionnaire (SCQ) consists of the learners' demographic profiles and the selected natural phenomena section (Appendix 3).

The purpose of the questionnaire was to extract information relating to the learners' demographic profiles, their conceptions of selected school science concepts and their attitudes towards science and the nature of science (NOS) and the nature of indigenous knowledge (NOIKS). As has been already stated, the broad range of concepts in the conceptions questionnaire were initially intended to gauge the comparability of learners coming from different schools. Finally, the purpose of the latter was to establish where the diverse learners had common conceptions of the selected concepts and hence to identify concepts which will drive the objectives of this thesis.

3.4.3.1 Demographic profiles of learners

The learners' personal data was required to assist in having a closer understanding of the subjects in the study, to be able to track them down for purposes of interviews. A further reason for this data was for establishing whether there was a correlation between their conceptions in the selected concepts and their socio-cultural backgrounds (Appendix 3A).

3.4.3.2 …Attitudes to science and the nature of science and IKS

Learners were presented with scientific statements relating to their general attitudes towards school science and IKS. Some of the items were derived after the myth categories by McComas (1998). It was hoped that the learners' responses and stances on these items would help in eliciting the learners' awareness of the nature of science and IKS. In respect to the above, learners had to read the statement and decide whether to agree or disagree with the statement on a 4-point scale agreement as follows:

Strongly agree – The learners' views matches perfectly with the given statement.
Agree – The learners' views tend to agree with the statement given.
Disagree - The learners' views tend to disagree with the statement given.
Strongly disagree - The learners' views are strongly in contrast to the statement given.

The learners were further provided with a space so that they should provide reasons in support of the choices they made. The learners' written responses were a means for the research to obtain qualitative data for interrogating and interpreting the learners' reasons in terms of the TAP and CAT categories. The Not-sure category in the learners' statement was left out as it tends to discourage learners from making concrete decisions on a particular view, thus resulting in the tendency of the learners' views being neutralised towards as central position. After all validation and reliability analysis, only nine items relating to attitudes about school science and IKS remained. Table 3.2 below presents the items.

Table 3.2: Attitudes and perceptions about science and IKS

	Statement of belief
1.	It is easier to learn cultural knowledge than school science knowledge
2.	I believe in science in the same way I believe in my culture
3.	Knowledge from science should be the same everywhere in the world
4.	Science knowledge is the only true knowledge
5.	Cultural or home-based knowledge is not scientific at all because it was not tested in the laboratory.
6.	With science, we can solve all our human problems
7.	Science is a method to prove the truth about nature and its environment
8.	Experiments in the laboratory are done to prove that what science stories say is true
9.	Indigenous knowledge is not scientific because it was not tested in the laboratories

The researcher could not categorise the above items as it was realised that the learners' reasons in support of the choices they make may give a different interpretation of statement. The learners' responses to the above items are dealt with in question 2 under the results section in chapter 4.

3.4.3.3 Learners' conceptions on selected school science concepts

This section sought to elicit the learners' conceptions of a selected number of school science concepts from a science-IK perspective. As has been highlighted in the objectives of this study, it was hoped that the selected concepts would help in assessing the learners' scientific and IKS worldviews. A furthermore objective would be to explore areas of compatibility or otherwise between the school science worldviews and those of IKS and how learners made connection between the two distinct worldviews.

Similar to the attitudes to science section, the learners were provided with statements depicting a particular scientific claim. The learners were requested to read the statement and to tick the appropriate box in accordance with whether they strongly agree, agree, disagree or strongly disagree with statement. These were in presented in a 4-point agreement scale as follows:

Strongly agree – The learners' views matches perfectly with the given statement.
Agree – The learners' views tend to agree with the statement given.
Disagree - The learners' views tend to disagree with the statement given.
Strongly disagree - The learners' views are strongly in contrast to the statement given.

The learners were further requested to supply written reasons in support of the claims in the statement. The purpose for requesting reasons was to be able to interrogate the learners' worldview presuppositions as well as assessing how the learners' negotiated their IK worldview presuppositions with those of school science. In this regard, Toulmin's Argumentation Pattern (TAP) assisted in evaluating the learners' substantive arguments as required for school science, while the Contiguity Argumentation Theory (CAT) helped in eliciting the learners' cognitive stances and the elucidation of how learners bridged between their IK worldviews and those of school science. Since there were a number of concepts dealt with, it will only be apposite to state that the survey consisted of concepts under topics such as light, sound, electricity, chemistry and astronomy. After the piloting of all the items among all learner groups as well as the assessment of the comparability of all the learners, concepts on light, sound and electricity remained and became the central focus of this thesis. The full set of instruments are presented in Appendix 3.

3. 4. 4 Validation, reliability and piloting of instruments

The full set of instruments consisting of 40 different items were subjected to a full validation process by five raters. Three of the raters used in the study were teachers who had been subject specialists for a number of years. The other two raters were teacher educators at the university level who were also subject specialists in science and mathematics education. The complete set of instruments had sub-scales focusing on various concepts within the Grade 11 school science syllabus. The reviewers were requested to rate the each item on the instrument on a scale ranging from 1 to 4 as follows:

1 = item is irrelevant
2 = Item is relevant, but not so clear
3 = Item is relevant and clear
4 = Item is excellent

As highlighted above, five raters were used. In this regard, the Intraclass Correlation Coefficient accessible from IBM SPSS was used to calculate the Inter-rate Reliability Coefficient for the five raters. According to Hallgren (2012), ICC can be used for ordinal, interval and ratio data where two or more raters are used to rate the subjects. ICC is also appropriate where either all the subjects are rated by multiple raters or where a sample of the subjects is rated by multiple raters and the rest of the subjects by one rater. Hallgren further argues that many researchers fail to disclose the type of ICC variant they have used, since each variant has its own assumptions. The main assumptions are whether or not the raters were randomly selected from a larger population of raters, whether or not absolute agreement in the rating of the raters was important or just consistency in rank order and finally, whether the ICC results are meant to inform ratings by a single researcher or to provide average rating for all the raters.

In order to identify the appropriate ICC variant of statistic the following assumptions were considered in respect of this study:

1. The five raters were purposively selected with the intention of being sole raters of the subjects. This suggests a **two-way mixed model** of the ICC variant.

2. For inter-rater reliability or agreement, **absolute agreement type ICC** has been chosen so that the average ratings of the raters should provide a true reflection of the quality of each subject rated**.**
3. Consistent with 2 above, the ICC is meant to quantify the reliability of the ratings based on the average ratings from the five raters rather than those by a single coder.This suggests an **average measures ICC type**.

In the overall analysis, the model of ICC employed based on the above is a two-way mixed, absolute agreement, average measures ICC. This information became the source data for selection of ICC in SPSS version 23. As part of the ICC calculation, SPSS also provides the Cronbach alpha reliability which measure the internal consistency of the items themselves.

In terms of levels of agreements stipulated by the ICC, four categories are provided as follows:

1. Poor IRR for ICC values less than 0.40 or 40%
2. Fair IRR for ICC values greater than 0.40 and less than 0.59.
3. Good IRR for ICC values greater than 0.60 and less than 0.74
4. Excellent IRR for ICC values greater than 0.75 and less than 1.0

As part of the ICC calculations, the Cronbach alpha reliability statistics for internal consistency for the instrument items are presented in Table 3.3 below.

Table 3. 3: Items reliability statistics as well as intraclass correlations coefficients for raters

RELIABILITY STATISTICS							
N = 40	**Cronbach'Alpha**			**0.929**			
INTRACLASS CORRELATION COEFFICIENT							
N = 5	**Intraclass Correlation**	95% Confidence interval		F Test wth True value 0			
		Lower Bound	Upper Bound	Value	Df1	Df2	Sig.
Single measures	.240[a]	.087	.736	14.108	4	156	.000
Average measures	**.927[c]**	.792	.991	14.108	4	156	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.
c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise

In terms of the overall reliability of the goodness or appropriateness and accuracy of the instruments, table 3.3 reveals an overall Cronbach alpha coefficient of 0.929 or (92.9 %). Looking at the last row of table 3, the average measures ICC reads 0.927 indicating an Inter-rater reliability of 92.7 which is an excellent inter-rater reliability for the five raters.

3. 4. 4. 1 Reliability analysis of instruments

This section presents the scale reliabilities values for the research instruments used in this study. As in the above section, SPSS also provides Cronbach's Alpha reliability as well as normality calculations. In terms of the reliability of scores from research instruments, Pallant (2011) states that the Cronbach's alpha coefficient provides an indication of the average correlation among all items that make up a particular scale. This is a measure of how items within a particular scale measure the same theoretical construct. These average correlations range from a value of 0 to 1. According to Nunnaly, as cited in Briggs and Cheek (Pallant, 2011, p. 97), a minimum of 0.7 or (70%) reliability is recommended for any scale to be regarded as sufficiently reliable or an optimal mean inter-item correlation ranging from 0.2 to 0.4 where the items in a scale are less than 10.

Appendix 3C presents the Cronbach alpha reliability values for the various scientific topics making up the data collection instruments. The table further shows that, where the number of items per topic were less than 10, the inter-item correlation means were provided. In this regard, all inter-item correlations means for the pre-test and post-test instruments are between 0.2 and 0.4 and thus have met the minimum requirements for reliability purposes.

In the attitudes towards science instrument, there were originally five items and only 2 passed the reliability test with inter-item correlation mean of 0.334 at pretest and 0.293 at post-test. For the nature of science instrument, seven out of eight items were reliable at 0.202 in the pre-test and 0.266 at post-test. All five items concern with the learners' conceptions of light were reliable with a reliability of 70.3% and 63.7 at the pre-test and post-test respectively. However their inter-item reliabilities were 0.319 and 0.265 respectively at the pre and post-test. For the items in sound instrument, only 2 out of the 5 original items were reliable with inter-item correlation means of 0.351 and 0.278 respectively at the pre and post-test. The last instrument on electricity, three out of five original items were reliable at 0.200 and 0.205 respectively for the pre and post-test.

Based on Appendix 3C, items which were accepted for comparing the learners' performances were abbreviated using the name of topic. For example, since there were five items under the topic of light, the items were named as Light 1, 2, 3, 4 and 5. This pattern was used for all items under other topics. Since there were only 2 items left under the attitudes to science topic which were reliable, then the remaining items were abbreviated as Attitudes 1 and 2. This is used throughout for all other items under each topic.

3.4.4.2 Normality test

Normality test using Kolmogorov-Smirnov were conducted (see Appendix 3D). This is a one sample non-parametric test to assess the level of skewedness of the distribution in each sample. In a normally distributed sample, the sample mean is equal to the median. According to Dawson and Trap (2004), "Violating the assumptions of normality gives P-values that are lower than they should be, making it easier to reject the null hypothesis and conclude a difference when none really exists" (p. 138). However, Miller & Freund (1985) have argued that, the assumption that, the sample must come from a normal population is not such a severe restriction as it may seem. They contend that review of various studies have shown that the distribution of random variable with t-critical values for independent samples is fairly close to a t-distribution even for samples from non-normal populations.

Miller & Freund (1985) however stresses that, at least the researcher should check and ascertain that the population from which the sample is taken is approximately bell shaped and that it is not strongly skewed. To ascertain this, normal Q-Q plots as well as histograms were assessed in SPSS and most of the plots were close to normal distributions. In this regard, parametric test were chosen since they are robust to minor violations and also stronger in terms of detecting significant differences than non-parametric statistics.

3.4.5 Preliminary data for the main study

The first part of the main study entailed ascertaining the comparability of the performances of the learners from the four schools in relation to the various selected concepts. As has been shown in reliability section above, the only reliable items under each topic were considered for comparison. To detect any differences among groups, a significant p-value less than 0.05 is required. However, all the p-values received were larger than p-values of 0.05, suggesting that there was no significant differences in the performances of learners from the four schools.

However, the 1-WAY ANOVA results showed that the top listed items are those in which the majority of learners have obtained the highest mean scores. The only items representing groups where there were significant differences among some groups are Sound 3 and Chemistry 1. For Sound 3, the mean scores of School A were significantly larger than those of School D while the mean scores of School for Chemistry 1 were significantly larger than those of School A and B. Despite the minor differences on one concept of sound and chemistry between schools A and D, the 1 – WAY ANOVA analysis revealed that there was no significance difference between the learners' conceptions from the four schools. The observations of the decrease in the learners' performances as one goes down Appendix 3E highlights the deviation of the concepts depicting the natural phenomena from everyday life contexts to those that are abstract and decontextualized.

The analysis further show that the majority of the concepts dealt with, involves the concept of light, sound as well as electricity or electrostatics. These three concepts have similar properties which hold for a **particle** as well as a **wave model**. For example, Light has visible as well as invisible properties while sound has also the property of audibility as well as inaudibility. According to Halliday & Resnick (1988) all the three concepts do conform the particle as well as the wave model and thus are usually dealt with together under common themes such as vibration and waves (see. also Pain, 2000).

In this regard, the main concepts that will be dealt with from this point onwards are those of light, sound and electricity.

3. 5 INTERVENTON: The TEI and DAIM teaching methods

As part of the interventions, learners were exposed to IK integrated science lessons where lessons for one group were mediated through dialogical argumentation instruction and another through traditional expository instruction. In this regard, this section will give highlight some observations from the TEI group as well as observations from the DAIM group.

3.5.1. Lesson observation for TEI Teacher

The lesson which teacher chose for observation was on electricity and the concept of flow of current. The teacher had in previous lessons introduced electrostatics where electrical charge is said to be stationary and hence no electricity. An electrical circuit apparatus was brought into the classroom. It consisted of three battery cells and holder, electrical conducting wires leading to a parallel circuit with a switch and an ammeter before the parallel circuit. The parallel circuit had a light bulb in each parallel circuit stream. The apparatus could also be set up for a series circuit where the light bulbs are connected one after another so that the electricity has to flow through all the light bulbs or if one light bulb in front of other dies (fuses) then no current can flow to the other bulbs.

The main objectives of the lesson as highlighted in the teacher's lesson plans was to show learners that electrical charge will:

1. Flow in a conductor.
2. Needs a source of electromotive force such as a battery.
3. When current meets a junction such as in a parallel circuit, the current will split proportionally across the parallel streams and add up again after the parallel streams. In this construction, resistors (light bulbs) are current dividers and the voltage remains the same.
4. When current meets a straight line series circuit, the current will remain the same across all three resistor (light bulbs) but the voltage will be divided across each resistor.
5. Finally, the main aim of the switch is to show that current or electrical charge will not flow from the battery to the remainder of the electrical circuit if the switch is off (open).
6. The second part of the experiment was to include a rheostat which is in fact a variable resistor of known resistance. This is to demonstrate Ohm's Law which in simple words describes the relationship between the voltage and the current in an electrical circuit.

An observation schedule prepared for observing the classroom lessons focused mainly on aspects such as the focus of the lesson; the socio-cultural relevance of the lesson focus and teaching materials; the teaching and learning strategies that were dominant; the effects of language of instruction in teaching and learning as well as the manner in which the teachers managed the classroom interactions and time management. All the latter aspects were geared towards the roles that the teachers played, the roles given to the learners in the teaching and learning process as well as the teaching and learning materials that were used to scaffold learning. A full observation schedule is presented in Appendix 3F.

3.5.2 Classroom observation

When interrogating the teaching and learning strategies, the teacher used demonstrations and probing questions for learners to try and predicting what would happen when certain independent variables are changed. This was done well with the appropriate equipment which enabled the process of enquiry and discovery. However, there was no immediate evidence of whether all the learners were understanding as some learners would not naturally put up questions for fear of showing signs of being less intelligent. As in most other lessons, the teacher relied on a later form of assessment such as class work and question time at the end of the lesson. This approach is not very effective because many learners at that time would have forgotten a whole lot of stuff and would usually say they don't understand.

When the teacher asks the learners or a particular learner to indicate exactly what he or she did not understand, the learners would normally say everything or decide to say they understand. With regard to the first criteria about the focus of the lesson, there was smooth introduction of the lesson in the roles of the teacher and his learners as well as appropriateness of the teaching and learning materials. In terms of social or cultural relevance, the lesson focused on the practical side of electricity and hence the demonstration with experimental apparatus was appropriate even though they were entrenched on traditional school science equipment and hence socially, but not necessarily culture relevant. In this regard, there are various culturally relevant analogies of river flows into separate streams which could be illustrated using water as charge, water flow as current etc. Below is excerpts of what transpired in the TEI classroom as the teacher introduced the concept of current flow:

Teacher: The flow of current in an electrical conductor is similar to water flowing in a copper or PVC pipe. The electrical current can be regarded as water, the electrical conductor as the pipe through which the water flows, the switch as the tap which one uses to let the water flow out. We can also regard the power source or battery as the water pump which is not in our houses, but is situated at the municipality. Now before we do some demonstrations is there any question?

Learner 1: Yes I see the similarities, but if the power source is the water pump at the municipality, how do they (council) know that we need water and switch on the pumps?

Teacher: No, the pumps are always on, they don't need to switch them on and off because people are using water in their houses all the time.

Learner 2: That is interesting, but I still have a problem, the battery does not behave as a pump because the pump will force the water out and cause the pipes to burst while the battery pushes charges.

Teacher: That is a very good question which we should keep in mind as we continue with the concept of electrical current. Remember that an electrical power source also exerts an electromotive force, but we switch it on and off. The municipality have pumps that switch on an off depending on how the pressures drop downstream of their pumps. Remember also, in the water pipes in our homes there is always water in the pipes in the same way there is always electrical charges in the electrical conductors.

Learner 3: Meneer, can I ask why is 'umbane' (electricity) and lightning also called 'umbane''? What is common between them and what is different?

Teacher: OK…the difference between lightning and electricity is that lightning is as a result of the rubbing of the clouds which becomes charged and these charges gets dissipated as lightning to the earth. This is done through the air. Electricity cannot be conducted through the air, it need a good conductor of electricity such as the copper wires you see in this table [pointing on the table in front of him].

Learner 3: Meneer, I understand that, but I was wondering why the same name if the two are different.

Teacher: We don't have enough time to explain everything, but I think that 'umbane' from lightning is called 'umbane' because it is fast as electrical charges when they move in an electrical conductor.

The above is just glimpse of the lesson on electricity. In general, the lesson went well because there were a number of demonstrations using series and parallel circuits using the analogy of water flowing in different pipe sizes and or parallel and series circuits. However, in terms of the above excerpts and some of the questions of the learners regarding the similarities between electricity and water flow, more could have been done if learners were allowed more space to argue the issue.

The last response by the teacher has implications for misconceptions as learners may think that electrical charges flow in a pipe as water would in a pipe. The teacher was for most time demonstrating and moving forward without exploring the conceptual issues such as the key question raised by learner 2 and 3. In this regard, water will flow out of a pipe when the tap is open and yet electricity will not flow when the switch is open. This could have been a nodal point for discussions into the nature of charge and water as well as the key commonalities between a battery and a water pump that need to be regulated to start and stop. Furthermore, more could have been done in the explications of the differences and commonalities between lightning and electricity to elucidate the nature of electrical charge.

In terms of language effect, there was evidence of some learners struggling with the English terminology concepts. This was supported by the teacher frequently using English and isiXhosa interchangeably in an unstructured manner. The lesson plan by the teacher also did not show evidence of predicting the possible language barriers and thus the preparation of corresponding electrical concepts in isiXhosa. The implications for not planning possible language barrier interventions within the lesson plans is that teachers would find them doing unstructured code switching with foreign and unknown non-scientific isiXhosa terms which are by-products of transliteration practices (Dlodlo, 1999; Diwu, 2010). Furthermore, the assessment was in English and not isiXhosa. The implications for this are that learners who are taught some concepts in isiXhosa usually fail to express themselves in English when the time for the English-based assessment comes.

With regard to time and classroom management, the teacher was able to control class noise and attention as he was at the centre of their attention as the demonstrator. As he had planned the lesson well ahead, he was able to stick to time for each specific activity for demonstration. The challenge however has been highlighted in the above paragraphs, it that learners did not have the larger part for themselves to explore the possible answers where the teacher could have set up the scenario and allowed each learner to spend time predicting the possible solution and again allowing learners in groups to discuss among themselves within specific time frames. In other words, demonstrations or even experimentation by learners should be preceded by enough time with learners hypothesizing, predicting and arguing possible solutions and outcomes. Experimental demonstrations should as such be at the end of a particular lesson or rather lag exploration by learners at each defined stage of enquiry.

3.5.3 Classroom interventions for the DAIM group

As a mentor and co-teacher for the DAIM teachers, we collaborated on developing two lessons that would be socially and culturally relevant. In addition, the lesson was designed to use a thematic approach which would cut across two or more Physical Science topics. In this regard, the concept of light was chosen.

The DAIM lessons followed the following sequence:

1. A social and culturally relevant concept map incorporating all the characteristics of a thematic approach with cross-cutting concepts.
2. Individual tasks (intra-argumentation) based on the case study with questions which exhibit multiple perspectives on the phenomena under discussion.
3. Small group tasks (inter-argumentation) where learners share their individual task answers and get opportunity to defend their own views and to convince each other of possible viable solutions to the problem statements.
4. Small group presentations to other groups within the classroom leading to whole class argumentation.
5. Lesson consolidation by teacher through a process called IK-to-school science contextualization; a process where an attempt is made to make border crossing from an IK worldview to the school science worldview relatively ‘smooth’.

Lesson 1: Lesson focus on the refraction of light

Learners were presented with a concept map in figure 1 of Appendix 3G and attempt to use it as a thinking tool in responding to the following five questions. The questions had to answer firstly on an individual basis and then to be discussed in a group where collaborative consensus is reached.

1. Is the sun, water and air related to each other in any way whatsoever?
2. Where does the rainbow come from and how is it created?
3. In your understanding what things enable people to see objects around them?
4. Why do you think some nocturnal animals are able to see in the dark while there is no light?
5. If the sunrays were not present or available, would it be possible for cellular phones to operate?

Learners were guided to present their answer(s) as **CLAIM** and then also provide reasons as **EVIDENCE** to support their claims. At the end of each answer they had to circle the source of their knowledge claims: Personal Experience = PE, Traditional knowledge = TK or School Knowledge = SK. Note: Traditional knowledge was deemed preferable as learners were more acquainted with the term, traditional knowledge as opposed to indigenous knowledge. 10 minutes was afforded for individual answers and another 20 minutes to discuss them in groups. At the end of 20 minute discussions each group was given 10 minutes to present and discuss their answers to the whole class. However, since there is a large number of learners, the individual task responses (for intra-argumentation) for those learners who belonged to a particular discussion group are put together and their resolution or consensus is presented in table 3.4 to save time and space.

TABLE 3.4: G.4 / Q.1 - Is the sun, water and air related to each other in any way whatsoever?

INDIV	CLAIM	REASONS (EVIDENCE)
L.29	Yes, the heat of the sun is what is common in them. They are not man-made (PE).	The heat of the sun warms the air and as the air warms it heats the sea water too. The see water evaporates and creates rain (SK).
L.15	They are related because they form raining (PE).	Because when the sun heat the water they form water vapour and that water vapour form clouds and clouds form rain (SK)
L.18	They all work for people and animals or they are	Air helps people breath, water is good for thirst. The sun can help people see or light their way (PE).

	all supportive to human beings/living beings	
Consensus	All support humans and animals and environment (SK).	Sun provides heat, air – oxygen, and water cooling and growth (SK).
Key: G = A group number, Q = a question number, L = a learner number,		

Observations of Tables 3.4 above to 3.8 below show learners' claims and reasons in support of their claims for each particular question stated. The provision of claims and supported with reasons is in line with the TAP. Furthermore, it should be noted that learners also indicated their sources of knowledge so that their worldview presuppositions could be identified.

As indicated by L.29, 15 and 18, have associated the sun, air and water as necessary for human survival. L.29 and L.15 related the three to the water cycle while L.18 broke each element down to what it does as a unit. For instance, she identified air as providing oxygen for breathing, water for quenching thirst and the sun as for the provision of light for vision. The discussions came to a consensus where the learners came to a conclusion that the sun, air and water are good for human survival. As one could see from the consensus, the learners cited school science and focussed on the individual attributes of the elements rather than a holistic relationship between them.

From the context of introducing the concept of light refraction by providing some of the necessary ingredients in the concept map, it is observed that the main thinking from the learners' perspectives is along the water cycle and the creation of rain using the sun. This was a nodal point to introduce the concept of the formation of the rainbow which is a phenomenon that can be explained by light refraction. In this regard, the next question asked the learners to explain where they thought the rainbow came from and how it was created. In this regard, the following excerpts from group 7 is presented below.

TABLE 3.5: G.7 / Q.2 - Where does the rainbow come from and how is it created?

INDIV	CLAIM	REASONS (EVIDENCE)
L.21	From God and rain (TK).	Because God judges his people because of sin and he decided to stop killing and created the rainbow after the flood of Noah (TK).

L.24	Rainbow comes from the refraction of water droplets and the sunrays then seven colours appears (SK).	In my cultural knowledge they believe that it's a sign that the rain has stopped (TK)
L.22	From the atmosphere (SK).	Because I can see it with my own eyes and at school we are taught about it and it comes after the rain has stopped (SK).
L.25	The rainbow comes from the rain when it falls down (TK).	It comes from the cultural knowledge because they believe is that the rain can make the seven colours called rainbow (TK).
Consensus	It is formed by the refraction of light on the water droplets in the clouds. (SK).	Because the rainbow comes after rain and sunshine and that the light is refracted through the water in the sky (SK).
Additional	God is the cause of all this (TK).	The bibles tells of Noah's story and the rainbow (TK).

Key: G = A group number, Q = a question number, L = a learner number,

Learners 21 and 25 have both derived the source of the rainbow from rain. Learner 21 cited that God caused rain to fall in the days of Noah and hence also created the seven colours of the rainbow when He stopped the rain. For learner 25, rain can cause the seven colours which he calls the rainbow. For both these learners, traditional knowledge has been the source of their knowledge.

Learner 22 however, has cited the source of the rainbow as coming out of the atmosphere. While also admitting personal experience, she states that she is taught at school that it comes after the rain has fallen. However, Learner 24 declares that the rainbow is as a result of the refraction of light, but however he also believes that the rainbow is a sign that the rain has stopped. This learner thus exhibits dual worldview presupposition; that of school science and that of IKS.

After much discussions, the learners came to a conclusion that light is refracted on water droplets in the atmosphere and hence the various colours of the rainbow are created. However, the learners also concluded that God is the main cause and they cited that the bible states so. This suggests that the learners somehow hold dual worldview presuppositions which is supported by Ogunniyi's (1988) harmonious dualism. Their conclusive responses also highlight that the learners know which context was appropriate for their report back, i.e., school science. This is also supported by Gunstone & White (2000) who had argued that, rather than trying to change learners' preconceptions, learners should be equipped with the skills of knowing which context is appropriate and applicable for a particular situation.

Now that the learners have identified the two worldview explanations of the sources and the formation of the rainbow, the teacher was able to help the learners to have a fresh perspective on the roles of the sun (light), the rain (water) and air in the formation of a rainbow and thus the concept of refraction.

Lesson 2: Lesson focus is was on the notion of visible and invisible light

The following lesson sought to interrogate the notion of vision and infra-vision. In this regard, two questions were posed for the learners and each one is presented in each of the following tables.

TABLE 3.6: G.2 / Q.3 - In your understanding what things enable people to see objects around them?

INDIV	CLAIM	REASONS (EVIDENCE)
L.16	It is the light (PE).	Without light there would be darkness and you would not be able to see a thing (PE).
L.26	The eyes of a person, microscope, spectacles and light (SK).	It is because a microscope can help a person see what a naked eye cannot see like cells (SK).
L.22	Our eyes, nose can help see and ears can make us see (PE).	When you smell something you can imagine it in your mind. Hearing can let you think and thinking can make you imagine (PE).
Consensus	The eyes and light	L.1 & L.2 argued that light and eyes are essential for seeing an object and that the microscope is a special aid to sight.
Key: G = A group number, Q = a question number, L = a learner number,		

In summation, the three learners above cited light and the eyes as something that enables people to be able to see objects around them. Learner 16 forcefully argued that without light, people cannot see while Learner 26 also argued that eyes are equally essential in the process of sight as without them, light was useless. While the use of microscopes were acknowledged as visual aids, the learners opted for eyes and light as two apparatus that enable vision.

Having established the role of eyes as well as light in the process of vision, the teacher then ventured into the mechanisms of how light reflection and absorption resulted in the perception of different colours within the visible electromagnetic spectrum. Prior to the introduction of the invisible spectrum the following question was interrogated.

TABLE 3.7: G.3 / Q.4 - Why do you think some nocturnal animals are able to see in the dark while there is no light?

INDIV	CLAIM	REASONS (EVIDENCE)
L.9	Their iris is not the same as ours (SK).	Our people's iris are black and animals are somehow reddish (PE).
L.12	They are created to see in the dark (TK).	They stay outside all the time, so that's why they are able to see in the dark (TK).
L.17	Nocturnal animals have bright eyes (TK).	They have animal characteristics (TK).
L.31	Animal eyes are transparent so all the light can enter (SK).	Animal eyes glow at night for them to see (TK).
Consensus	The iris of animals allow more light in	Animals have bright eyes
Key: G = A group number, Q = a question number, L = a learner number,		

Since the majoring of the learners in the previous question had come to a conclusion that light was key in the process of vision, the focus of the four learners was on eyes. They all somehow decided that there must be something that enables the nocturnal animals to see in the darkness when there is no visible light. Learner 9 thought that the iris from animals must have something to do with their ability to see in the darkness as he argued that the animal iris are red while that of humans are black. On the other hand, Learner 12 concluded that adaptation could be the explanation as she argued that since animals stay in the darkness most of the time, they must then been created for that environment. Learner 17 and 31 have respectively pointed out that nocturnal animals have bright eyes and transparent eyes. Similar to Learner 12, Learner 17 gave his reason that suggest adaptation to the environment. However, Learner 31 suggested that the transparency of the animal eyes results in their eyes glowing at night. The learners argued among themselves until they somehow came to a conclusion that the iris from animals must be opening up at night and allowing more light to enter. This view was echoed by various other learners from other groups. Other learners held the view that animals do produce their own light at night especially when they detect some evil spirits or ghosts.

In order to extend the learners' imaginations a little bit further, the notion of the applications of cellular phones and light was introduced in the following question.

TABLE 3.8: G.6 / Q.5 - If the sunrays were not present or available, would it be possible for cellular phones to operate?

INDIV	CLAIM	REASONS (EVIDENCE)
L.1	Yes it would be able to operate (PE).	At night you can use a cell phone and you can even phone a person (PE).
L.4	It would be possible for cell phones to operate without the sunrays (PE).	Cell phones are working with electricity which means cell phones get the heat from the electricity (PE). They use heat from the electricity i.e. infrared rays (SK).
L.3	It will operate without the sun (PE).	Because at night there is no sun but still the phones can operate (PE).
L.5	It is possible (PE).	They do not use solar radiation, they use network such as Vodacom and cell C (PE).
Consensus	Phones work in the absence of visible light	Cell phones use invisible light from the sun (SK).
Key: G = A group number, Q = a question number, L = a learner number,		

Interestingly, all the learners answered the above question without any doubt and highlighted that it was common-sense that cellular phones do not need light as they operate in the darkness as well. For instance Learner 4 suggested that if there was any heat required, then it would come from electricity. He suggested that infrared rays will enable cellular phones to operate. On the other hand, Learner 5 argued that cellular phones do not need solar radiation as they operate on the network (Vodacom or cell C).

While dealing with the previous question on the ability of nocturnal animals being able to see in complete darkness, the above arguments suggests that learners the majority of learners assumed that nocturnal animals only can see only the basis of adaptation, but the notion of invisible light was still not clear. However, the above question has somewhat caused the learners to think about what could be the medium for cellular communication if visible light was not a barrier. For example, while still incorrect, Learner 4 suggested infrared radiation (heat) which is an invisible form of light. Learner 5 suggested that cellular networks must be responsible. While the teacher probed the learners, a number of learners in the classroom could not clearly explain the nature of what they call 'cellular networks'. These grey areas allowed the teacher to have a way of introducing the role of the various frequencies of the electromagnetic spectrum. It was interesting that the learners were however well acquainted with the electromagnetic spectrum, but they could not really relate to their everyday lifeworlds in their daily use of television, cellular phones or microwaves.

3.5.3 General discussions for the TEI and DAIM interventions

Learning theories advocate for learners' prior knowledges to be prioritised in the process of teaching and learning engagements (Ausubel, 1968). In this regard, both teachers made attempts to engage the learners in making predictions about the purpose of the artefacts used for the lessons. The teaching and learning support materials used for both groups seemed appropriate as demonstrations and experimentation were used for the TEI group while a case study and physical artefacts were brought into the DAIM classroom.

However, Campbell and Lubben (2000) have argued that amongst the various resources a learner bring into the science classroom is his/her own socio-cultural background which is inclusive of IKS. While the lessons in the TEI group were practical and relevant, they were more focussed on traditional school science worldview with no culturally relevant examples. As Jegede (1997) and Tobin & Garnett (1988) has suggested, Traditional teaching approaches usually lead learners to adopt learning strategies for the memorisation of facts. Although, teacher now know that IKS should be included in every science lesson, they however do not do so for various reasons such as not having appropriate resource materials such as textbooks reflecting indigenous worldviews of science (Ninnes, 2000).

However, an important point of note with regard to departure from prior knowledge to the main body of the lesson is the form of bridging principle used for both intervention strategies. For example, Vygotsky (1978) speaks of social constructivism where learners learn from each other and that learning is determined by what he has called the Zone of Proximal Development (ZPD) which defined as the measure of the cognitive distance traversed from the learners' prior knowledge to the expected knowledge. The two intervention strategies were similar in terms of sourcing of the learners' prior knowledge and some engagement of learners within the introduction as well as in the main body of the lesson. There seemed to be some differences in terms of how learners traverse that ZPD.

In the TEI intervention the teacher seemed to have used prior knowledge only as means of introducing the lesson and creating interest for the learners rather than using their prior knowledge as support materials for the construction of the main body of the lesson. The general trend observed amongst other TEI group classes was that were attempts to include the learners' IK into the lessons, that was only done to introduce the lesson and to abandon the process and to go into the supposedly 'real science' in the main part of the lesson.

As Chiappetta, Koballa and Collette (1998) have succinctly put it, 'Culturally diverse students develop meaningful science understandings when they see their culture facilitating learning rather than seen as an impediment to it" (p. 51). Since the TEI learners were also observed to be struggling with language barrier issues as there were no scaffolding language materials or glossaries, teachers in this regard may deliberately avoid bringing in indigenous perspectives into the science classrooms as this may exacerbate their challenges with respect to language. Supporting this view is assertions made by Sutherland and Dennick (2004) and Rollnick and Fakudze (2008) that, communicating IK to learners will also necessitate the use of the learners' first or home languages. The implications for not planning possible language barrier interventions was that the TEI teachers were frequently observed to be doing unstructured code switching resulting in foreign and unknown words which were neither English nor isiXhosa known words (Dlodlo, 1999; Diwu, 2010).

However, though group work was observed among both groups, the one among the TEI group was unstructured as the teacher learners were allowed to debate and discuss without an opportunity given for each learner to first express his/her views on a particular issue. The teacher was frequently observed to be focussing and targeting more able learners. As Tobin (1988) has suggested, most teachers do this to keep momentum so as to complete the syllabus. The DAIM learners were provided with individual tasks which repeated themselves over to small groups, group presentations where they also heard the other groups' views and then the whole class discussions where the teachers were also brought in.

According to Diwu & Ogunniyi (2012), the purpose of the dialogical argumentation instruction as highlighted above was to allow all the learners the opportunity to reach a cognitive consensus where it was feasible. As opposed to the DAIM group, the TEI teacher was leading with demonstration in highlighting some phenomenon. In this regard, the teacher could first create scenarios or case studies that would create controversy or inquisitively where the learners will automatically hypothesise even way before any demonstrations. Thus, demonstration would have serve to confirm or disconfirm their predictions and thus activate their cognitive abilities.

In terms of social cultural relevance, the concept map approach applied to the DAIM group which the learners read provided some clues for learners to compare cross-cutting concepts and a multiple worldview atmosphere was inculcated. With regard to the teaching and learning strategies, more time was devoted to the learners in their individual, group and whole class discussions while the teacher only facilitated by clarifying issues as well as offering probing questions. In the process, the learners were speaking in their own home languages but using the terminology glossaries to help translating their ideas into English for assessment purposes.

As the teacher was not very much conversant with the argumentation framework as well as knowledge of IK practices, the teacher's self-efficacy and confidence was not so good as she was overwhelmed with the learners' responses and enthusiasm. This caused the teacher to side track most of the time and lost the sense of time for each individual stage in the dialogical argumentation process.. As Ogunniyi & Ogawa (2008) have argued, informing teachers about how to integrate IKS into school science is not sufficient to guarantee that they will be able to effectively integrate the two knowledge systems into their instructional practices as required by the IKS policy documents. In this regard, they highlight that a number of studies have shown that mentee teachers need to be engaged in a long-term mentoring process. In this regard, the researcher had to chip in at various times to assist as he had mentored the teacher only for a few weeks. Of most importance, was how to bridge the learners' 'alternative' explanations with that of school science. Instead of encouraging the learners to abandon their own views, the researcher took over and assisted in a process he calls IK – to – school science contextualisation and vice versa. This ensured that while learners are able to appropriate knowledge claims (Gunstone & White, 2000), they are able to use one worldview as a place holder for a concept in another worldview and thus know when one form of explanation is necessary.

For example, in the DAIM group the learners were initially engaged on their awareness of the concept of light in various contexts and then presented with a concept map to allow their cultural and personal views to be awakened. For instance, Keane (2007) suggests that, learners' worldview presuppositions are more essential for them that the normal examples of school science. She further argues that even in cases where IK examples are introduced, their introduction usually occur within a western science paradigm. Contrary to the latter, learners individually engaged with some leading questions so that they could express their own views. This is in line with what Ogunniyi (2007) calls intra-argumentation. The teacher did not take over, but facilitated the switch from individual to small group tasks so that the peer learning Vygotsky speaks about can be effected. In support of the teaching and learning processes used by the DAIM teacher, Stears et al. (2003) succinctly puts this way that:

> While an individual's knowledge is personally constructed, the constructed knowledge is socially mediated as a result of cultural experiences, personal history, interaction with others in that culture, and the collective experiences of the group. This view of learning places importance on the context in which learning occurs. (p. 110).

As the last sentence in the above citation state, learning places importance on the context in which learning occurs. With regard to learners in the two intervention groups, isiXhosa has been the learners' first or home language and hence the language they can express themselves the best. It is therefore assumed that since Vygotsky was a Russian and the language of teaching and learning being Russian, social construction of knowledge may have occurred in the context of that language. In this regard, '…the way that students take up classroom or disciplinary discourses are shaped by the social or everyday discourses they bring to the classroom" (Anderson, 2007, p. 15).

3.5.4 Challenges and opportunities presented by the TEI and DAIM approaches

Key characteristic and distinctive aspects of the two interventions, the challenges and opportunities they presented during the course of the observations are as follows:

- The TEI approaches seemed to be a good teaching and learning strategy geared at assisting teachers to have a uniform approach that is easily evaluated. It also helps teachers to focus and not to deviate from the key concepts specified in the syllabus. In this regard, the TEI approach does not need a lot of prior lesson preparations and can accommodate less experienced teachers with less subject content knowledge as much guidance is given within the text books and the subject guideline documents.

- On the other hand, the DAIM approach showed that it is an approach that needs teachers to be well trained and knowledgeable in the subject. The DAIM approach needed more time for lesson planning and resources preparation. Once these had been done, it showed that a large aspect of the syllabus can be covered in fewer lessons as duplication of concepts across various areas of the Physical Science syllabus are visited simultaneously. This seemed to have given the DAIM more broader understanding of the concepts in unfamiliar contexts.

- The DAIM approach has shown that various teaching and learning aspects such as language barriers, teaching and learning across the curriculum and the various categories of the specific aims which are normally dealt with on an individual basis can be infused in one lesson or a number of lessons in a sequence so that learners can develop a holistic rather than a dichotomized or compartmentalized view of knowledge.

With regard to language and terminology issues, the TEI groups prioritized on English and underrated the effects of language barriers in science teaching. Implications highlighted undesirable unsystematic code switching practices which resulted in transliterations having no cognitive meanings but only served as placeholders to cover up for the teachers' language deficiencies.

3. 6 DATA ANALYSIS

Data derived from the various instruments in the study were analyses following in terms of quantitative and qualitative descriptions. For the quantitative data, Statistical Package for Social Sciences (SPSS) version 23 was used to code and to interpret both the quantitative and qualitative data. The statistical software enabled performs the inter-rater reliability of the raters who did validation of my instruments. The application was further used to perform scale reliabilities (using Cronbach alpha) to check for the inter-item reliabilities of the scales. The normality of the data samples was also assessed in order to determine whether non-parametric or parametric statistical procedures were applicable.

The data set collected was critically analysed using Toulmin's (1958) Argumentation Pattern (TAP) and the, Ogunniyi's (2002) Contiguity Argumentation Theory (CAT) as units of analysis. Remember that TAP focuses on the logical arguments used by the learners in performing cognitive tasks whereas CAT focuses on logical and non-logical or culturally embedded arguments.

3. 7 ETHICAL CONSIDERATIONS

The following steps were taken to ensure that the study conformed to the ethical standards laid down by the Senate Research Committee of the University of the Western Cape and that of the Western Cape Department of Education. In this regard, once the research proposal was approved by my supervisor, a data collection process as well as the nature of the data collection instruments were presented for face validation by peers, in-service teachers as well as educators.

I therefore completed the required application forms by the University's Research Ethics Committee to obtain a letter for ethical clearance approval. When I had done all required corrections to meet the university's ethical clearance standards, I had to consult the Western Cape Department of Education (WCED) for written permission to conduct research in their public schools. To this effect, I also consulted with the specific district offices to which the specific schools belonged and asked to meet with the relevant curriculum advisers responsible for the research schools. The purpose for contacting the curriculum advisors was to inform them about the research that was going to take place in the schools they are in charge of and the nature of the research.

The rationale for consulting the WCED and curriculum advisors was based on the perception that research by students doing research is that contact times for teaching being is wasted while there is a little no concrete intervention to help the learners or the teachers. The second concern relates to the unfair treatment on learners which is normally as a result of the research designs that either exclude or expose some learners to interventions that are known to be ineffective. To this effect, all participating learners were of one class grade; all being exposed to IK integrated lessons which the researcher moderated and supervised to see to it that all learners had relatively similar experiences. While it is important to evaluate the effects of interventions, the focus of the research has been more on understanding the nature of the learners' underlying presuppositions so as to recommend teaching strategies that prove to be effective.

The last phase was to consult the principals of the respective schools and the relevant teachers and learners to introduce the purpose of the research and how they will benefit from it. Following the above, workshops were conducted with relevant teachers were conducted and introductory lessons with learners in each participant school. This was also to ensure that all participants understood and comfortable with the contents of the research so that I could receive their relatively informed written consents. All interviews, observation notes, questionnaires with respect to the subjects' names were anonymised. A confidentiality letter accompanied this to the respective schools.

At the end of the study a summary report of the findings of this study was submitted to the Western Cape Department of Education (WCED) and the school principals whose schools participated in this study.

CHAPTER FOUR
PRESENTATION OF RESULTS

4.1 INTRODUCTION

As has been indicated in chapter 1, the purpose of this thesis is to explore grade 11 learners' scientific and IKS worldviews exposed to the Traditional Expository Instruction (TEI) and the Dialogical Argumentation Instruction (DAI) on selected natural phenomena. As highlighted in the previous chapter, this study employed a pre-posttest quasi-experimental design. In line with the latter, the learners' conceptions before and after the two interventions strategies were assessed. As a reminder the two research questions that this thesis addresses are as follows:

- What were grade 11 learners' understanding of the selected natural phenomena before and after being exposed to traditional expository instruction and a dialogical argumentation instructional model?
- What are the relative effects of the teaching methods on their attitudes towards an integrated science-indigenous knowledge curriculum?

Since this study employed a mixed methods approach, where applicable, each question is analysed quantitatively to give a descriptive picture. This will be followed with an in-depth qualitative analysis to interrogate the underlying substantive factors corresponding to the quantitative descriptive summaries. The following two main sections as well as sub-sections that will follow from henceforth will address the research questions and their sub-questions.

In this regard, section 4.2 below addresses the first research question with sub-section 4.2.1 dealing with the preliminary investigation of ascertaining the comparability of the learners from the four different schools of whom the two study groups came from. Sub-section 4.2.2 will deal with the actual conceptions of the learners before and after the teaching methods. Section 4.3 deals with research question 2 with sub-section 4.3.1 dealing with the opportunities and challenges the intervention methods posed in the integration of science with IKS; while sub-section 4.3.2 deals with the learners' attitudes and experiences as a result of the IK integrated science within their science lessons. Finally, section 4.4 presents a summary of the findings in the chapter.

NOTE: I have highlighted section 4.3.1 on the actual intervention in case it is felt that it is not necessary in answering the two research question

4.2 GRADE 11 LEARNERS' CONCEPTIONS OF NATURAL PHENOMENA BEFORE AND AFTER INTERVENTIONS

In an attempt to interrogate the learners' preconceptions cognisance of the above approaches, the learners' pre-conceptions were collected using a survey questionnaire consisting of 21 phenomena under the rubric of light, sound, electricity, and chemistry. The learners' task was to read each statement representing a particular assertion and to tick the relevant box which represented their own claim. They were further requested to support their claim (tick) by providing reasons (evidence) in support of their claim. The learners were further provided with another tick box for selecting the source of their knowledge/conceptions as either school science, knowledge, traditional or personal knowledge.

In order to give the learners some leverage the learners choices were spread using a 1 – 4 agreement scale. This comparison was done on the basis of the learners' claims or assertions on an agreement of a scale of 1 – 4 where 1 represented the least understanding of a concept and 4, the most acceptable understanding. Based on the large number of learners, the above approach, based on claims was key in giving a quick quantitative summary of the learners' conceptions. For instance, as Skoumios & Hatzinika (2009) have pointed out, learners usually focus more on claims than on the provision of reasons in support of their claims.

However, before the constitution of the TEI and the DAI groups, it was felt necessary to first establish the comparability of the learners from the four schools in terms of their preconceptions on the selected phenomena or scientific concepts. This facilitated the quick assessment of mean scores of a large number of learners from four schools and hence their comparability. Since there were four schools representing independent groups, a ONE–Way ANOVA analysis was performed using SPSS version 23. In this regard, the first section below deals with the comparability of the schools' pre-test mean scores.

4.2.1 Preliminary investigations on the comparability of the learners in the four schools.

Since a 1-Way ANOVA generates a lot of data, the complete 1-WAY ANOVA for comparing the four schools' performance scores is presented in Appendix B while table 4.1 below provides a simplified version for ease of reference and discussions. The table also presents the Levine's Test for equality or homogeneity of variance test, the ANOVA test for pointing at items where there are significant differences among one or more groups. Where there are significant differences, the post hoc analysis (Appendix B) provides the specific groups where a significant difference occurred.

Where the assumptions of the test of equality of variances has been violated (i.e. where p is less than 0.05 for the Levin's Test), alterative Brown-Forsyth and the Welch test (Appendix B) have been requested. If the p value given there is still less than 0.05, then the assumptions of homogeneity of variance among the groups is violated, hence the group means cannot be compared statistically. In this regard, no conclusions could be made statistically with regard to comparing the learners' apparent preconceptions in relation to the concepts where the variances of the learners' mean scores were not homogeneously equal, thus results are shown as 'not valid.'

Table 4.1: A 1-Way ANOVA of the learners' performance scores in the four schools

21 Phenomena	N	Overall Mean scores	VARIANCE TEST LEV	VARIANCE TEST SIG.	ANOVA F-VALUE	ANOVA SIG.	POST-HOC TEST
1. Astronomy 4:	114	3.00	3.255	0.024*	3.077	NA	Not valid
2. Electricity 3	126	2.95	0.372	0.773	0.048	0.986	No sig.
3. Electricity 1	125	2.64	0.851	0.468	0.388	0.762	No sig.
4. Terminology 8	125	2.53	1.617	0.189	1.169	0.324	No sig.
5. **Sound 3***	119	2.47	1.650	0.181	**3.089**	**0.030**	Significant
6. Light 2	115	2.36	12.421	0.000*	0.355	0.786	No sig.
7. Chemistry 2	116	2.28	0.554	0.646	0.302	0.824	No sig.
8. Terminology 6	123	2.23	0.775	0.510	0.697	0.556	No sig.
9. Light 1	115	2.13	15.551	0.000*	0.073	0.974	No sig.
10. Light 3	122	**2.07**	2.299	0.081	0.455	0.714	No sig.
11. Light 4	125	**2.07**	2.455	0.066	1.115	0.346	No sig.
12. Sound 5	117	2.01	4.516	0.005*	0.785	0.505	No sig.

13. Light 5	124	**1.97**	2.835	0.041*	0.799	0.497	No sig.
14. Astronomy 1	115	**1.97**	0.294	0.830	1.874	0.138	No sig.
15. Astronomy 3	102	1.95	0.866	0.461	1.143	0.375	No sig.
16. Terminology 4	120	1.94	2.173	0.094	1.915	0.130	No sig.
17. Terminology 2	123	1.92	2.306	0.080	0.095	0.963	No sig.
18. Electricity 4	127	**1.89**	2.299	0.081	0.208	0.890	No sig.
19. **Chemistry 1***	118	**1.89**	1.578	0.199	**6.379**	**0.000***	Significant
20. Chemistry 5	114	1.81	5.556	0.001*	**9.226**	**N/A**	Not valid
21. Astronomy 5	111	1.69	4.436	0.005*	2.026	0.114	No sig.

Note:

- **Mean differences are significant at alpha = 0.05**
- **Effect size: Eta squared = Sum of squares between groups/Total sum of squares.**

Cohen's (1988) criteria for effect size regards 0.01 as small, 0.06 as medium and 0.14 as a large effect size (Pallant, 2011 p. 254).

Table 4.1 above shows that the top listed items are those in which the majority of learners have obtained the highest mean scores. Looking at all other items, the assumptions of homogeneity of variances among the groups' scores are not violated as per the robust test by Welch and Brown-Forsythe tests.

Furthermore the corresponding ANOVA tests are not significance ($p > 0.05$) and hence the scores of the various groups on the items are not significantly different from each other. The only items representing groups where there are significant differences among some groups are Sound 3 and Chemistry 1.

For Sound 3, the mean scores of School A are significantly larger than those of School D while the mean scores of School for Chemistry 1 are significantly larger than those of School A and B. Since Sound 3 is an item that learners from rural contexts might be acquainted with as opposed to Chemistry 1 which learners from urban context may be more acquainted, the demographic profile of the learners might share some light on the observed phenomena.

The learners' demographic profile show that, out of 41 learners in School A, 25 of them are born in rural areas as opposed to 22 out 26 learners from School D who were born in a big city. Furthermore, 35 of the learners in School A have rural homes which they frequently visit on a yearly basis while 19 in School D still live in the city rather than in a township where the study was conducted.

4.2.2 Summary analysis of the learners' comparability in the four schools

The above observations show that the four groups of learners were comparable in terms of their understanding of the various scientific concepts. Despite the minor differences on one concept of sound and chemistry between schools A and D, the 1 – WAY ANOVA analysis revealed that there was no significance difference between the learners' conceptions from the four schools. The observations of the decrease in the learners' performances as one goes down table 3 highlights the deviation of the concepts depicting the natural phenomena from everyday life contexts to those that are abstract and decontextualized.

The analysis further show that the majority of the concepts dealt with, involves the concept of light as well as sound. These two have similar properties which hold for a **particle** as well as a **wave model**, couple with their dual perceptual phenomena. For example, Light has visible as well as invisible properties while sound has also the property of audibility as well as inaudibility. These properties are the main reason for treating light and sound together under the major themes of Waves and Vibrations in advanced Physics (see, Halliday & Resnick, 1988).

In this regard, the main concepts that will be dealt with from this point onwards are those of light as well as sound. Further analysis for addressing the main research question dictated that the learners from the four schools be divided into two cohorts; two classes for the traditional expository instruction (TEI) model while the other two classes be devoted to the dialogical argumentation instruction (DAI) model.

4.2.3 The effect of the intervention methods on the learners' understanding of the selected scientific concepts

The concept of light constitutes the phenomena of the Tyndall Effect, Refraction and Infra-vision while those under sound are Acoustic Impendence and the Infrasonic rumbles. Acoustic impendence deals with the property of the sound medium as well as the speed of sound propagation while infrasonic 'rumbles' refer to infrasonic sound propagated by elephants over several kilometres (Nepgen, 1990, p. 40).

In an attempt to assess the above, the two groups' pre-intervention and post intervention mean scores were compared using t-tests for independent groups as well and dependent groups. These tests were affected to assess whether there was a significant difference between the performances of the two groups. To assist in making conclusive decisions, eta squared values were calculated to measure the effect size where significant result were obtained. The formulae for calculating the effect size for independent and dependent samples are represented by equations (1) and (2) below:

Eta Squared = $t_{ratio}^2/[\ t_{ratio}^2 + (N_1 + N_2 - 2)]$ ……Independent groups…………(1)

Eta Squared = $t_{ratio}^2/[\ t_{ratio}^2 + (N - 1)]$ …………..Dependent groups……………(2)

According to Cohen as cited in Pallant (2011, p. 243 & 247) the guidelines for interpreting the Eta Squared results are:

0.01 = Small effect size

0.06 = Moderate effect size

0.14 = Large effect size

In terms of analysis, small effect sizes were regarded as insignificant and hence will not be considered to be very important for making any claims. If the effect sizes are 0.06 and upwards, then the corresponding significant values will be considered worthwhile in making claims about the significant differences in the intervention strategies. With respect to the long list of phenomena and space constraints, the results of the pre-test to post-test evaluations (for measuring the extant of the interventions) as well as the group comparison statistics will be presented in one single table which is focussing on a theme phenomenon.

Each table is briefly explained and discussions done in a separate section. Furthermore to save space, items where there are no significant differences between the DAI and the TEI groups were grouped and discussed together while the same applied to those items where there are significant differences between the two groups. Table 4.2 below deals with learners' pre to post intervention performances relating to selected natural phenomena of light.

Table 4.2: Effects of DAI on learners' performances of the phenomena of light

DATA PARAMETERS: N_{TOTAL} = 139, N_{DAI} = 76, N_{TEPSI} = 63, t_{crit} Independent@ df(137) = 1.960, t_{crit} DAI-Bridge@ df(75) = 1.980, t_{crit}TEPSI@df(61) = 2.000, Alpha = 0.05.						
Phenomena	**Group Info**	**Means Pre**	**Means Post**	**t-ratio**	**p-value**	**Eta^2**
Light 1.	**Mean_DAI**	2.93	3.55	-4.708	0.000	0.09
"Ukusinga"a process used in looking	**Mean_TEI**	2.85	3.44	-3.668	0.001	0.04
for bees uses sunrays to make small	**t-ratio**	0.350	3.077	Moderate: small		
objects visible or identifiable in the	**Sig.**	0.727	0.003			
air	**Eta^2**	NA	**0.06**	Moderate effect size		
Light 2.	**Mean_DAI**	2.13	2.97	-6.311	0.000	0.35
Because light can bend in clear	**Mean_TEI**	2.00	2.80	-4.336	0.000	0.23
water, fish at the bottom of the river	**t-ratio**	0.692	0.980	**Large**		
can see people before they get to the	**p-value**	0.490	0.329			
edge of the water, then escape.						
Light 3.	**Mean_DAI**	2.16	3.37	-8.979	**0.000**	0.18*
At night while it is dark there are	**Mean_TEI**	2.10	2.84	-4.067	0.000	0.08
sunrays which we cannot see	**t-ratio**	0.283	3.903	**Large: moderate**		
	p-value	0.778	**0.000**			
	Eta^2	NA	**0.10***	Moderate to large		
Light 5.	**Mean_DAI**	2.43	3.08	-5.448	0.000	0.11
Cats and dogs as well as other	**Mean_TEI**	2.29	3.06	-4.195	0.000	0.09
animals can see in the darkness	**t-ratio**	0.630	0.112	Moderate effect sizes		
because their eyes glow in the	**p-value**	0.530	0.911			
darkness.						
Light Totals	**Mean_DAI**	10.77	16.10	-16.935	0.000	0.22
	Mean_TEI	11.07	14.69	-7.964	0.000	0.04
	t-ratio	0.578	2.736	DAI/TEI: large: Small		
	p-value	0.565	**0.007***			
	Eta^2	NA	**0.17**	Large effect size		

1. For the pre-intervention stages, a quick scan in table 4.3 above shows that there was no significant difference between the performance scores of the DAI group as well as the TEI group, thus an indication of the comparability of the two groups before their respective interventions started. All t_{ratio} values are less than t_{crit} Independent @ df(137) = 1.960.

2. Also when looking across each item from their pre-test to post-test scores, one can see that all learners' performance scores had significantly improved from their pre-intervention

stages. This seems to suggest that both intervention strategies were somehow effective in enhancing the learners' performance scores. This is supported by the moderate effect sizes which are evident for all items except in item 1. However, the DAI still significantly outperformed the TEI group for items Light 1 and Light 3 suggesting that the DAI was more effective than the TEI intervention.

3. As one looks at the overall (Light Totals) pre-test to post-test performance scores one can see that the performances for the TEI group had a small effect size ($Eta^2 = 0.04$) as opposed to the very large effect size ($Eta^2 = 0.22$) of the DAI-Bridge suggesting that the DAI seem to be more effective than the TEI teaching strategy. All t_{ratio} values (except for Light 2) for the DAI and the TEI are greater than t_{crit} DAI@ df(75) = 1.980, t_{crit}TEI@df(61) = 2.000 respectively.

4. Finally, the overall performances of the two groups in their post-test performance scores shows a significant difference in favour of the DAI group. This is attested to by the p-value of 0.007 which is less than p = 0.05. As stated in the introductory part of this section, the effect sizes of Eta^2 that are above 0.06 will be considered in deciding whether the significant values are worth consideration. In our case, the effect size is very large at 0.17 suggesting that on the overall the DAI intervention may have been responsible for the differences in the pre and post-test scores of the DAI group. Again, the t_{ratio} values is 2.736 and hence larger than the tcrit Independent @ df(137) = 1.960.

From this statistical analysis, the results show that the DAI intervention seem to be a better teaching and learning strategy as opposed to the TEI teaching and learning strategy. This view will however be revisited when looking at the actual learner written responses.

Table 4.3: Effects of DAI on learners' performances of the phenomena of sound.

DATA PARAMETERS: N_{TOTAL} = 139, N_{DAI} = 76, N_{TEI} = 63, t_{crit} Independent@ df(137) = 1.960, t_{crit} DAI@ df(75) = 1.980, t_{crit}TEI@df(62) = 2.000, Alpha = 0.05.						
Phenomena	**Group Info**	**Means Pre**	**Means Post**	**t-ratio**	**p-value**	**Eta^2**
Sound 3.	**Mean_DAI**	2.48	3.43	-7.675	0.000	0.42
The voice of a man on a hot windless	**Mean_TEI**	2.22	2.93	-4.437	0.000	0.24
day will travel a longer distance than	**t-ratio**	1.520	4.426	**Large: Large**		

on a cold day which is also windless	**Sig.**	0.131	**0.000***			
	Eta²	NA	0.13	**Mod/large effect size**		
Sound 5.	**Mean_DAI**	1.88	3.38	-11.947	0.000	0.65
An elephant has the ability to	**Mean_TEI**	2.17	3.07	-5.408	0.000	0.32
communicate with another elephant a	**t-ratio**	-1.311	2.832	Large: moderate		
few kilometres away without	**p-value**	0.193	0.005			
releasing any audible sound	**Eta²**	**NA**	**0.06***	Moderate effect size		
Sound Totals	**Mean_DAI**	4.59	6.86	-9.132	0.000	0.18
	Mean_TEI	4.34	5.94	-4.304	0.000	0.08
	t-ratio	1.003	4.761	Large: moderate		
	p-value	0.318	0.000			
	Eta²	**NA**	0.14	Large effect size		

1. A quick scan in table 4.3 above again shows that there was no significant difference between the performance scores of the learners in the DAI as well as the TEI groups, thus an indication of the comparability of the two groups before their respective interventions started. All t_{ratio} values Sound 3, Sound 5 and Sound-Totals are respectively (1.520, 1.311 and 1.003) less than t_{crit} Independent @ df(137) = 1.960.

2. When looking across each item from their pre-test to post-test scores, one can see that the performance scores of both groups had significantly improved, again suggesting that the two interventions may have been responsible for the two groups' significant performances. This is supported by large effect sizes obtained in the two items as well as in their total scores.

3. As one looks at the overall (Sound Totals) pre-test to post-test performance scores one can see that the performances for the TEI group had a medium effect size suggesting that the TEI intervention may have also been responsible for the learners' pre to post-test performances. All t_{ratio} values for the DAI and the TEI are greater than t_{crit} DAI@ df(75) = 1.980, t_{crit}TEI@df(61) = 2.000 respectively.

4. However, while both interventions seemed to have been the cause for the two groups' pre to posttest performances, the overall performances of the two groups in their post-test

performance scores shows the DAI intervention had still significantly outperformed the TEI intervention. This is supported by the p-value of 0.000 which is less than $p = 0.05$. In the above case, the effect size is large at $Eta^2 = 0.14$ suggesting that on the overall the DAI intervention was more effective than the TEI intervention. Again, the t_{ratio} values is 4.761 way above the tcrit Independent @ df(137) = 1.960.

In conclusion, all the results in the above tables suggest that the DAI teaching strategy seem to be more effective than the TEI teaching strategy; but again, as stated earlier, the qualitative analysis of the learners' written responses will highlight the underlying conceptions and worldview presuppositions exhibited by the learners.

4.2.4 Qualitative analysis of the learners' pre and post-test conceptions of the selected concepts of light and sound.

In this section we turn our attention to the individual learners' underlying conceptions on the selected phenomena. As Abrams et al., (2001, p. 1271) have argued, "the ability to explain natural phenomena is a hallmark of scientific understanding" and that, "students' explanations are mirrors for their underlying conceptions."

In accordance with Toulmin's Argumentation Pattern (TAP), all qualitative excerpts are composed of claims/counter-claims as well as grounds or reasons in support of the propositions. The excerpts are further analysed for the learners' cognitive stances using the Contiguity Argumentation Theory (CAT). The CAT is further augmented by Hempel's Internal and Bridge Principle for exploring how the learners' IK presuppositions relate to the school science worldview. In this regard, the learners' claims were tied to their reasons to formulate an argument which is interrogated and analysed.

4.2.5 A qualitative analysis of the learners' responses on the concept of light

While both the TEI as well as the DAI interventions seemed to have had a significant effect on improving both groups' performances, the quantitative analysis showed that the DAI instructional strategy significantly outperformed the TEI intervention. Some excerpts to interrogate the probable causes for such differences as well as possible connections between the learners' IK and school science presuppositions were explored. For ease of reference, the three phenomena of light explored below are that of the Tyndall effect, refraction of light and infrared light. Note: Some of the excerpts have been translated from isiXhosa to English so as to make sense to non-isiXhosa speaking readers. For each assertion or statement with respect to either of the three phenomenon of light, learners were expected to state their agreements or disagreements followed by reasons to support their choices or claims.

4.2.6 The light phenomenon of the Tyndall effect

4.2.6.1 "Light from sun rays are used (a process called 'ukusinga' in isiXhosa) in order to identify beehives by track small objects like bees flying in the air."

The above represents a physics phenomenon whereby small particles have the capability of scattering light rays thus making the particle visible to the naked eye. For example, although the actual mechanisms may not be well understood by African traditional societies, its applications have been advanced into the 'hunting' or identification of beehives as well as in studying of the constellations of heavenly bodies. In this regard, pre and post-test excerpts of Learner 39 in the TEI group and 40 from the DAI groups are presented below:

TEI Learner 39 before intervention

> I Agree – When we were in the veld we used to see a trail of bees in the air looking like smoke particles in the air, so we would follow where they are going (IK).

DAI Learner 40 before intervention:

> I Agree – When you sweep the floor at home in the morning you can
> see the dust floating through the sunlight (iimitha yelanga) at the
> door (IK).

In terms of the learners' preconceptions on the phenomenon of the Tyndall effect, Learner 39 and 40 have agreed to the claim that sunrays can make small objects identifiable in the air. For example, Learner 39 narrates his experience out in the veld where he states that he is knowledgeable about the traditional practice which is called 'ukusinga'.

Similar to Learner 39, Learner 40 cites her own experience which involves sweeping in the hut in the early morning hours when the sun first strikes the front door. It should be noted that most

African huts face the west so the sun can enter the huts in the early mornings. This girl states that dust can be seen floating in the sunrays which enters the door of a hut in the morning especially when she is sweeping the floors. Again, the floors of the huts are made of mud and hence generate a lot of dust when sweeping without first spraying the floor with some water.

As has been shown that both the TEI as well as the DAI group had high mean scores in terms of the above phenomenon of light, the above excerpts corroborates such findings. The two learners representing both intervention groups have shown that they are acquainted with the phenomenon of the Tyndall effect. The tag at the end of their excerpts show that they had both chosen IK as their source of knowledge. This suggests that the phenomenon is amenable to their IK presuppositions, hence IK is the learners presented an IK dominant cognitive stance. In terms of the learners' explanations of the phenomenon, the learners' excerpts reveal evidence of their knowledge or experience with the observable aspects of the phenomenon which is consistent with the scientific explanation of the Tyndall effect. In this regard, all the can be regarded as having relatively good preconceptions of the phenomenon under discussion.

TEI Learner 39 after intervention:

> I Agree – The Tyndall effect causes light to be scattered by small particles so that the particles can be easily observed (SS).

DAI Learner 40 after intervention:

> Agree – It is true because when you are in the house you can see small particles like dust through light rays which makes the dust shine (IK).

In the above, Learner 39 argues that the Tyndall effect causes light to be scattered by small particle in the air and attributing that to school science. This suggests a border crossing cognitive shift from IK into school science, hence the school science worldview became the dominant worldview after interventions. His reason seem to highlight some misunderstanding of the fact that the Tyndall effect is not a cause but the effect. His post-test highlights a misconception as he also cites school science as his source of knowledge as opposed to his more accurate explanation in his pre-test stage. This learner has therefore not identified any of the predicates which shows how he abruptly decided to change his former explanation.

As opposed to the TEI learner, the DAI learner held to her IK worldview and gave more evidence in support of her claim by pointing out that dust particles will shine in the sunlight making them more visible. The TEI learner seemed not able to use the apparent observations of smoke-like effects of light scattering by bees to formulate his own bridge principle to connect school science to his own IK knowledge.

For the DAI learner, the IK worldview is dominant at the pre-test stage and while IK is the source of the post-test explanation, an emergent cognitive stance is evident. This difference between the two groups thus corroborates the quantitative results which showed that, the DAI had significantly outperformed the TEI group's performance at the post-test. This suggests that the DAI intervention seemed to have created authentic learning experiences which promoted emergent cognitive stances as opposed to adopting the school science worldview at the expense of destroying the learners' IK authentic knowledges. It is therefore, important to identify bridge principles to connect school science and IK in order to acquire IK or school science emergent cognitive stances.

4.2.7 The light phenomenon of refraction

Because light can bend in the water, fish at the bottom of water in rivers can see people before they get to the edge of the water. This phenomena is as a result of what is called, the refraction of light in water. Box 4.2 presents some excerpts depicting learners' worldview conception on the phenomena.

Box 4.2: Excerpts depicting learners' worldview presuppositions their understanding of the phenomenon of refraction of light.

LIGHT 2: Because light can bend in the water, fish at the bottom of water in rivers can see people before they get to the edge of the water.

Pre_TEPSI-Learner 67: Agree – When light strikes the water it gives reflection of shadows (isithunzi) of people (IK).

Post_TEPSI-Learner 67: Agree – Light can bend due to refraction (SS).

Pre_DAI-Learner 88: Agree – Yes I agree, but if the water is dirty the fish will not see anything because light will not go through (IK).

Post_DAI-Learner 88: Agree – The top of the water is like a mirror (isipili) when you look at it.

This is the reason why spoons bend in water to go and hit a different position at the bottom of the water (IK).

IK = Indigenous knowledge, SS = School science, TEI = Traditional Expository Pace-Setter Instruction, DAI = Dialogical Argumentation Instruction Bridge.

4.2.8 Before the DAI and TEI interventions

Again as has been observed for Light 1, the similarity between the two items lie in the fact that in both situations light is either diffracted or refracted and their effects are visually observed. Judging from the excerpts, TEI as well as the DAI learner have both agreed on the assertion by Light 2, that because light can bend in water, fish below the surface of water can see people beyond the edge of water. Since these learners support a school science claim using IK worldview explanations, they can be regarded exhibiting equipollent cognitive stances. For Learner 67 the school science explanation of light bending in the water seems to be associated with the formation of shadows. For example, in support of his claim, Learner 67 states that when light strikes the surface of the water, reflection of peoples' shadows are created. On the other hand, Learner 88 agrees with the assertion but states that no refraction is possible when the water is not clear. In terms of TAP categories, this contingent condition is was is called a qualifier.

While refraction involves unobservable entities and processing such as the linearity of light waves, their bending or slowing down/speeding up, both learners seemed to have highlighted some connectors such as light shadows (Learner 67) as well as physical obstructer such as dirt particles in the water. In this regard, the pre-intervention explanations by the two learners provides that bridge principle. This bridge principle thus explains why the phenomenon of harmonious dualism put forward by Ogunniyi (1988) occurs.

4.2.9 After the DAI and TEI interventions

As has been established from the quantitative results, both groups performed significantly well at their post-test stage. Furthermore, the two groups' performances were statistically equal, suggesting some comparability in the two interventions. Learner 67 states that light bends in water due to refraction. This learner's explanation shifted from light forming shadows to a school science worldview of light refraction without making the connection of how that notion of refraction is connected to how fish can observe people outside water. In this regard, the TEI learner can be regarded as having crossed from the IK worldview to the school science worldview. Without the identification of how the border crossing occurred or how the new school science worldview complements the IK worldview, the TEI learners' pre to post-test explanations suggest a cognitive shift from an IK dominant to a school science dominant worldview. The observation from Learner 67 is typical of the majority of the TEI learners.

As opposed to the TEI learner, Learner 88 has somehow maintained her IK presupposition from pre-test to post-test without being influence by the school science teaching. Her post-test explanation suggests that the reason for light bending in water is as a result of the water surface being like a mirror. She further argues that fish will be able to see someone's image or shadow outside water because of reflection. This learner further go on to explain that the mirror surface is a reason for objects like spoons being bent to a different position under water. In support of the mirror effect, water has a surface tension which results in some insects being able to walk on the surface of water.

Furthermore, the observation about spoons bending in water is analogous to the school science explanation of refraction which states that light waves bend when intercepting the surface of water. The argument presented by the DAI learner does somehow show how her IK presupposition connects to that of school science, thus presenting a bridge principle. These observations were prominent among the DAI learners and while the two groups' performance scores were comparable, the DAI intervention seem to have provided authentic learning experiences for the learners. This suggest that the DAI intervention did not focus on conceptual change in favour of the school science worldview, but rather on creating connections between the learners' IK and the school science worldview which they require at school. As have been noted for the Light 1 (Tyndall effect) where the DAI significantly outperformed the TEI intervention, learners in the DAI seemed to have adopted school science emergent cognitive stances as a result of the identified bridge principles.

LIGHT 5: "Cats and other animals can see in the dark because their eyes glow in the darkness."

Box 4.3: Excerpts depicting learners' worldview presuppositions of their understanding or awareness of why animals has the ability to see in the darkness as well as the existence of invisible light enabling animals to see in the darkness.

LIGHT 5: Cats and other animals can see in the dark because their eyes glow in the darkness.

Pre_TEPSI-Learner 46: **Agree –Cats have eyes that light in the darkness so that is why they can see in the darkness (IK).**

Post_TEPSI-Learner 46: **Agree – These animals can see in the night because their eyes are adapted to see in the darkness and so can use infrared light to be able to see (SS).**

Pre_DAI-Learner 59: **Agree – Cats and dogs can see evil spirits that is why their eyes turn red or green in the darkness (IK).**

Post_DAI-Learner 59: **Agree – Yes I agree, because the invisible light is used to see invisible things like evil spirits and ghost at night, that is why they make funny noises (IK).**

IK = Indigenous knowledge, SS = School science, TEPSI = Traditional Expository Pace-Setter Instruction, DAI-Bridge = Dialogical Argumentation Instruction Bridge.

4.2.10 Before the DAI and TEI interventions

As shown by the performance scores of the learners in for the item, a large number of learners agreed with this view. This view can be seen as the main reason for the item being categorised among those that are said to be IK-contextualised phenomenon. However, not all the learners agreed to the argument as framed in the assertion. However the case may be, both the TEI as well as the DAI groups performed comparably in their pre-intervention stages.

In terms of the learners underlying preconceptions, while Learners 46 and 59 were correct in terms of cats and dogs being able to see in the darkness, their reasons however do not agree with the actual accepted school science explanation. For instance, Learner 46 suggests that the eyes of nocturnal animals glow at night thus have a source of light in themselves, while Learner 59 seem to suggest that the eyes of cats and dogs reflect some strange light from sources such as ghosts. For these learners the school science claim about cats and dogs being able to see in the darkness agrees with their own IK-based conceptions about some animals being able to see in the darkness. As has been observed for other items already discussed above, harmonious dualism is also observed for the notion of infravision by nocturnal animals. This phenomenon thus led the two learners to exhibit equipollent cognitive stances where the school science claim is supported by an IK based reason.

In conclusion, it can be seen that the majority of the learners do agree with the notion that nocturnal animals can see in the darkness while humans cannot. However, they attribute this ability to existence of light sources either in the animals' eyes or as reflection of light from other invisible entities onto the eyes of the animals, which allows humans to see the phenomenon. From an IK perspective, the above suggests a bridging principle which the majority of the learners use to traverse between the chasms of school science and IK with respect to the school science phenomena of infravision.

4.2.11 After the DAI and TEI interventions

As the above suggests, the two groups of learners were exposed to different intervention strategies to mitigate against the short comings within their prior knowledge bases discussed above. From a quantitative perspective, both groups of learners had performed significantly better than their pre-intervention stages.

From the perspective of the TEI group, Learner 46 started from an equipollent cognitive mental state where both the school science and his own IK explanatory model of the phenomenon combined to form an argument. In his post-intervention, while maintaining the same claim he abandoned his metaphysical belief about eyes glowing to a commonly acceptable school science concept of adaptation and the existence of invisible infrared light which were put forward in support of his claim. Since the TEI learner's argument from the pre-test does not show how or under what circumstance he adopted the school science explanatory model, his final cognitive stance is school science dominant as opposed to a school science emergent cognitive stance.

From the perspective of the DAI learner, the pre-test argument is that cats and dogs see evil spirits which are represented by the light usually observed from the eyes of the animals in the darkness. Learner 59 seemed to have maintained his source of knowledge as IK, but somehow have come to recognise the existence of invisible light which is proposed by school science. This learner emphatically replied in agreement with the school science explanation, but reiterated that the 'invisible light' talked about in school science is used to see invisible things like evil spirits. In other words, Learner 59 seems to suggest that the lighting or glow in the animals' eyes is a representation of invisible light since he has stated that invisible light suggested by school science is used to see invisible objects. This is not very different from school science when talking about unobservable entities and processes. Hempel's bridge principle thus provides means to bridge the observable and the unobservable. Again, as has been indicated by the DAI learners for the other light phenomena, the DAI learners seemed to have grasped the art of scientific arguments and explanations to enrich their conceptual understanding of school science.

LIGHT 3: "At night when it is "dark there are light waves that people cannot see**."**

The above item is the same as Light 5, but the difference is in how it has been phrased. This may be the reason that the learners' responses have placed it among the context-dependent phenomena. It was then found to be interesting to try and tease out differences in the learners' written responses that led to this item being separated from Light 5.

Box 4.4: Excerpts depicting learners' worldview presuppositions of their understanding or awareness of awareness of and/or understanding of the existence of invisible light in the dark.
LIGHT 3: At night when it is "dark there is invisible light that people cannot see. Pre_TEI-Learner 47: Disagree – When it is dark it is only the moon and stars that have light and we can't see anything around us (IK). Post_TEI-Learner 47: Disagree – The infrared ray of the electromagnetic spectrum is not the same thing as light because people use light to see and not invisible infrared waves (SS). Pre_DAI-Learner 118: Disagree – It is not true, because the light we see is because of street lamps and so it is never pitch dark (IK). Post_DAI-Learner 118: Agree – There are infrared rays that only cats can see, we humans see only visible light that is why we cannot see ghosts unless they light up (SS).
IK = Indigenous knowledge, SS = School science, TEPSI = Traditional Expository Pace-Setter Instruction, DAI-Bridge = Dialogical Argumentation Instruction Bridge.

As has been established in the quantitative results, both the TEI as well as the DAI had performed comparably thus suggesting equality of the two groups before the intervention took place. However, at the post-test, both groups were observed to have significantly performed as compared to their pre intervention stage. Learner 47 from the TEI group disagreed with the assertion and stated that only the moon and stars have light at night. At his post test, somewhat gathered that there are infrared rays of the electromagnetic spectrum, but still maintained that they cannot be regarded as light since light is used by humans to see.

Changing from an IK to a school science worldview seemed to not have made any difference in terms the learner's conceptual understanding. This explanation is typical of the other TEI learners' explanations. Taking a cue from Learner 43 for the previous Light 5 item which is similar to this item, he had argued that animals can only see in the darkness because of adaptation leading them to eventually able to use infrared waves. Despite this, some of the TEI group's significant performance at their post-test, the intervention somehow seem not have sufficiently addressed the concept of the nature of invisible light.

Learner 118 from the DAI group also disagreed with the assertion that there is light in the darkness, she argues that it is never really dark because of the light from the street light that makes it as if there is invisible light. Her answer is similar to that of the TEI learner (Learner 47). The pre-test pattern seen from both the TEI and the DAI-Bridge groups may be the reason for the apparent performances of both group being comparable before the intervention. After the intervention, Learner 118 somehow changed her mind and accepted there was invisible light in the darkness. This learner's motivation for a cognitive shift from IK to school science explanation shows that IK was the initiator for the change rather than a conceptual change approach from school science.

The view in the latter statement is premised on the fact that she started by accepting that infrared waves exist and are used by cats to see and that humans can only use visible light and hence the reason why we cannot see ghost. My own assumption would suggest that this learner somehow believes that cats can see ghosts. Again, from the bridge principle perspective, the ability of cats being able to see ghosts may be the bridge principle that the learners in the DAI group have used to have accepted the school science worldview explanation of the existence of invisible light. This bridge principle suggest that the learner's cognitive stances in the post-test is a school science emergent cognitive stance as opposed to a school science dominant cognitive stance.

4.2.12 Summary discussions on the phenomena of light

As has been shown, the three light items (Light 1, Light 2 and Light 5) which were categorised under context-familiar phenomena seemed to have invoked all learners' IK presuppositions. In this regard, various IK examples or practical experiences were seen to be evident in all intervention groups. For example, Light 3 and Light 5 represent the same phenomenon of invisible light, but the manner in which they were phrased led to one (Light 5) being categorised as a context-familiar item while Light 3 as a context-dependent item. As a result of the above, a large percentage of learners performed well on Light 5 and poor for Light 3.

Initially, all learner groups were comparable and started with equipollent cognitive stances as a result of some compatibility between the IK and the school science with respect to knowledge claims. Equipollency seemed to be due to school science claims concurring with IK claims regarding the existence of infravision in nocturnal animals. From comparing the cognitive shifts between the TEI and the DAI groups, it became clear that, as opposed to the DAI learners, the TEI learners seemed to be moving from an equipollent cognitive stance to a school science dominant cognitive stance where IK becomes recessive. This is somehow similar to the common teaching and learning strategies that sees IK as starting point and school science as the final destination. For instance, Stears et al. (2003, p. 111) stated that:

> Learners' everyday knowledge and purposes can be used in the curriculum in a number of ways. as a starting point for learning science, as a reference point for thinking about the nature of science, and as a context for applying scientific ideas and skills.

While this is also a desirable result, it should be a reversible process so that knowledge within IKS can also edify our current school science knowledge base. Contrary to the above, the DAI learners seemed to have retained their IK-based presuppositions and used them to align their claims with that of the school science explanations, thus the exhibition of emergent cognitive stances. From this perspective it seems that the DAI intervention has helped learners to find connections between their IK conceptions and those from school science. As opposed to the DAI intervention the TEI intervention approach seemed to have only attempted to move the learners from their so called naïve knowledge to that of the commonly acceptable school science knowledge without any value given to their own IK worldview presuppositions.

However the case may be, there is no guarantee that the TEI learners completely abandoned their IK worldview presuppositions. The apparent observation can be characteristic of the traditional conceptual change teaching approach which generally requires learners to do away with their alternative conceptions which are seen as stumbling blocks in the path of scientific indoctrination (Feltham & Downs, 2002; Jegede, 1996, 1997; Jegede & Aikenhead, 1999; Nuno, 1998). As Gunstone & White (2000) have stated, learners should be able to discern when it is appropriate to use one knowledge claim as opposed to the other in the case where there is a difference between two distinct knowledge claims. Furthermore, 'Culturally diverse students develop meaningful science understandings when they see their culture facilitating learning rather than seen as an impediment to it" (Chiappetta, Koballa and Collette, 1998, p. 51).

In this regard, Marin, Solano & Jiminez (2001) warns us about learners' underlying preconceptions; that they have their own concepts which the literature often refers to as naïve ideas which learners need to get rid of if real science learning is to take place. Because learners have come to understand how school works or what is important for passing exams they usually just focusses on claims about facts and declarative knowledge and do not bother much about explanations (Skousmios & Hatzinikita, 2009). As has been explained for the harmonious dualism (Ogunniyi, 1988), learners seem to always create own bridge principle to cross over to the scientific worldview, but in the process retaining their own explanatory models

As various scholars have alluded (Corsiglia Snively; Emeagwali, 2003; Fleer, 1999; Gunstone & White, 2000; Keane, 2007; Marin et al., 2001; Ogunsola-Bandele, 2009; Rollnick and Rutherford, 1996; Skousmios & Hatzinikita, 2009) learners' alternative knowledge systems are more important than the final product of learning. For instance, Linder (1992) and Keane (2007) have both suggests that, learners' prior understandings depicting their worldview presuppositions are more essential or legitimate for them that the knowledge presented in school science. Accordingly, Malcolm & Stears, 2005), the relationship between parts of knowledge and their ways of knowing are essential parts of knowing. According to Mohapatra (1991) these IKS framework is what contribute to "the single most important factor" (p. 431) of personal concepts which "…will be scientific to the same extent as is the knowledge acquired by pupils in the school" (p. 432).

In conclusion, while all the phenomena of light discussed above exhibited all the three predicates proposed by Hempel (1966), the context presented by each item largely exhibited observational predicates which the learners are familiar with. This resulted in pre and post-test high performance scores for both learner groups. While all groups performed significantly better than their post intervention stages, the DAI group significantly outperformed the TEI group for Light 1 (Tyndall Effect) and Light 3 (Invisible light). On the overall, the DAI intervention significantly outperformed the TEI intervention at their post intervention stage. This was further corroborated by the DAI learners' explanations which seemed to be more authentic and grounded in their IK worldviews, resulting in corresponding emergent cognitive stances.

4.2.13 A qualitative analysis of the learners' responses on the concept of sound

In Physics, sound is a phenomenon whereby a source impulse or oscillations creates a sound wave. Unlike like which can be propagated in a vacuum, sound requires as medium such as air, water, glass, steel or rocks etc. As in heat transfer or electrical conductivity, some media are bad conductors of sound. Sound can move only if the particles of the medium can move or vibrate. The movement of air particles causes a rarefaction which allows a receiver (e.g. a human ear) to hear the frequency of the sound. Since also, the particles of a medium are sensitive to temperature, sound transfer will also be affected. For example, cold air is more denser than hot air and thus it will have higher sound transfer than the warmer air. Another example, is that at night the same level of sound will appear louder than during the day. In interrogating the learners' conceptions about sound, two phenomena of sound presented below are discussed.

SOUND 3: "**The voice of a man calling another one on a hot day will travel a longer distance than on a cold day"**

As an example of how sound propagation is dependent on the temperature of the medium, excerpts from learners are present in box 4.5 below. Furthermore as has been established in the previous section, Sound 3 has been classified as a context-dependent phenomena. In accordance with this classification, the learners' responses will also be interrogated for whether they show this context dependency.

Box 4.5: Excerpts depicting learners' worldview presuppositions of the relationship between sound and temperature.

SOUND 3: The voice of a man calling another one on a hot day will travel a longer distance than on a cold day
Pre_TEPSI-Learner 21: Agree – When it is hot the air will expand and the sound will travel faster as there is less air to block it (IK). Post_TEPSI-Learner 21: Disagree – Because the air on a hot day is so hot and thin and will make your voice drown so your voice will only travel a short distance (SS). Pre_DAI-Learner 73: Agree – On a hot day the sound expands better than on a cold day so making the man's voice travel faster (IK). Post_DAI-Learner 73: Disagree – When it is hot the air has less density so there is less particles and also less air collisions to make sound (SS).
IK = Indigenous knowledge, SS = School science, TEPSI = Traditional Expository Pace-Setter Instruction, DAI-Bridge = Dialogical Argumentation Instruction Bridge.

4.2.14 Before the DAI and TEI interventions

In the beginning both learners agreed on the assertion that sound travels or propagates more efficiently on a hot day. Learner 21 supported her statement by arguing that hot air on a hot day expands as thus will allow sound to travel with it. Similarly, Learner 73 states that sound itself will expand on a hot day. A close observation of the two learners' explanations suggest that the concept of sound is viewed from a substance perspective as opposed to a wave model of sound. In other words, the two learners perceive sound as an entity separate from the medium of propagation such as in air or water. For example, Learner 21 perceives sound as something that can be blocked, while Learner 73 perceives sound as something that can expand or be stretched. From the CAT perspective, the two learners have exhibited IK dominant worldview presupposition.

4.2.15 After the DAI-Bridge and TEPSI interventions

After the two respective interventions of the TEI as well as the DAI, the learners' performance scores were observed to have significantly improved for both groups. However, DAI was observed to still have significantly outperformed the TEI group.

In this case, Learner 21 from the TEI group seemed to have had a change of view about the effect of temperature on sound by disagreeing to the assertion that an increased temperature will also result in a corresponding increase in sound. Her argument suggests that since hot air is thin it will cause one's voice to drown and hence not travel a long distance. While having showed an understanding of the relationships between sound and temperature, the mechanisms of how sound is propagated in the different temperature dependent situations is still a conceptual impossibility. With respect to the relationships between sound and temperature, this learner seem to have shifted from an IK dominant worldview to a school science dominant cognitive stance.

From the perspective of the DAI learner, Learner 73 a more refined argument is made. Firstly, similar to the TEI learner, his claim has been changed to disagree with the assertion of Sound 3. A closer look at the reason in support of his claim, the substance schema or entity model of sound seem to be absent since the learner now suggest collisions between air particles resulting in different levels of sound. This explanation is now close to the wave model which depicts sound as a result of compressions and rarefactions of the particles of air. This suggests that the DAI intervention seemed to have created some form of bridges for the learners to connect their IK knowledges to that of school science.

SOUND 5: "**An elephant can communicate with another elephant a couple of kilometers away by releasing sound which a human cannot hear while next to it."**

Similar to Light 3 which rendered sound as a context-dependent phenomena, Light renders sound as a discrepant phenomenon.

Box 4.6: Excerpts depicting learners' worldview presuppositions on their understanding of ultra sound or inaudible sound.

SOUND 5: An elephant can communicate with another elephant a couple of kilometers away by releasing sound which a human cannot hear while next to it.
Pre_TEPSI-Learner 127: Disagree – It is impossible, how can an elephant far away hear when you next to the elephant can't hear it. The elephant sound is like a cow sound (IK).

Post_TEPSI-Learner 127: Agree – Elephants make high pitch sound above 20000Hz so humans cannot hear high frequency sound (SS).
Pre_DAI-Learner 99: Disagree – If it is sound then you must hear it, otherwise we would not call it sound waves.
Post_DAI-Learner 99: Agree – I think it is true that elephants makes sound of low frequency that cannot be had because they blow with their nose and also have very large ears to hear sound which we cannot hear (IK).
IK = Indigenous knowledge, SS = School science, TEI = Traditional Expository Pace-Setter Instruction, DAI = Dialogical Argumentation Instruction Bridge.

4.2.16 Before the DAI-Bridge and TEPSI interventions

As the performances of both the TEI as well as the DAI were very low at their pre intervention stages, the item itself enjoyed a high response rate from the learners. This was a motivation to study the item more closely. A conclusion arrived at suggested that the item was not only discrepant, but its discrepancy created a sense of controversy among most learners, hence the majority of the subjects turned up to challenge its claims. Unlike other phenomena where the IK claims coincide with that of school science, the claim made by Sound 5 is inconsistent with what learners would expect to occur in real life, hence discrepant.

As a starter, both the TEI learner 127 and DAI- learner 99 disagreed with the claim that elephants can communicate at long distance with sound that cannot be heard by human beings. For instance, Learner 127 supported his objection by stating that the sound of an elephant is similar to that of a cow and that it was impossible for a human next to the elephant not to have detected such a sound. On the other hand, Learner 99 made a counter-claim that sound by nature is something that is audible, otherwise it cannot be called sound. The two learners' conceptions highlights dualistic aspect of sound – that is, the audible and inaudible ranges of sound. In this regard, as exemplified by the two learners' responses, most learners in both groups seemed to be holding somewhat mixed conceptions of sound that is contradictory to the learners' lifeworlds. One possible view as represented by Learner 127 suggest that some learners have no conceptions of the concept of inaudible sound while some, as represented by Learner 99 may have a linguistic challenge where 'sound' may only be associated with sound that can only be detected by humans. In terms of border crossing models, the nature of discrepancy presented by the dualistic nature of Sound 5 suggested an impossible border crossing. According to the

Contiguity argumentation theory, these learners' pre-intervention claims (disagreements to Sound 5) are in contradiction to that of school science and hence exhibit IK dominant worldview presuppositions.

4.2.17 After the DAI and TEI interventions

In terms of both groups' performance scores after the interventions, both groups were again observed to have achieved significant performances. In order to verify the nature of their post-intervention conceptions the two learners post-test responses are interrogated. In this regard, Learner 127 shifted from an IK perspective to a school science perspective. He exhibited an understanding of the effects of different sound frequencies on audibility or inaudibility. This learner's IK worldview seemed to have been suppressed in favour of the more plausible explanation of school science. This points to school science as a dominant worldview.

Now, with regard to finding a bridge principle between school sciences or attempting to find out how border crossing took place, there is very little evidence to suggest any understanding of the concept. In fact, Learner 127 from the TEI group seem to have grasped the general understanding of the frequency ranges of sound audibility, but still holds a misconception about the sound frequency ranges employed by elephants. Contrary to the above, elephants release infrasonic rumbles below 20Hertz frequencies as opposed to above 20000 Hertz. This is typical of traditional teaching approaches where a lot of misconceptions are introduced in the lessons.

4.2.18 Summary discussions on the phenomena of sound

The results showed that, both learners from the TEI as well as the DAI group were comparable from a quantitative as well as in terms of qualitative descriptions. In sum, although both groups seem to have achieved significant improvements from their pre-intervention to their post-intervention stages, their underlying explanations in support of their claims were considerably different. Data as shown from the two exemplary sound phenomena (Sound 3 and 5) show that the TEI group only improved in terms of making claims, but fell short in their of their understanding of the explanation for sound.

Despite the pre to post-test significant performances of the TEI group, the DAI group's pre to post-test performances for both Sound 3 and 5 was however significantly larger than that of the TEI group. This suggests that the DAI intervention seemed to have been a more effective intervention strategy for the phenomena of sound. Furthermore, the DAI group learners seem to have shown a much more deeper understanding of the phenomenon of sound. In terms of the differences between apparent quantitative performances and underlying qualitative performances, Abram et al. (2001) assert that the ability for learners being able to explain scientific phenomena is a ‘hallmark’ of scientific understanding and their explanations are in turn ‘mirrors for their underlying conceptions.’ (p. 1271).

As opposed to the TEI teaching approach which is mainly based on traditional teaching approaches that are based on pace-setting geared for completion of the syllabus, the DAI approach focussed on cooperative learning with explicit argumentation frameworks that sought to study the explanatory models of both school science and IKS. A related suggestion is put forward by Wittman (2003) who states that learning material that are designed for group-learning whose focus is on the explicit investigation of learners’ understanding of sound can enhance the learning of the sound concept.

In terms of border crossing, the learners seemed to have experienced impossible border crossing because of the extent of conceptual conflict presented by the sound concept. With regard to challenges observed for these learners, West & Wallin (2013) noted that learning of abstract and discrepant concepts such as sound requires ontological shifts. They argue that, in order for learners to conceptualise sound propagation as a process of transition or motion demands abandoning their everyday substance schema perspective conceptualisations to that of the wave forms. As Posner et al. (1982) stated, changing the learners’ prior conception is almost an impossible.

4.2.19 Preliminary findings and general discussions

In terms of the learners’ preconceptions, the findings showed that:

- The performance scores for both the TEI as well as the DAI group were found to be statistically comparable. Performance for both groups were however found to be higher for the context-familiar phenomena (Tyndall effect, refraction and infravision) and lower for those that are context-dependent (Light 3 and Sound 3) and much lower for those that are discrepant such as Sound 5. In this regard, the learners’ preconceptions on the selected phenomena were observed to been based on IK internal principles.

It is argued that when school science is closed linked to the learners' lifeworlds, learners will tend to develop interest and want to participate in lessons. Chiapetta et al. (1998) argues that learners will developed meaningful science understanding when they see their culture facilitating learning. Dealing with science concepts which are culturally relevant also accommodates the learners' home languages. As has been argued by various language scholars and activists, language plays a very important role in enhancing the learners' understanding of the content being taught in a classroom (e.g., Kearsey & Turners, 1999; Rollnick & Rutherford, 1996; Sutherland & Dennick, 2002; Young et al. 2005).

- The phenomena of sound presented the most challenge to learners and their response highlighted that sound largely involved context-dependent as well as discrepant concepts. These were with respect to audible sound and inaudible infrasonic or ultrasonic sounds where audible sound was observed to be less complicated than inaudible sound. In this regard, the majority of learners' for both groups generally exhibited the substance schema of the sound model or what others have called the entity model.

As studies from various scholars (e.g., Eshach & Schwartz, 2007; Hrepic, Zollman & Rebello, 2002; Linder, 1992; West & Wallin, 2013; Wittman, 2003) had argued that the concept of sound presents the most challenges for learners. The latter scholars further found that the learners' prior conceptions about sound are dominated by the substance schema model. As Linder (1992), succinctly have put it, these learners' pre-intervention depiction of sound 'matches the everyday meaning of the word: the interpretations our brains make from a range of complex eardrum movements' (p. 262). Also studies conducted by Hrepic et al. (2002) on sound discovered that learners frequently use the same terminology which is used by scientists or experts, but often with different meanings that is inconsistent with the wave model of sound.

A supporting reason for the above observation is that the school science vocabulary or terminology does not carry the same meaning as the one used in everyday talk or in the local languages of the learners (Kearsey & Turner, 1999; Rollnick & Fakudze, 2008; Scot et al, 2007; Sutherland & Dennick, 2002; B. L. Young, 1979).

Linder (1992) further noted that the learners' misconceptions does not seem to hinder learners' progress for further studies in the field. Some studies he have conducted showed that, many graduate student who had managed to get good grades on sound seem to show systemic challenges in conceptualising the correct conceptions about sound. He cited a number of issues highlighting why it is possible to have graduate learners who continue to harbour incorrect concepts of sound.

Some sources cited for the incorrect teaching of sound include textbooks, teachers' unfamiliarity with the topic coupled with the general trend for textbooks and teachers' attempting to reduce inherent complexities of the subject beyond recognisable physics. He further argued that everything is aggravated by the usual tendencies of attempting to compress as lot of concepts into a short of time, thus resulting in what he has called concept overload.

The implications for the above suggests that the concept of sound is an abstract concepts that involves ontological shifts from the everyday experiences of audible sound to conceptualisation of unobservable sound (West & Wallin, 2013).

In terms of the learners' interventions, the findings showed that:

- For all selected phenomena both interventions of TEI and DAI seemed to have significantly enhanced the learners' pre to post-test performances. However the DAI significantly outperformed the TEI intervention for phenomena which were more abstract such as those that were found to be context-dependent and discrepant.

- While both groups' cognitive stances were equipollent before interventions, the cognitive stances of the majority of TEI group learners were found to be school science dominant after interventions. As opposed to the TEI group, the cognitive stances of the DAI group learners were observed to be predominantly school science emergent.

As has been observed among the TEI learners' cognitive shifts, the conceptual change theory teaching and learning approaches has a tendency of undermining the learners existing knowledge base and regarding it as misconceptions which must be replaced by the seemingly more valid and accurate scientific view (Feltham & Downs, 2002; Jegede, 1997). As opposed to the conceptual change tendency observed among the majority of the TEI learners, a better way to facilitate border crossing is to link the learners' prior knowledge to what they ought to know. This is as Vygotsky (1978) would call transversing the zone of proximal development or as we would see later what Ogunniyi (1997) calls an emergent cognitive contiguity as observed among the majority of the DAI learners.

For the DAI group, the kinds of lessons designed attempted to be generously inclusive of the leaners' experiences to such an extent as to initially accord all ideas same status irrespective of whether the learners' views are scientifically valid or not (Hamza & Wickman, 2007). Since the DAI learners were involved in argumentation activities (dealing with the nature of scientific explanations) they were able to see the value of their IK and thus were in a position to construct their own bridging principles as connectors of IK and school science.

The above suggests that the DAI presented its learners with authentic knowledge acquiring opportunities. This view is supported by Campbell & Lubben (2000) who have also argued that effective learning takes place when the learners' preconceived knowledge is used in the science teaching. In this regard, some forms of classroom interactions may ensue where learners may start to argue with each other without the teacher's involvement, thus resulting learners' personally and socially constructing knowledges (Stears et al., 2003).

The above is in contrast to traditional transmission approaches such as the TEI where declarative knowledge is the focus. In this regard, Skousmios & Hatzinikita (2009) have suggested that, learners, given the opportunity would generally prepare to make claims than to give reasons in support of their claims. The findings above then suggest that the TEI learners' quality of understanding could only be identified through their written responses.

- As opposed to the TEI intervention strategy, the DAI intervention strategy seemed to have explained the phenomena of border crossing in terms of the exact mechanisms they follow when they decide to cross or not cross cognitive borders. In other words, the DAI seemed not to just have enhanced the learners' abilities to provide reasons in support of their claims, but also terms of interrogating the nature of the theories underpinning particular scientific phenomenon.

In support of the above, Marin, Solano & Jiminez (2001) argued that learners had always found their own ways of linking their IK worldview presuppositions with that of school science in ways which '…might be unlinked to the content in an adult scientific logical sense'… and yet '… linked for the student.' (p. 685). This phenomena has long been identified as 'harmonious dualism' where learners would tend to find answers for scientific claims using their own IK worldview presuppositions without experiencing any cognitive conflict (Ogunniyi, 1988). For example, Rollnick and Rutherford (1996) have alluded to the above when they said that learners use two knowledge systems and somehow would operate happily in both systems of thought.

The implication for this finding also suggests that the ability of argumentation being able to enhance teachers' as well as learners awareness of and understanding of the NOS may not be unrelated to learners understanding of internal and bridge principles which scientific theories consists. In this regard, learners may be in a better position to appropriate knowledge claims and use whichever is appropriate when the context requires so (Gunstone & White, 2000). In conclusion it should be born in mind that every scientific explanation finds its relevance and rationality upon the understanding of the principles and beliefs that underpin the worldview that created its knowledge claims (Kelly, Carlsen & Cunningham, 1993; Ogunniyi & Ogawa, 2008).

- The level at which integration is possible between school science and IKS is moderated to a large extent by the nature of the internal principles as well as bridge principles inherent in a particular scientific theory or law underpinning a particular phenomenon. A related observation made was that each phenomena has internal principle peculiar to a particular worldview, hence the importance of the context of how the phenomena is presented.

Immediate issue with regard to the above finding is understanding of the nature of both science and IKS. As Ogunniyi (2016) have noted, as science have its own internal principle, so is IKS and what brings them together is a common bridge principle which consists of common predicates that anyone from any worldview can relate with. For example, in the Xhosa tradition of which the majority of the learners in this study come from as well as in the |xam bushmen beliefs as related by Hollmann (2007), there is an anthropomorphic as well as an anthropocentric relationship between human and non-human objects, hence example of such instances came up through some of the learners' excerpts. As also been put forward by some socio-cultural scholars (e.g. Aikenhead, 1996; Fakudze, 2004; Sutherland and Dennick, 2002, Phelan et al, 1991), the sociocultural environment of the learners is embedded in belief systems, norms and values and attitudes.

In conclusion, the findings thus, seem to also have responded to the concerns raised by various scholars (e.g., Cobern and Loving, 2000; Finley, 2009; Onwu & Mosimege, 2004; Onwu, 2009) on the possible models of integrating IK and school science as well their relative level of feasibility within the science classroom (Ogunniyi, 2004, 2006, 2007a & b; Ogunniyi & Hewson, 2008; Ogunniyi & Ogawa, 2008).

Current literature suggests that teachers in general also have a poor understanding of the NOS as has been noted by scholars in comparative cross-cultural studies conducted in several continents (e.g. Lin & Chiu, 2004; Ogunniyi et al, 1995; Ogunniyi, 2004, 2007a & b). The latter has implications for the training and retraining of teachers, curriculum advisers and policy makers with regard to the NOSIKS as well as in-depth content knowledge so as to be able to appreciate the DAI teaching and learning model.

- As opposed to the TEI teaching and learning approach which seemed to be dichotomizing IK and school science, the DAI teaching and learning strategy seemed to be the most appropriate intervention approach for integrating school science and IKS in a manner in a holistic manner.

The findings suggests the importance of ameliorating the distorted notion about the two systems of thought in the extant literature (Aikenhead & Jegede, 1999; McComas, 1998). As many scholars have alluded, dichotomising IK and science is a phenomenon that only exists in the minds of adults as learners will continue to operate in diverse worldviews (e.g., Gunstone & White, 2000; Hewson & Hewson, 2003; Marin, Solano & Jiminez, 2001; Rollnick & Rutherford (1996); Posner et al., 1981).

4.3 The relationship of learners' conceptions to their socio-cultural background

4.3.1 The role of gender on the learners' conceptions of selected phenomena

To address the above research issue, Chi-Square for independence analysis was requested across all concepts. The results presented in the following tables will be just for those items which showed that there was a significant relationship between an item and the socio-cultural background of the learners. Table 4. 4 below presents a cross tabulation on the effect of gender on item 5 (the phenomena of inaudible sound on nature of science) and item 5 (on NOSIKS) relating the learners' rural home background with the notion of scientism.

Table 4.4 Gender Crosstabs for sound

5. SOUND: An elephant can communicate with another elephant a couple of kilometers away without you hearing any audible sound coming out of it.						Total		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
		SD	**D**	**A**	**SA**		Pearson Chi-Square	11.050^a	4	**.026****	.024		
Male	**Count**	22	13	9	3	53	Likelihood Ratio	11.702	4	.020	.026		
	% within gender	41.5	24.5	17.0	5.7	100.0	Fisher's Exact Test	10.736			.027*		
	% within sound: 5	50.0	40.6	33.3	18.8	42.1	Linear-by-Linear Assos	9.420^b	1	.002	.002	.001	.001
	% of total	17.5	10.3	7.1	2.4	42.1	N of Valid Cases	126					
Female	**Count**	22	19	18	13	73	**RESULTS**						
	% within gender	30.1	26.0	24.7	17.8	100.0	a. 2 cells (20.0%) have expected count less than 5. The minimum expected count is 2.94. This means than 80% cells have expected count of 5.						
	% within sound: 5	50.0	59.4	66.7	81.3	57.9	b. The standardized statistic is 3.069.						
	% of total	17.5	15.1	14.3	10.3	57.9	**NOTES**						
TOTAL	**Count**	44	32	27	16	126	SA = Strongly Agree, A = Agree, D = Disagree, SD = Strongly Disagree						
	% within gender	34.9	25.4	21.4	12.7	100.0	p-value = 0.05						
	% within sound: 5	100	100	100	100	100.0							
	% of total	34.9	25.4	21.4	12.7	100.0							

In Table 4.4 above, a larger proportion of girls showed an understanding or awareness of animals having the ability to communicate using high or low frequency sound below the 20Hz threshold limit and above 20 000Hz. Among the girls, 66.7% and 81.3 % agreed and strongly agreed that elephants can communicate without humans hearing them. This is significantly higher than the proportions of boys who agreed and strongly agreed (33.3% and 18.3%) respectively. The chi square results shows a significant result with 80 of the cells holding the expected count of 5 and the Pearson correlation equal to p = 0.026 which is more than the confidence level of 95%.

In trying to understand the worldview presuppositions of some of the girls around their views and rationale for their beliefs about elephants and other animals' ability to communicate through inaudible sound, suitable excerpts from four girls' were selected purposively from learners' questionnaires among the four schools. Only learners who had agreed to the notion of elephants being able to communicate without audible sound and had also offered reasons for their answers were chosen. Box 4.7 below presents the learners' rationale.

Box 4.7: Excerpts depicting learners' worldview presuppositions on their understanding or awareness inaudible sound in respect of animals in nature as depicted in table 4.3 above.
Girl 1: I agree because in our culture we believe that dogs can also hear sounds from witches which we cannot hear at night **Girl 2:** It is true because when people are pregnant, I hear that the doctors send sound to the baby without us hearing the sound. **Girl 3:** I strongly agree because elephants can blow very sharp sound and have very big ears to catch the sharp sound which we cannot hear. **Girl 4:** When we go and fetch water in the rivers we usually see crabs and frogs in the water. When the frogs are out of the water we hear the sound, but when they are under the water we can't hear the sound so they must also be communicating with their babies under the water. **Boy 1:** Yes I know that dogs at night can hear sound which we cannot hear as people. **Boy 2:** I believe it is true because I know it when an aeroplane is two fast we cannot not hear its sound and when it has already passed we hear the sound. **Boy 3:** I strongly agree because this is how the scientists created a cell phone so that we cannot hear the sound of someone speaking but only hear from our phones. **Boy 4:** Humans can only hear sound between 20Hz and 20000Hz so elephants can create bigger sound.

Girl 1 presented a cultural perspective where dogs are usually bark at night, but nothing seen and the barking being attributed to witchcraft. On the other hand Girl two must have seen or heard that sonar scans use sound to create pictures of an unborn baby in the mother's stomach. Girl three related the elephant's ears and trunk to its ability to blow sharp inaudible sound and the other being able to receive such sound. Finally, Girl four used her experience and logical thinking about how frogs or other water animals are able to communicate under the water without making sound that is audible to the human ear. What could probably be common to women is excerpts form Girl 2 and Girl 4 with their experiences in hearing about gynaecologists and their own experiences fetching water from rivers in the rural areas. Girl 1 and 3's views are common to both boys and girls.

With respect to boys' views, only Boy 1 expressed as view that is both rural and urban-based experience of dogs being able to hear inaudible sounds at night. Boys 2 to 4 expressed mainly urban-based or school based reasoning of why they thought elephants are able to produce inaudible sound. For instance Boy two's explanation relates to the Doppler Effect rather than inaudible sound. Boy 3 and 4 had accurate school science notion of high and low inaudible frequency sounds. For example, cellular phones have as a transmitter and a receiver or convertors of high frequency sound to the human range.

With respect to girls, it seems that the high proportion of girls to boys with respect to awareness of audible sound is probably due to a variety of everyday experiences which may favour girls more than boys. Although the chi square test for evaluating the effect of gender on learners' rural home background was not significant, this may have had a contribution in tipping the scale in favour of girls. For instance 79 (56.8%) of girls are from the rural areas as opposed to 60 (43%) of boys who are from the rural areas. This can also be supported by the girls excerpts above which are mainly rural based as compared to those of the boys which are urban based. To interrogate this further, a t-test for independent groups for males and females was obtained specifically for item 5 on the sound construct. The pre-test mean scores for the boys which was 1.64 as opposed to 2.27 for girls corroborates the Pearson Chi Square test. The mean differences presents a significant difference with $t_{crit} = -3.179$ and $p = 0.002$.

4.3.3 Summary

Evidence from the chi-square test suggests that there is a significant between the boys and girls' pre-test conception about the existence of infrasonic sounds transmitted by elephants. This was further verified using the t-test for independent groups. The learners' excerpt suggested that the girls excerpt represented predominantly rural experiences as opposed to those of boys which were predominantly from settings. The demographics also showed that 79 (56.8%) of girls are from the rural areas as opposed to 60 (43%) of boys who are from the rural areas.

4.4 The role of home background on the learners' conceptions of selected phenomena

In Table 4.5 below, a larger proportion of learners who disagree or strongly disagreed about science being able to solve all human problems were from the rural areas. 76% and 70.8% proportions of all learners who respectively disagreed and strongly disagreed to the notion of scientism were from the rural areas and the chi square test shows that this was a significant result. Only 16.7% of cells had an expected count of 5 thus the assumption has not been violated. The Pearson chi square test shown in Table 4.5 gives a significance value of p = 0.037. As already highlighted, the relationship between item 5 on sound and gender showed that a large proportion of learners, that is, 79 (56.8%) were girls who came from rural areas versus 60 (43%) boys who also came from the rural areas. Based on this, it can be deduced that the larger proportion of the village cohorts who disagreed with the notion of scientism may be girls. This seems to suggest that learners who are from the rural areas especially girls are most likely open to different scientific worldviews other than those of school science. This is supported by the fact that women in rural areas depend more on the environment and agriculture and hence may be more aware of IK practices that man, since man spend most of their lives in urban areas in search of work to support their families.

Table: 4. 5. Rural home-background crosstabs for Nosiks 5

5. With science we can solve all human problems.						Total
		SA	A	D	SD	
Village	Count	17	15	39	17	88
	% within Background	19.3	17.0	44.3	19.3	100.0
	% within Nosiks: 5	48.6	51.7	76.	70.8	63.3
	% of total	12.2	10.8	28.1	12.2	63.3
City	Count	10	4	7	4	25
	% within Background	40.0	16.0	28.0	16.0	100.0
	% within Nosiks: 5	28.6	13.8	13.7	16.7	18.0
	% of total	7.2	2.9	5.0	2.9	18.0
Township	Count	8	10	5	3	26
	% within Background	30.8	38.5	19.2	11.5	100.0
	% within Nosiks: 5	22.9	34.5	9.8	12.5	18.7
	% of total	5.8	7.2	3.6	2.2	18.7
TOTAL	Count	35	29	51	24	139
	% within Background	25.2	20.9	36.7	17.3	100.0
	% within Nosiks: 5	100	100	100	100	100
	% of total	25.2	20.9	36.7	17.3	100

	Value	df	Asymp.(2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	13.264[a]	6	.039	**.037**		
Likelihood Ratio	12.779	6	.047	.059		
Fisher's Exact Test	12.477			.047*		
Linear-by-Linear As	6.265[b]	1	.012	.014	.007	.002
N of Valid Cases	139					
RESULTS						
a. 2 cells (16.7%) have expected count less than 5. The minimum expected count is 4.32. This means more than 80% cells have expected count of 5. b. The standardized statistic is -2.503. c. The Pearson Chi-Square is 0.039 for this test.						
NOTES						
SA = Strongly Agree, A = Agree, D = Disagree, SD = Strongly Disagree						
p-value = 0.05						

4.4.1 Summary.

- 76% and 70.8% proportions of all learners who respectively disagreed and strongly disagreed to the notion of scientism were from the rural areas and the chi square test shows that this was a significant result. The Pearson chi square test gives a significance value of p = 0.037. As been highlighted for the relationship between item 5 on sound and gender, a large proportion of learners, that is, 79 (56.8%) were girls who came from rural areas versus 60 (43%) boys who also came from the rural areas. Based on this, it was deduced that the larger proportion of the village cohorts who disagreed with the notion of scientism may be girls.

4.4.2 *The effect of the interventions on the learners language and terminology abilities?*

The above research questions sought to establish the effects of the DAI-Bridge as well as the TEPSI strategies on language. While the language issue could be explored within other phenomena items, the items on terminology were specifically geared towards this purpose. To this effect, a special table to highlight the learners' language effects on their performances is presented below.

4.4.3 *Quantitative treatment of the effects of the interventions on language and terminology*

Item 2 and 4 in Table 4.8 below reveal that there were no significant performance differences between the pre and post-test results for the TEPSI group while there were very strong significant differences for the DAI-Bridge group as indicated by the very large significance effect sizes with Eta^2 values of 0.55 and 0.16 for Terminology 2 and 4 respectively. These results suggest that the DAI-Bridge intervention seemed to have been more effective in intervening with the conceptual understanding of Terminology 2 and 4 and that the TEPSI intervention seemed to be less effective.

Table 4.7: Effects of DAI-Bridge on learners' conceptual understanding of terminology relating to natural phenomena.

DATA PARAMETERS: N_{TOTAL} = 139, N_{DAI} = 76, N_{TEI} = 63, t_{crit} Independent@ df(137) = 1960, t_{crit} DAI-Bridge@ df(75) = 1980, t_{crit}TEPSI@df(61) = 2000, Alpha = 0.05.

Phenomena	Group Info	Means Pre	Means Post	t-ratio	p-value	Eta^2
Terminology 2.	**DAI_mean**	1.96	3.11	-9.735	0.000	0.55
Temperature is the amount of **heat**	**TEI_mean**	1.89	1.98	-5.10	0.612	N/A
contained in an object	**t-ratio**	0.375	8.674	Very large effect size		
	Sig.	0.708	0.000			
	Eta^2	NA	**0.35****	Moderate effect size		
Terminology 4.	**DAI_mean**	2.70	3.43	-7.839	0.000	0.16
Energy and work represent the	**TEI_mean**	2.35	2.24	0.552	0.583	N/A
same concept because they are both	**t-ratio**	1.860	8.154	Large effect size		
measured in Joules	**Sig.**	0.065	0.000			
	Eta^2	NA	**0.33****	Large effect size		

Terminology 6. Two objects with the same **mass** will exert different **forces** on the floor if they have different base areas	**DAI_mean**	2.30	3.06	-6.111	0.000	0.33
	TEI_mean	2.14	2.87	-4.709	0.000	0.26
	t-ratio	0.851	1.495	Large effect sizes		
	Sig.	0.397	0.137			
Terminology 8. An athlete from a country with higher altitude will not easily get tired in a country with lower altitude than his/her own.	**DAI_mean**	2.14	2.89	-4.709	0.000	0.23
	TEI_mean	1.71	2.60	-5.279	0.000	0.31
	t-ratio	2.358	1.460	Very Large effect sizes		
	P-value	0.020	0.149			
	Eta^2	0.03	N/A	Small: None		
Terminology Totals	**DAI_mean**	9.10	12.49	-12.594	0.000	0.67
	TEI_mean	8.10	9.69	-3.730	0.000	0.18
	t-ratio	2.125	7.938	Large effect sizes		
	Sig.	0.036	0.000			
	Eta^2	0.03	**0.32****	Small to very large		

With regard to items 6 and 8 in table 4.8 above, it is observed that both groups presented the same level of terminology understanding in their pre-intervention status except for item 8 where a significant result of $t_{ratio} = 2.358$ at $p = 0.020$ which is less than the confidence alpha level of 0.05. The calculated eta squared value is 0.03 representing a small effect size, thus it can be ignored. Similarly, the post-intervention results were similar for the DAI-Bridge and TEPSI groups. The post-test results for both groups were significantly high with very large effect size results indicating that both intervention methods had a significant effect.

In general, the performance of all groups as a result of both interventions were high as can be seen in Terminology Totals' eta squared results which represented a large effect size of 0.67 and 0.18 for DAI-Bridge and TEPSI respectively. Again, the effect sizes does show that the DAI-Bridge intervention seem to be more effective as compared to the TEPSI. This is also corroborated by the large effect size of 0.32 in the post test comparisons between DAI-Bridge and TEPSI. The qualitative treatment will illuminate on the nature of the item differences.

4.4.4 Qualitative treatment of the effects of the interventions on language and terminology.

The results above show that, both groups performed comparable for items 6 and 8 and the TEPSI was significantly outperformed on Items 2, 4 and the total scores for terminology. In this regard, excerpts from Terminology 2 and 4 will be boxed and discussed together and similarly for those of Terminology 6 and 8. Boxes 4.7 and 4.8 below presents the excerpts.

In items 2 and 4 in Box 4.8 below, the DAI group significant outperformed the TEPSI group in their post-test scores. If we look at Learner 72 in his pre-test response, he states that temperature is a number or value representing heat in a substance. This learner sees the two concepts as one concept. On the other hand, Learner 73 from the DAI-Bridge group had it all in reversed by imagining the temperature changing and thus resulting in flow of energy. When we again analyse the learners' post-test responses, we see that Learner 72 from the TEPSI group again swopping the roles of heat and temperature by asserting that heat changes result in temperature flows as opposed to heat flows and temperature changes.

Box 4.8: Learners' cognitive shifts where learners had incorrect claims with incorrect reasons in their pre-test and where the DAI-Bridge interventions performed significantly better than the TEPSI intervention.

Item 2 Assertion: Temperature is the amount of heat that is contained in a substance.

Pre_TEPSI-Learner 72: Agree – Temperature is the number or the amount of heat in a substance (IK).

Post_TEPSI-Learner 72: Disagree – When the heat changes, the temperature will flow from hot object to the cold object (SS).

Pre_DAI-Learner 73: Agree – If the temperature of water goes up, the heat flows into the water. (SS)

Post_DAI-Learner 73: Disagree — It is not true because temperature is a number that tells us if heat is entering or leaving an object and they are also not measured by the same units (SS).

Item 4 assertion: Energy and work are both measure in Joules and therefore represents the same concept.

Pre_TEPSI-Learner 68: Agree – It is true because they are measured the same way. (SS)

Post_TEPSI-Learner 68: Agree – Energy allows work to be done. (SS)

Pre_DAI-Learner 69: Agree – If work and energy are measured in one unit, it means they are the same thing (SS).

Post_DAI-Learner 69: Disagree – To do work we need energy like food so they are different (IK).

IK = Indigenous knowledge, SS = School science, TEPSI = Traditional Expository Pace-Setter Instruction, DAI-Bridge = Dialogical Argumentation Instruction Bridge.

Traditional school science teaching and learning approaches usually result in unconscious swopping around of concepts where the dependent variable is usually exchanged for the independent various. In other words, learners are usually confused by which concepts or variables are functions or domains of each other. This pattern among the majority of the TEPSI learners seemed to be prevalent resulting in lower performance scores both at their pre and post-tests.

When we look at Learner 73, we see that the learner has had a change of perspective after the DAI-Bridge intervention. The learner has clearly noted that temperature and heat have different units of measurement. Furthermore, this learner made a considerable distinction between temperature and heat as he noted that, temperature changes occur as a result of heat exchanges in the environment. In other words, temperature is dependent variable and heat an independent variable. The majority of the learners from the DAI-Bridge group seemed to provide similar arguments as exhibited by Learner 73 and thus suggesting that the DAI-Bridge intervention may be an effective strategy to negotiate complex terminologies used in complex concepts like in temperature and heat.

For item 4, learners from both groups had misconceptions about the concept of work and energy in their pre-test. They both argued that since energy and work are measured by the same unit, they actually represent the same concept. After intervention, Learner 68 defined energy as the ability to do work using school science as her source of knowledge, but maintained that they are represent the same concept. On the other hand, Learner 69 related energy to food which give people energy so that work can be done and also claimed that they are different in that regard. This learner cited IK as his source of knowledge. In conclusion, it can be seen that although the TEPSI learners made correct claims in their post-test responses, their reasons where however slightly incorrect highlighting some conceptual and language challenges.

For items 6 and 8 in box 4.8 below, both the DAI-Bridge and the TEPSI groups performed comparable in terms of their pre to post-test scores. With regard to item 6 where Learner 35 and 36 provided similar responses. Both learners in essence argued that objects with the same mass but with different base areas will exerts different forces on the floor. This is a conceptual misunderstanding of the concept of force and pressure. After the interventions, this misconception was corrected and Learner 35 noted that an object with a large base area will exert less pressure than an object with a small base area. On the other hand, Learner 36 based his answer on the notion of force and its direct proportionality to mass and hence also came to similar conclusions and the former learner.

Turning to item 8 which relates altitude and atmospheric pressure, we see that Learner 19 argued that places with lower altitude are very hot resulting in athletes from higher altitudes not doing well. In her post-test, she argued that places with low altitude are flat making it easy for athletes to run. This excerpt is typical of most other pre and post-test responses from the TEPSI group. When we interrogate Learner 20's pre-test response, it also shows that the learner had no idea about the concept of altitude and atmospheric pressure relationships and how they influence sport.

Box 4.9: Learners' cognitive shifts where learners had incorrect claims with incorrect reasons in their pre-test and where the DAI-Bridge interventions performed significantly better than the TEPSI intervention.

Item 6 assertion: Two objects of the same mass but different base areas will exert different forces on the floor.

Pre_TEPSI-Learner 35: Agree – If the bases are not the same size, then the forces will be different. (SS)

Post_TEPSI-Learner 35: Disagree –the object with the smaller area will exert more pressure than the one with a larger area. (SS)

Pre_DAI-Learner 36: Agree – Two object can have the same mass, but the object with a bigger area will also exert more force than the object with small area (SS).

Pre_DAI-Learner 36: Disagree – It is not true, the objects will have the same force because they have the same mass (SS).

Items 8 assertion: An athlete who comes from a country at a higher altitude to one with a lower altitude will run faster than in the country where she/he comes from.

Pre_TEPSI-Learner 19: Disagree – Places at low altitude are very hot so I think he will not run better (IK).

Post_TEPSI-Learner 19: Agree – Places that are low are flat and easy to run than on the mountains so they are more fit (IK).

Pre_DAI-Learner 20: Disagree – A person will run the same way anywhere he goes if he is fit.

Post_DAI-Learner 20: Agree – At high altitudes there is less oxygen so it is better to run in a low altitude where there is more pressure and more oxygen (SS).

IK = Indigenous knowledge, SS = School science, TEPSI = Traditional Expository Pace-Setter Instruction, DAI-Bridge = Dialogical Argumentation Instruction Bridge.

Learner 20 in the above box basically felt that place will not affect a sportsperson's performance. After some interventions relating to the phenomena through IK-based dialogical arguments, Learner 20 was able to associate low altitudes with high atmospheric pressures which in turn relate to more oxygen supplies. This and other similar arguments made by the DAI-Bridge group led to higher post-intervention scores.

In conclusion, the two items seemed to have two interconnected and interrelated concepts. For example, Item 4 relates work and energy through the same measurement unit of Joule, while item 6 relates pressure and force in a direct proportionality and area in a inverse proportionality. The concepts depicted by the two items seemed to be more amenable to school science worldview which can also easily memorisable. For example, 'Energy is the ability to do work' and 'pressure is force per unit area'.

4.4.5 Preliminary findings and further discussions on language matters

In terms of the learners' performances and written responses on language matters, the following observations were noted:

- The DAI-Bridge intervention seemed to have been much effective than the TEPSI intervention when it comes to terminology concepts that had represented complex and yet with very similar scientific ideas. As opposed to the TEPSI intervention strategy, the DAI-Bridge significant improved the learners' performances on the concepts of temperature versus heat (Terminology 2) as well as energy versus work (terminology 4).

The concepts of temperature versus heat as well as energy and work are common ideas which learners are frequently exposed in their daily lives. However, school science uses these concepts to explain hidden and abstract ideas which are not in the interest of their everyday use by the public. As been highlighted above, scientific concepts depends on a variety of factors such as the language in which they occur (Rollnick & Rutherford, 1996; Young et al. 2005) and the discourse of the discipline for which they are used (Diwu, 2010; Dlodlo, 1999; Kearsey & Turner, 1999; Scot, Asoko, & Leach, 2007; Setati, Adler, Reed & Bapoo, 2002) as well as the conventions of the discourse in their home, mother tongue or first language (Sutherland & Dennick, 2002).

As the DAI-Bridge group were involved in home language mediated argumentation discourses coupled with IK-based resource materials they seemed to have been able to develop meta-linguistic skills which acted as socio-linguistic border crosses into the scientific meanings of the concepts. In support of the above, Kearsey and Turners (1999) has also added that, if bilingualism is treated as a resource then scientific learning can be enhanced. In support of IK-based linking of scientific concepts, Odora-Hoppers (2005) has rightfully and eloquently put it that:

> …language plays a crucial role in that it contains the map of the land, the relationships to the energies and the spirits of all living things – rocks, trees, plants, birds and animals. The flux in which they live is perfectly expressed in what could be termed their 'process language.' (p. 6).

This has been observed by a number of scholars who asserted that without the linguistic etymology of words or concepts, it becomes almost impossible for learners from diverse backgrounds to access school science concepts (Diwu, 2010). The latter view has been clearly articulated by Rampal (2005) who argued that school science for most times uses 'dead' languages in the formulation of scientific concepts, thus hiding the meaning behind the concept. Furthermore, the nature of school science discourse and etymology is what Ogunniyi (2007) claimed as the source of the diverse epistemologies between IKS and school science.

With regard to the TEPSI group, although observations showed that the learners as well as the teachers were generally using the learners' home languages as a scaffold to make them understand what was being taught at any given time, the teachers as well as the learners were using code-switching which can be regarded as unsystematic or unstructured. The code-switching practices were observed to be predominantly transliterations of scientific terms which were forced to conform to the lexicon of the learners' language. In the context of the concepts of temperature versus heat, the isiXhosa terms for these concepts have connotations of high temperature for the term 'heat' or temperature as a substance that can flow. On the other hand, because energy is defined as the ability to do work coupled with the two quantities measured in the same unit, learners from the TEPSI group generally were tempted to claim that they represent the same concept although they finally could define the concept.

However, as the excerpts have shown, learners can make an incorrect claim with a valid reason as well as a correct claim with an invalid reason which shows no understanding. Since no structured argumentation process were in place for the TEPSI group, ability to see whether learners understands the concepts may be very limited. In this regard, Newton, Driver & Osborne (1999) argues that active participation by learners in the discourse of their lessons is key in proving enabling teaching and learning conditions such as learners being able to put forward scientific claims and to learn to defend them (also see, Ogunniyi, 2008). In this way, everyone in class may gain clarity on fine and subtle linguistic issues.

Furthermore, as a result of the lack of scientific registers within the learners' indigenous languages and the added challenge of not having teachers who are trained in multilingual or IK-based approaches (Ogunniyi, 2004), the teachers verbal sentential translations (transliterations) usually result in what Dlodlo (1999) have called 'clumsy-sounding nguni words' with no scientific meaning in either languages. (p. 324). These practices are predominant in schools from African as well as in other contexts where English or any other colonial language is the language of teaching and learning while not the language of the learners. In the South African context, this practice is exacerbated by the fact that there are very limited scientific dictionaries and where they exist, they were compiled in the context of the limited role the African languages play (Chabata & Nkomo, 2010).

- The DAI-Bridge as well as the TEPSI interventions seemed to have had a significant effect on scientific concepts that were of practical everyday experiences. These items were force versus pressure (Terminology 6) as well as altitude versus pressure (Terminology 8)

The first item related the mass of an object and its weight and the second one related altitude and sports. These experiences are frequented by learners when talking of weights of objects as well as sport teams moving from one country to another where the athletes need to acclimatise and adjust to the atmospheric conditions of the place. It is therefore not very surprising to see that the concepts could be taught without the learners experiencing any cognitive conflicts.

In view of the above and in the context of the attempts made by both groups to introduce some context based learning and teaching materials into the science classrooms, it can be argued that such activities might also have awakened some of the learners' experiential knowledges (Ninnes 2000, Stears et al., 2003, Stears & Malcolm, 2005). Further support explaining learners' performances on concepts which are closely linked to their everyday contexts is offered by Jegede (1996) asserts that prior knowledge is related to the environment and as such that environment is in turn an aspect it. He further points out that the environment could be geographic, domestic or socio-cultural and as such the two (prior knowledge and environment) are inseparable where the environment can be seen as nurturing prior knowledge. Jegede 'view is also shared by Enderstein and Spargo (1998) who conducted a longitudinal and cross-cultural study in South Africa where they looked at the effect of context, culture and learning on the selection of alternative options in similar situations by South African learners. Their findings came to a conclusion that the environmental context of learners predisposes them to do better on school science activities which are designed and aligned in favour of the learners' socio-cultural backgrounds.

In conclusion, it seems that language play various roles in understanding of scientific concepts. It is further shown, as highlighted above that the nature of natural phenomena can also be made to link to the learners' socio-cultural backgrounds where language can also act as custodian and library of the learners' prior knowledges. In the this regard, when learners are able to discuss and argue on their experiences as has been seen with the DAI group, learners may be in a better position to traverse Vygotsky's (1978) Zone of Proximal Development (ZPD) or to acquire what Ogunniyi (1997) had called, the emergent cognitive contiguity.

4.5 Quantitative and qualitative treatment of the effects of the interventions on the learners' attitudes and awareness of and understanding of the NOSIKS.

Table 4.8a: The ease of IK as compared to school science

DATA PARAMETERS: N_{TOTAL} = 139, N_{DAI} = 76, N_{TEPSI} = 63, t_{crit} Independent@ df(137) = 1960, t_{crit} DAI@ df(75) = 1.980, t_{crit}TEPSI@df(61) = 2.000, Alpha = 0.05.

Attitudes assertions	**Group Info**	**Mean PRE**	**Mean POST**	**t-ratio**	**p-value**	**Eta^2**
Attitudes. 4 Learning cultural knowledge is easier than that of school science.	**DAI**	2.76	3.04	-3.103	**0.003**	**0.11**
	TEPSI	2.53	2.63	0.637	0.527	N/A
	t-ratio	1.683	2.836	**Large effect size - DAI**		
	p-value	0.095	0.005			
	Eta^2	NA	**0.06**	**Moderate effect size**		

Some excerpts to support the above.

Pre_TEPSI-Learner 120: Agree - Because in our culture we learn it from birth and we experience things differently in science (Eq_Par).

Post_TEPSI-Learner 120: Disagree - Sometimes it is hard to catch up with cultural knowledge, but it is better at school to catch up with science (IK_S).

Pre_DAI- Learner 101: Disagree - Cultural knowledge is difficult because people believe in many things, I get confused (IK_S).

Post_DAI-Learner 101: Agree - Because in science we must communicate in English while in our culture we use isiXhosa which is easy to understand (IK_D).

KEY: IK_D = **IK dominant,** IK_S = **IK Suppressed,** A = **Assimilated,** IK_Em = **IK Emergent,** S_Em = **Science Emergent,** Eq_Par = **Parallel Equipollency,** Eq_Div = **Divergent Equipollency, Eq_Conv = Convergent Equipollency.**

The above table shows that both the DAI-Bridge as well as the TEPSI groups performed comparably before interventions started and that their performances were moderate. However, after interventions the DAI-Bridge group significantly outperformed the TEPSI group. The DAI-Bridge groups means shifted from 2.76 to 3.04 which was a significant performance with t_{ratio} = -3.103 > t_{crit}-df(75) = 1.980 and p = 0.003. This performance represented a moderate to large effect size of 0.11 which is worth consideration.

For Learner 120, the initial cognitive stance is equipollent where both worldviews coexists side by side (Parallel equipollence). After intervention the excerpts for learner 120 show a change in his view by saying that it was difficult to keep up with cultural knowledge as it was better to catch up with school science. This now suggest that school science was now dominant and IK was suppressed, hence IK_S at the post test. A general trend depicted the above among the TEPSI learners may have led to the non-significant performance of the TEPSI group in their post-test.

In contrast to the Learner 120 from the TEPSI group, Learner 101 started by arguing that cultural knowledge was difficult as many people believed in many things, thus exhibiting a school science dominant worldview which suggest that IK was suppressed in favour of school science. Later, after the DAI-Bridge intervention the learner seem to have developed some compromise position by recognizing that IK uses an easier communication medium and thus the two could enhance the learning of school science. This may have been possible because of the dialogues which enabled the learners to use their own languages where necessary. Learner 101's cognitive stance can be regarded at being equipollent with the two worldviews converging towards each other or in support of each other with respect to language issues.

In summary, the performance scores of the learners have showed that the DAI-Bridge interventions has significantly outperformed the TEPSI intervention. This performance is represented a moderate to large effect size of 0.11 which is worth consideration. The effect size for the significant differences between the two interventions is 0.06, hence a moderate effect size. The above is corroborated by the learners' cognitive shifts which have showed that the TEPSI learners' cognitive shifts moved from being equipollent to a situation where IK became suppressed in favour of school science. On the other hand, the DAI-Bridge learners' cognitive stances seemed to have moved from positions of equipollency or where IK is suppressed (e.g., Learner 101) to a situation where IK becomes dominant.

The next item is similar to the above except that it interrogates the status of IKS in relation to its status with school science.

Table 4.8b: The affirmation of the scientific status of IKS						
DATA PARAMETERS: N_{TOTAL} = 139, N_{DAI} = 76, N_{TEPSI} = 63, t_{crit} Independent@ df(137) = 1960, t_{crit} DAI@ df(75) = 1.980, t_{crit}TEPSI@df(61) = 2.000, Alpha = 0.05.						
Attitudes 5.	**DAI**	2.09	2.78	-5.651	**0.000**	**0.29**

<table>
<tr><td rowspan="4">Cultural knowledge is equally scientific as school science.</td><td>TEPSI</td><td>1.81</td><td>2.06</td><td>-1.592</td><td>0.117</td><td>N/A</td></tr>
<tr><td>t-ratio</td><td>1.787</td><td>5.084</td><td colspan="3" rowspan="2">Large effect size - DAI</td></tr>
<tr><td>p-value</td><td>0.076</td><td>0.000</td></tr>
<tr><td>Eta^2</td><td>N/A</td><td>0.16</td><td colspan="3">Large effect size -DAI</td></tr>
<tr><td colspan="7"><u>Some excerpts to support the above.</u>
Pre_TEPSI-Learner 124: Disagree – Because some of the things I believe from my culture are different from science (Eq_Par).
Post_TEPSI-Learner 124: Disagree – I believe in science but I believe God exist also (Eq_Par).
Pre_DAI- Learner 116: Disagree - Because science says there is no God while I believe there is (Eq_Div).
Post_DAI-Learner 116: Agree - Because I take everything that I am taught by my parents and my teacher to be true (Eq_Conv).</td></tr>
<tr><td colspan="7"><u>KEY:</u> IK_D = IK dominant, IK_S = IK Suppressed, A = Assimilated, IK_Em = IK Emergent, S_Em = Science Emergent, Eq_Par = Parallel Equipollency, Eq_Div = Divergent Equipollency, Eq_Conv = Convergent Equipollency.</td></tr>
</table>

On the scientific status of IKS, the performances of the DAI-Bridge learners' performances as seen in the above table shows a significant performance over that of the TEPSI learners. This is represented by a very large effect size of 0.29 for the effectiveness of the intervention. The two interventions are significantly different in favour of the DAI-Bridge with a large effect size of 0.16. Again in terms of Att.5, the DAI-Bridge learners also came to realize that cultural knowledge was equally scientific as school science. This could have been as a result of IK-based science lessons which were mediated through dialogues and discussions

In corroboration of the above, Learner 124 did not change his stance but showed a change in a cognitive stance where IK was initially dominant to a cognitive stance where science and IK were equipollent but divergent in a sense that science is seen to be in opposition to religion. This suggests that the intervention of TEPSI may not have emphasized any cultural aspects of the school science to the extent that the learners would have made significant performances.

As opposed to Learner 124, Learner 116 from the DAI-Bridge group initially disagreed with the assertion but after the intervention changed his views. In the pre-test, this learners had a concern with the contrast that exists between scientific knowledge and religion, thus held equipollent cognitive stances with divergent ideas. The post-test reveal that the learners somehow has accepted both worldviews of religion as well as school science as being valid knowledge but assigned different roles or serving different interests. This suggest that this learner may have developed an equipollent cognitive stance as a result of the dialogical argumentation approaches which may have exposed most of the learners in the DAI-Bridge group to multiple worldview perspectives such as religion and science. The learner's last cognitive stance suggest an equipollent cognitive stance where both IK and school science can be regarded as entities that coexist side by side as parallel ideas.

In summary, the performance scores of the learners have showed that the DAI-Bridge interventions has significantly outperformed the TEPSI intervention. This performance is represented by a very large effect size of 0.29 which is worth consideration. The effect size for the significant differences between the two interventions is 0.16, hence also a large effect size. The above is corroborated by the learners' cognitive shifts which have showed that the TEPSI learners' cognitive shifts where the majority of the TEPSI did not accept cultural knowledge as being scientific or rather serving a different purpose. On this note, the TEPSI learners' views on IKS seem to be close to the views by Cobern & Loving (2000), who are of the view that IKS and school science should be separated.

On the other hand, the DAI-Bridge learners' cognitive stances seemed to have moved from positions of equipollency where the two thought systems are divergent to each other and later seemed to have developed equipollent cognitive stances where IK and science seemed to converge towards each other. This is consistent with cross-cultural and sectional studies conducted by Ogunniyi et al. (1995) who concluded that the learners' beliefs are to a large extent influenced by the beliefs of their teachers.

Table 4.8c: Scientific validation of IKS with respect to its testability in the laboratories

DATA PARAMETERS: N_{TOTAL} = 139, N_{DAI} = 76, N_{TEPSI} = 63, t_{crit} Independent@ df(137) = 1960, t_{crit} DAI@ df(75) = 1.980, t_{crit}TEPSI@df(61) = 2.000, Alpha = 0.05.

Nosiks 3 Cultural or home-based knowledge is not scientific at all because it was tested in the laboratory.	**DAI**	2.22	2.80	-4.933	0.000	**0.25**
	TEPSI	2.10	2.31	-1.388	0.170	N/A
	t-ratio	0.784	3.032	**Large effect size-DAI**		
	p-value	0.434	0.003			
	Eta^2	NA	0.06	**Moderate effect size-DAI**		

Nosiks 8 Indigenous knowledge is not scientific because it was not tested in the laboratory.	**DAI**	2.70	2.86	-2.535	**0.013**	**0.08**
	TEPSI	2.27	**2.05^{L}**	1.343	0.184	N/A
	t-ratio	2.447	4.685	**Moderate effect size-DAI**		
	p-value	0.016	0.000			
	Eta^2	**0.04**	**0.14**	**Large effect size-DAI**		

Some excerpts to support the above.

Nosiks 3 assertion: Cultural or home-based knowledge is not scientific at all because it was tested in the laboratory.

Pre_TEPSI-Learner 103: Agre - Everything in science should be tested in the laboratory. (IK_S).

Post_TEPSI-Learner 103: Agree - It (IKS) has nothing to do with science – it is generated from our forefathers and mothers (IK_S).

Pre_DAI- Learner 119: Agree - Some home knowledge is scientific and some is not (IK_Em).

Post_DAI-Learner 119: Disagree - Not everything I know in science I have tested. Some of the knowledge I get from my home is also scientific and also find it in the science books (Eq_Conv).

Nosiks 8 assertion: Indigenous knowledge is not scientific because it was not tested in the laboratory.

Pre_TEPSI-Learner 54: Agree – Because there is no scientific proof for indigenous knowledges (A).

Post_TEPSI-Learner 54: Agree – We don't test indigenous knowledge in the laboratory, science only could be tested in the laboratory (Eq_Par).

Pre_DAI- Learner 48: Agree - Because it is knowledge you had before you came to school (A).

Post_DAI-Learner 48: Disagree - There are indigenous knowledges which are scientific as well which do not need testing (IK_Em).

KEY: IK_D = **IK dominant,** IK_S = **IK Suppressed,** A = **Assimilated,** IK_Em = **IK Emergent,** S_Em = **Science Emergent,** Eq_Par = **Parallel Equipollency,** Eq_Div = **Divergent Equipollency, Eq_Conv = Convergent Equipollency.**

In the above table, NOSIKS 3 used the term cultural or home-based knowledge while NOSIKS 8 uses indigenous knowledge. This was to see if the two terms would have the same effect on the learners' perspectives or would contrast against each other. Looking at the results, it seems that there was consistency in the way the majority of the learners had responded in the two NOSIKS items. This suggest that the term 'cultural knowledge' seems to be synonymous to 'indigenous knowledge' from the learners' point of view. For this study this is important so as to understand the learners' perspectives on IK and how it relates to their culture.

For example, the DAI-Bridge group's pre to posttest performances across the two items is significant with $p = 0.000$ for NOSIKS 3 and effect size of 0.25 (very large) and $p = 0.013$ for NOSIKS 8 and effect sizes of 0.08 (moderate effect size). In conjunction with Att.4, Att.5, NOSIKS 3 and 8, the DAI-Bridge learners seem to have come to a conclusion that traditional knowledge was much easier to comprehend, equally scientific as school science although it had not been validated or tested in a laboratory.

This above observation is in contrast to the TEPSI group where there were no significant differences between their pre to posttest performances for all the two items, suggesting that their views about traditional knowledge being easier than school science knowledge or scientific was not significantly strong. A close look at NOSIKS 8 the TEPSI group's post-test mean scores were slightly lower than their corresponding pre-test mean scores. Their mean scores, although not significant, decreased from 2.27 to 2.05 in the post-intervention stages. The mean score differences in the DAI-Bridge and TEPSI post-test scores was significance with eta squared effect sizes 0.14 (large).

In corroboration of the above, Learner 103 initially argued that cultural knowledge must be tested in the laboratory to be scientific and later also argued that it had nothing to do with science. For the TEPSI learners, this view suggests that school science is dominant before and after interventions. On the other hand, while Learner 119 initially agreed with the assertion that some cultural knowledge was not scientific (IK_Em), she however disagreed with the assertion that IK was not scientific and at the post-test stage pointed out that not everything in science is tested and that there is some cultural knowledge which forms part of school science and yet is also not being tested in laboratories. This learner initially exhibited IK emergent stances as well as school science emergent stances, thus presented an equipollent cognitive stance. This suggest compatibility of the two worldviews as the learner came to acknowledge emergent ideas in both worldview which converge towards each other.

Moving to item 8 (NOSIKS 8) we again note similarly to the previous items, all the learners rejected the idea of IK being scientific as they argued that it was not tested in a laboratory. For example, Learner 54 initially argued that there was no scientific proof for indigenous knowledge and that view suggest an IK assimilation cognitive position. However, in the post-intervention stage the learner makes an argument that ‘they’ – meaning people from his culture do not test IK in laboratory; only science is reserved for the laboratory. Combining the pre and post-intervention arguments for this learners suggest that IK is reserved for a different purpose and hence also coexist with science on a parallel equipollent cognitive stance where the two worldviews do not interact.

As can be seen from the learners’ pre and post-test responses, the majority of the learners with respect to NOSIKS 8 seemed to have developed a misconception about IK rather than seeing them as not valuing IK. This misconception might have led to the TEPSI group learners gaining lower mean scores in their post-test as compared to their pre-test. However, their mean scores were not significantly low, hence it can be said that the TEPSI intervention seemed not to have been effective in dealing with the item.

Similar to Learner 54, Learner 48 also showed an IK assimilated cognitive stance in his pre-test by asserting that IK is prior knowledge and hence is not knowledge gained at school and thus non-scientific. However, after intervention this learner moved from an assimilated position to one of IK emergent cognitive category by recognising that some IK practices are scientific although they may not necessarily go through the validation processes of laboratory testing.

In summary, the DAI-Bridge intervention significantly outperformed that of the TEPSI learners with respect to the learners’ attitudes about the testability or otherwise of IKS. The majority of the DAI-Bridge learners exhibited equipollent and IK emergent cognitive stances after interventions while the majority of the TEPSI learners seemed to have exhibited IK suppressed cognitive stances which suggest that the TEPSI intervention strategy was associated with a conceptual change approach where the learners’ prior conception were to be abandoned for the dominant school science presuppositions on the nature of both school science and IKS. In conclusion, the DAI-Bridge intervention seemed to have edified the learners’ awareness of and understanding of the NOSIKS as they had the opportunity to navigate different worldviews and their means of knowledge construction.

Table 4.8d below interrogates the learners’ attitudes laboratories as places or tools for the development of scientific knowledge. Some excerpts are provided to support the statistics.

Table 4.8d: Laboratories as means of developing scientific knowledge						
DATA PARAMETERS: N_{TOTAL} = 139, N_{DAI} = 76, N_{TEPSI} = 63, t_{crit} Independent@ df(137) = 1960, t_{crit} DAI@ df(75) = 1.980, t_{crit}TEPSI@df(61) = 2.000, Alpha = 0.05.						
Nosiks 4 *<u>Scientific knowledge</u>* can only be developed in the laboratory.	**DAI**	2.66	3.03	-3.036	0.003	**0.11**
	TEPSI	2.43	2.87	-2.901	0.005	**0.12**
	t-ratio	1.423	1.212	**Moderate effect size-Both**		
	p-value	0.157	0.227			
<u>Nosiks 4 assertion:</u> Scientific knowledge can only be <u>developed</u> in the laboratory **Pre_TEPSI-Learner 4: Agree –** In laboratory there are many chemicals or there are practicals that we can do there and understand better (IK_S). **Post_TEPSI-Learner 4: Disagree** – Not everything in science should be developed in the laboratory (S_Em). **Pre_DAI- Learner 109: Agree -** You cannot say something is scientific without testing it. You are assuming in other words (IK_S). **Post_DAI-Learner: Disagree 109 -** The knowledge about the Khoisan's Devil's claw was not developed in the laboratory (IK_Em).						
<u>KEY:</u> IK_D = **IK dominant,** IK_S = **IK Suppressed,** A = **Assimilated,** IK_Em = **IK Emergent,** S_Em = **Science Emergent,** Eq_Par = **Parallel Equipollency,** Eq_Div = **Divergent Equipollency, Eq_Conv = Convergent Equipollency.**						

The above table shows that the learners' performance scores have significantly improved after interventions, thus suggesting that the both intervention strategies were effective. However, regarding the TEPSI learners, it is somehow interesting to see that their performance scores significantly improved for the above item. One would expected the same result as for Nosiks 3 and 8 which similarly suggested that IK or cultural knowledge was not scientific because it was not tested in the laboratory. The only assumption that seems to be the reason for the perceived difference between the TEPSI learners' performances in Nosiks 3 and 8 as well as Nosiks 4 above could be in the interpretation of the words 'testing' (Nosiks 3 and 8) and 'developing' as used in the above case. In this regard, the excerpts were followed to verify the latter statement.

In this regard all the majority of learners as exemplified by Learner 4 and 109 above initially claimed that scientific knowledge can be developed in the laboratories – a claim similar to the previous the Nosiks 3 and 8 for the TEPSI learners. However, at the post-test, all learners changed their views and noted that not everything part of school science has to go through the laboratories for validation. At the post-test, Learner 4 noted that not everything in science should be developed in the laboratory (a science emergent cognitive stance) while Learner 109 cited some medical interventions such as the Devil's Claw which were developed through indigenous practices. This learners thus presented with an IK emergent cognitive stance. For the DAI-Bridge learners, both the IK integrated lessons as well as the teaching strategy seemed to have been the primary drive for the learners' cognitive shifts from Nosiks 3, 8 and Nosiks 4 above.

For both the TEPSI as well as the DAI-Bridge learners presented emergent cognitive stances which suggest that there was a change which may have been influenced by one aspect of the intervention. Since the TEPSI intervention was not effective in changing the learners' attitudes towards the scientific status of IKS in Nosiks 3 and 8 it is assumed that the TEPSI learners still are of the view that scientific knowledge has to be tested in the laboratory, but may be developed in and outside laboratories as suggested by Learner 4 – "Not everything in science should be developed in the laboratory." This latter views by the TEPSI learners may have been as a result of the IK integrated lessons which may exhibited everyday context school science which may have lead the TEPSI learners to the view.

Table 4.8e: Science as a method to prove the truths about nature.

DATA PARAMETERS: N_{TOTAL} = 139, N_{DAI} = 76, N_{TEPSI} = 63, t_{crit} Independent@ df(137) = 1960, t_{crit} DAI@ df(75) = 1.980, t_{crit}TEPSI@df(61) = 2.000, Alpha = 0.05.

Nosiks 6 *<u>Science is a method</u>* to prove the truth about nature and its environment	**DAI**	1.80	2.20	-3.842	0.000	**0.16**
	TEPSI	2.06	2.31	-3.913	0.001	0.17
	t-ratio	-1.935	1.410	**Large effect size-DAI**		
	p-value	0.060	0.161			

Some excerpts to support the above.

Nosiks 6: Science is a method to prove the truth about nature and its environment.

Pre_TEPSI-Learner 19: Agree – Because most knowledge about nature we get from science (IK_S).

Post_TEPSI-Learner 19: Disagree – It (science) cannot prove where nature comes from (S_Em).

Pre_DAI- Learner 118: Agree - Through science I have discovered many things about nature and

science (S_Em).
Post_DAI-Learner 118: Disagree - I still don't believe that we are from monkeys (Eq_Div).

In terms of the learners the scientific method used as a method for proving the truth about nature and environment, all the learners agreed on the assertion. At the post-test Learner 19 shifted to a science emergent worldview by questioning the ontology of science, a limitation of science as it cannot explain its origin. On the contrary, Learner 118 shifted from a science emergent worldview to a parallel equipollent cognitive stance as she admitted learning about nature from science, but still rejected the notion of some of the evolutionist theories about humans as having originated from monkeys. In this regard, this learner accepted both science and IK worldviews, but puts some of the different ideas in parallel non-interacting compartments.

The findings above suggests that while the attitudes of both learners from both the TEPSI as well as the DAI-Bridge may have significantly improved, their cognitive shifts are different. The majority of the TEPSI learners as exemplified by Learner 19 post-test disagreed on the assertion largely based on school science limitations, but not on its ability to prove or probe nature. On the other hand, the majority of the DAI-Bridge learners as exemplified by Learner 118 post-test were outright opposed to science being able to prove anything about nature – and mostly exhibiting equipollent cognitive stances where the IK and science worldviews were divergent.

In conclusion, it can be assumed then, that the TEPSI intervention through its inclusion of IKS must have had an influence in terms of highlighting some aspect of nature which the learners may not have attributed to school science. This suggests that, while the TEPSI learners may not have agreed to IK or cultural knowledge as scientific, they may somehow reserving those ideas for religious or other cultural purposes which they view as not scientific. On the other hand, since the DAI-Bridge learners seemed to have embraced both IK and school science they seem to have developed an awareness of the limitations of both worldview while also accepting their scientific nature.

Table 4.8f: The role of experiments in the laboratories.						
DATA PARAMETERS: N_{TOTAL} = 139, N_{DAI} = 76, N_{TEPSI} = 63, t_{crit} Independent@ df(137) = 1960, t_{crit} DAI@ df(75) = 1.980, t_{crit}TEPSI@df(61) = 2.000, Alpha = 0.05.						
Nosiks 7	**DAI**	1.53	1.54	-1.270	0.206	N/A

Experiments in the laboratory are done to prove that what science theories say is true.	**TEPSI**	1.56	1.64	-1.335	0.342	N/A
	t-ratio	-.211	1.048	**No effects**		
	p-value	0.833	0.296			
Some excerpts to support the above. **Item 7 assertion: Experiments in the laboratory are done to prove that what science theories say is true.** **Pre_TEPSI-Learner 88: Agree - To** see how this things done and see by our naked eyes (IK_S). **Post_TEPSI-Learner 88: Agree -** Because experiments help us to understand more about science (IK_S). **Pre_DAI- Learner 58: Agree -** Because we need proof in order to believe that it is true (IK_S). **Post_DAI-Learner 58: Agree -** Practicals really proves them and get them right (IK_S).						
KEY: IK_D = **IK dominant,** IK_S = **IK Suppressed,** A = **Assimilated,** IK_Em = **IK Emergent,** S_Em **= Science Emergent,** Eq_Par = **Parallel Equipollency,** Eq_Div = **Divergent Equipollency, Eq_Conv = Convergent Equipollency.**						

Both groups' pre to posttest performance scores were not significant and both groups were statistically comparable. Both groups had very low performances score before and after interventions, thus suggesting that both teaching strategies were not effective. In this regard, learners' awareness and understanding of the role of experiments seems to have continued to be poor even after interventions. In this regard, as indicated in the excerpts, all the learners agreed, both at their pre and post-test responses that experiments are conducted to prove that what science theories claim is the truth.

Learner 88 from the TEPSI moved from a science dominant stance to a science emergent cognitive stance as she initially stated that she wanted to see things with her naked eye and further added that experiments enhances one's understanding of science. Similar to Learner 88's pre-test response, Learner 58 added that he need proof in order to believe. At post-test he further argued that experimental practical get things right (thus by confirmation). All the learners seemed to have a lack an understanding of the nature of science with respect to laboratory experiments despite the interventions.

In conclusion, the cognitive shifts of both the TEPSI as well DAI-Bridge were observed to have moved from IK suppressed to IK suppressed cognitive stances, thus suggesting no effect by either the inclusion of IKS or the TEPSI and DAI-Bridge teaching strategies.

Table 4.8g below interrogates the learners attitudes towards universalism. Some excerpts are provided to support the statistics.

Table 4.8g: Effects of interventions on learners' tendencies towards universalism						
DATA PARAMETERS: N_{TOTAL} = 139, N_{DAI} = 76, N_{TEPSI} = 63, t_{crit} Independent@ df(137) = 1960, t_{crit} DAI@ df(75) = 1.980, t_{crit}TEPSI@df(61) = 2.000, Alpha = 0.05.						
Nosiks 1 Knowledge from science should be the same everywhere in the world. **[SD = 1 and SA = 4]**	**DAI**	2.16	3.16	-6.487	0.000	0.36
	TEPSI	2.40	3.06	-4.482	0.000	**0.24**
	t-ratio	-1.505	0.481	**Large effect size-Both**		
	p-value	0.135	0.631			
Some excerpts to support the above. **Pre_TEPSI-Learner 33: Agree -** Because there is science everywhere in the world (IK_S). **Post_TEPSI-Learner 33: Disagree -** We are not taught the same way at school (Eq_Par). **Pre_DAI- Learner 99: Agree -** Because if they could be different we will be confused (IK_S). **Post_DAI-Learner 99: Disagree** – Science can be easy if we can be taught in our language (S_Em).						
KEY: IK_D = **IK dominant,** IK_S = **IK Suppressed,** A = **Assimilated,** IK_Em = **IK Emergent,** S_Em = **Science Emergent,** Eq_Par = **Parallel Equipollency,** Eq_Div = **Divergent Equipollency, Eq_Conv = Convergent Equipollency.**						

In terms of item 1 (NOSIKS 1) all learners in their pre-test argued that knowledge derived from science should be the same everywhere in the world. After the intervention, all the learners from both the TEPSI and DAI-Bridge group changed their views and made significant performance in terms of their mean differences from their pre-intervention stages. However, the differences between the TEPSI and DAI-Bridge groups for item 1 is that Learner 33 shifted from a science dominant stance to a parallel equipollent cognitive stance where she started by noting that science should be the same everywhere and later noted that 'they' are taught science differently. In this regard, the 'they' could be related to the separate schools with different economic status.

On the other hand, Learner 99 shifted from a science dominant worldview by arguing that there should be one science or else everyone else will be confused. This presented a Universalist science learning approach which underrates the role of context in science learning. After intervention, this learners changed his view and said that science can be easy if 'they' can also be taught in their own languages. This learner thus presented with a science emergent cognitive stance.

In conclusion, both interventions showed to be significantly effective in improving the learners' attitudes towards contextualized science. This may be attributed to the IK integrated science lessons which seemed to have affirmed the learners' IK such that they developed favourable dispositions to IK integrated science.

Table 4.8h: Effects of interventions on learners' tendencies towards scientism.						
DATA PARAMETERS: N_{TOTAL} = 139, N_{DAI} = 76, N_{TEPSI} = 63, t_{crit} Independent@ df(137) = 1960, t_{crit} DAI@ df(75) = 1.980, t_{crit}TEPSI@df(61) = 2.000, Alpha = 0.05.						
Nosiks 5 With science we can solve all human problems.	**DAI**	2.66	3.22	-4.637	**0.000**	**0.22**
	TEPSI	2.23	2.58	-1.793	0.078	N/A
	t-ratio	2.477	4.107	**Large effect size-DAI**		
	p-value	0.014	0.000			
	Eta^2	0.04	**0.11**	**Moderate effect size-DAI**		
<u>Some excerpts to support the above.</u> **Pre_TEPSI- Learner 97: Agree -** Because all things we do like giving birth to a child in hospital, all surrounds science (IK_S). **Post_TEPSI-Learner 97: Disagree -** There is no cure for HIV and cancer (S_Em). **Pre_DAI-Learner 122: Agree -** Science teach us more and give us knowledge (IK_S). **Post_DAI-Learner 122: Disagree -** Because science teaches about our body but cannot solve all sickness problems when someone is sick (Eq_Par).						
<u>KEY:</u> IK_D = **IK dominant,** IK_S = **IK Suppressed,** A = **Assimilated,** IK_Em = **IK Emergent,** S_Em = **Science Emergent,** Eq_Par = **Parallel Equipollency,** Eq_Div = **Divergent Equipollency, Eq_Conv = Convergent Equipollency.**						

In terms of scientism where science is seen as a solution for all human problems, the difference between the TEPSI learners' performances from their pre to post test was not significant. This suggest a tendency towards scientism on the part of the TEPSI learners. On the other hand, the DAI-Bridge learners' performances improved significantly after interventions. This significance in terms of the learners' pre to post intervention had a very large effect size (Eta^2 = 0.22) as well as a large effect size for the differences between the groups (Eta^2 = 0.11).

In terms of the learners' written responses, the excerpts showed that most learners were initially of the view that science can solve all human problems. However, at the post-test views for both learners changed. Learner 97 was biased in favour of school science in his pre-test by also stating that science help people in giving birth in hospitals – a science dominant cognitive category. However, at the post-test the learner changed his view and came to note that science cannot or rather has some limitations such as the inability to heal HIV-AIDS disease. This suggests a science emergent cognitive stance where the learner has gained new knowledge pertaining to what science can and cannot do. However, although close to being significant the TEPSI learners' mean score differences performances were not significantly different.

Similar to latter, Learner 122 from the DAI-Bridge group initially developed an IK suppressed cognitive stance where she initially argued that science provides knowledge and later rejected that view in the post-test by stating that science cannot help with all forms of healing of disease for sick people. This position suggest an equipollent position where science and IK co-exist to support or reinforce each other. This was a prominent view for the DAI-Bridge learners.

In conclusion, the findings suggest that, despite the inclusion of IK into the TEPSI learners' lessons, their intervention seemed to have led them to view school science as a solution for all human problems. On the other hand, the findings for the DAI-Bridge suggests that the DAI-Bridge intervention seemed to have managed to harmonise the hegemony of school science through the inclusion of IK and through argumentations to enhance their understanding of the limitations of both school science and IKS.

The next section presents the findings that emanated from all the above items that attempted to interrogate the learners' attitudes and awareness of and understanding of the nature of both school science and IKS.

4.5 Preliminary findings and further discussion on the role of interventions on the learners' attitudes and awareness of and understanding of the NOSIKS.

Items where only the DAI-Bridge learners' were significant **(Points 1 to 4 below).**

1. Attitudes 4 - With respect to the ease of comprehending IK, findings show that:

- While the learners from both groups had comparable attitudes towards science, at the pre-test stages the DAI-Bridge group significantly outperformed the TEPSI group in the post-test stage, thus suggesting that the DAI-Bridge intervention seemed to be more effective in terms of showing that IK was easily assessable and comprehensible. The above is corroborated by the learners' cognitive shifts which have showed that the TEPSI learners' cognitive shifts moved from being equipollent to a situation where IK became suppressed in favour of school science. On the other hand, the DAI-Bridge learners' cognitive stances seemed to have moved from positions of equipollency or where IK is suppressed (e.g., Learner 101) to a situation where IK becomes dominant.

As many scholars (e.g. Aikenhead & Jegede, 1999; Chiappetta, Koballa & Collette, 1998; Nuno, 1998; Rollnick & Rutherford, 1996) have argued that the school science worldview may not be compatible with that of the learners it made sense that the only way to overcome the intuitiveness of school science was to give the learners opportunity engage with school science in a manner where they are also able to voice their own views and opinions (Fleer, 1999, Jegede, 1996). As has been the case with the IK integrated lessons for the DAI-Bridge group, Keys (1997) as well as Chiappetta et al. (1998) have added that the presentation of scientific concepts using familiar and culturally oriented objects, artefacts, examples and analogies can enhance the learners understanding as well and hence their attitudes towards science. In this regard, the DAI-Bridge were favourably disposed to IKS.

With respect to the TEPSI intervention, it can be expected that since most teachers were taught in western-Eurocentric ways, teaching learners in non-western ways such as attempts to integrate school science and the learners' IK would have been a challenge for the TEPSI teachers. As has been argued by Ogunniyi et al. (1995), '…knowledge of what teachers and students bring into the class is critical in situating the teaching – leaning process within a meaningful context' (p. 819).

In later years with the introduction of IK into the science syllabus Ogunniyi (2004) lamented the fact that teachers were expected to infuse the learners' IK into school science without being trained in the nature of both school science and IKS. It is therefore not surprising to see significant differences between the DAI and TEI learners' attitudes towards school science. As Harlen and Holroyd, (1997) and Papanastasiou, C and Papanastasiou, E, (2004) have stated, the learners' attitudes towards science is due to teachers' lack of Subject Matter Knowledge (SMK), parents' negative predispositions and the school environment.

2. <u>Attitudes 5</u> - With respect to the learners' affirmation of the scientific status of IKS:

- The performance scores of the learners have showed that the DAI-Bridge interventions has significantly outperformed the TEPSI intervention. The above is corroborated by the learners' cognitive shifts which have showed that the majority of the TEPSI learners' did not accept cultural knowledge as being scientific but rather as serving a different purpose. On the other hand, the DAI-Bridge learners' cognitive stances seemed to have moved from positions of equipollency where the two thought systems were divergent to each other and after interventions seemed to have developed equipollent cognitive stances where IK and science seemed to converge towards each other. As opposed to the TEPSI learners, the DAI-Bridge learners seemed to have gained more awareness of the scientific nature of IKS.

The findings above with respect to the TEPSI learners is consistent with the views shared by Cobern and Loving (2000) who expressed their concerns about integrating school science and IKS. Their concern is centred on the prestige which western science already enjoys which they felt that it would be further renegaded or marginalised, hence their proposal that perhaps, IKS should be viewed to serve a different purpose. Others authors (e.g., Finley, 2009; Onwu & Mosimege, 2004) and Onwu, 2009) have also expressed their reservations and also echoed the sentiments of Cobern and Loving (2000). The confusions in the TEPSI classrooms are an attestation of the disillusionment experienced by the learners.

The findings relating to the cognitive shifts by the DAI-Bridge group into equipollent cognitive shifts is in line with cross-cultural and sectional studies conducted by Ogunniyi et al. (1995) who concluded that the learners' beliefs are to a large extent influenced by the beliefs of their teachers. Furthermore, the affirmation of the scientific nature of IKS also supports claims by various curriculum policy documents such as the RNCS Grades R - 9 and the NCS Grades 10 to 12 as well as the Curriculum and Assessment Policy Statement (CAPS) (e.g., Department of Education in South Africa, 2002; Department of Basic Education in South Africa, 2011). These documents and findings are further supported by other scholars (e.g., Corsiglia & Snively, 2001; Emeagwali, 2003; Fleer, 1999; Ogunniyi, 2007a; Ogunsola-Bandele, 2009) who argue that there is scientific knowledge embedded within IKS. Similar findings in the classroom (e.g., Diwu &

Ogunniyi, 2012) have also showed that teaching based on dialogical argumentation does indeed enhance the learners' understanding of the nature of science and that of IKS.

3. Nosiks 3 & 8 - With respect to the scientific validation of IKS with respect to laboratory experimentation:

- DAI-Bridge intervention significantly outperformed that of the TEPSI learners with respect to the learners' attitudes about the testability or otherwise of IKS. The majority of the TEPSI learners seemed to have suggested that IKS is not scientific since it is not tested in the laboratory as school science. The majority of the DAI-Bridge learners exhibited equipollent and IK emergent cognitive stances after interventions while the majority of the TEPSI learners seemed to have exhibited IK suppressed cognitive stances which suggest that the TEPSI intervention strategy was associated with a conceptual change approach where the learners' prior conception were to be abandoned for the dominant school science presuppositions on the nature of both school science and IKS.

While the TEPSI learners seem to have excluded IKS from been accorded the same scientific status, their observation seem to be a concern of the various scholars (e.g., Emeagwali, 2003) who have suggested that IKS should also be exposed to validation processes similar to those of school science. In other words, IKS should be validated using its own internal consistencies so that meaningful interrelationships between IKS and school science can be forged. However, even from the nature of science perspective, laboratories are not used for the validation of school science claims. As Karl Popper (1963) have alluded, even a scientific explanation that cannot be refuted by any means is not scientific at all. In other words, all scientific theories and laws stand upon the proviso that no new counter-knowledge exists. According to McComas, (2014) laboratory experiments should be used to introduce lesson rather than using them to emphasize the known scientific claims.

The opportunities afforded the DAI-Bridge learners exposed them to the nature of school science as well as IKS so that they could know the limitations of both knowledge systems. The DAI-Bridge learners' cognitive shifts are consistent with various findings (e.g., Asterhan & Schwarz, 2007; Diwu & Ogunniyi, 2012; Erduran, 2004; Newton et al., 1999; Ogunniyi, 2006; Simon et al., 2006) which suggest that argumentation enhances the teachers' as well as the learners awareness of the nature of science.

4. With respect to the learners' tendencies towards scientism:

- In conclusion, the findings suggest that, despite the inclusion of IK into the TEPSI learners' lesson, the TEPSI intervention seemed to have led the learners to view school science as a solution for all human problems. On the other hand, the findings for the DAI-Bridge suggests that the DAI-Bridge intervention seemed to have through the inclusion of IK managed to harmonize the hegemony of school science and hence through argumentations enhanced the learners understanding of the limitations of both school science and IKS.

In respect of the above NOSIKS aspects, it is interesting to have noted in the pre-intervention stages that the combined majority of learners had valued IK more than school science and that there was no significant differences between the DAI-Bridge and TEPSI learners. This is in line with the TEPSI learners' excerpts which revealed that the TEPSI learners did not necessarily think that IK or cultural knowledge was not scientific, but rather saw school science associated with the laboratory testing procedures and thus agreed to the assertion that IK was not scientific.

This can be further linked to the notion of scientism which develops through the hegemony of school science and its mechanistic approaches which are defined by the general enquiry approaches of school science. As opposed to the TEPSI group, the DAI-Bridge group seemed to have grasped the complex aspects about the nature of science and IK as a result of the DAI-Bridge context embedded activities (e.g. see Asterhan and Schwarz, 2007 and Newton et al., 1999; Ogunniyi, 2006).

Furthermore, when observing the DAI-Bridge learners' responses, it is observed that the learners' cognitive shifts moved from largely IK-dominant cognitive stances to those which are equipollent, thus the accommodation of both worldviews of school science and IK. These finding thus collaborate studies in the area of integration of multiple worldviews (e.g. Aikenhead & Jegede, 1999; Fakudze, 2004; Ogunniyi, 1988, 2004, 2007a & b; Ogunniyi & Hewson, 2008; Ogunniyi & Ogawa, 2008).

As has also been shown in the learners' responses, the equipollent cognitive stances revealed that sometimes the ideas the learners accommodated co-existed in parallel compartments for use in different contexts. The experiences of the DAI approach resulted in what Scholtz, Braund, Hodges, Koopman & Lubben (2008) have called 'inclusive argumentation' where the learners seemed able to harmonise their IK worldviews with that of school science This is in agreement with Gunstone & White (2000) who argued that when learners are taught science in an appropriate manner which recognises multiple worldviews they may be in a better position to know when one worldview is appropriate over another.

In items where both the TEPSI and the DAI-Bridge learners, performance were significant.

5. Nosiks 1 – Learners' tendencies towards universalism:

- Both learner groups rejected the notion of the universality of science. This may be due to both groups' exposure to IK integrated lessons. In conclusion, both interventions showed to be significantly effective in improving the learners' attitudes towards contextualized science. This may be attributed to the IK integrated science lessons which seemed to have affirmed the learners' IK such that they developed favourable dispositions to IK integrated science.

6. Nosiks 4 - Laboratories as places or means for developing scientific knowledge:

- Initially, both the TEPSI as well as the DAI-Bridge learners were of the view that scientific knowledge is developed in laboratories. After the interventions, both groups' performance scores were observed to have significantly improved, suggesting that the learners did not generally accept the view that laboratories are the only places or processes of the development of scientific knowledge. For both the TEPSI as well as the DAI-Bridge learners presented emergent cognitive stances which suggest that there was a change which may have been influenced by one aspect of the intervention.

7. Nosiks 6 - Science as a method to prove the truth about nature:

- Both the TEPSI as well as the DAI-Bridge learners' showed a significant improvement in terms of their understanding of the scientific method's role; that is, not to prove but to probe. In terms of intervention, it can be assumed that the TEPSI intervention through its inclusion of IKS must have had an influence in terms of highlighting some aspect of nature which the learners may not have attributed to school science. On the other hand, since the DAI-Bridge learners seemed to have embraced both IK and school science they seem to have developed an awareness of the limitations of both worldview while also accepting their scientific nature.

In terms of the above items (Nosiks 1, 4 and 6) where both interventions seemed to have been effective, the inclusion of IK into the learners' lessons may have played a role. For example, Nosiks deals with universalism; Nosiks 4, with laboratories as places of developing scientific knowledge while Nosiks 6 deals with the notion of the scientific method as a mechanism for developing knowledge or 'truths' about nature.

The above three items suggest that, for the TEPSI group to have been against all the three and yet also view IKS as not being scientific may suggest that IKS may be viewed as serving a different purpose for them (e.g., Cobern & loving). Furthermore, the introduction of IK in the learners' science lessons may have also played a strong role against universalism (e.g. see, Le Grange, 2004).

In concluding, the findings from the three items above suggests that, after all, the TEPSI learners were not assimilated to the school science worldview, but that they viewed IKS as serving a different role as compared to school science. All the learners seemed to have shown an awareness that there are many ways of interpreting nature, that not all school science is developed in laboratories and finally, that school knowledge was not a method to gain knowledge about nature. The latter statements thus suggest that, as a result of their own experiences and the formal school science knowledge, the learners had developed a relatively fair awareness of and understanding of the NOS. The above further highlight that it is almost impossible to obliterate the learners views or beliefs about their IK no matter how much hegemonic school science may have been (Hewson, 1988; Hewson & Hewson, 1988, 2003; Posner et al. 1982).

An item where both the TEPSI as well as the DAI-Bridge interventions were not effective

8. Nosiks 7 – The role of experiments in teaching:

- With regard to the role of experiments in the laboratory, both groups seemed to have exhibited poor understanding of the role of experiments in the laboratory. The majority of all learners seemed to suggest that experiments are conducted to prove the truthfulness of scientific theories and laws as opposed to probing them. In conclusion, the cognitive shifts of both the TEPSI as well DAI-Bridge were observed to have moved from IK suppressed to IK suppressed cognitive stances, thus suggesting no effect by either the inclusion of IKS or the TEPSI and DAI-Bridge teaching strategies.

The learners' performances had been very low from their pre-test scores and thus have continued throughout the intervention period. This may be due to the fact that the interventions were not focused on experiments although an experiment on electricity was conducted with the TEPSI group. As has been established for the TEPSI intervention observations, the teacher focused more on demonstrations where the demonstrations were largely to regurgitate or reproduce or confirm what the learners already know than for the learners to learn the scientific processes leading to the scientific claims. As opposed to the latter practice McComas, (2014) has suggest that laboratory experiments should be used to introduce lesson rather than using them to emphasize the known.

The above observations are exacerbated by the fact that many of the schools within which this study was conducted fall with schools labeled as school of poor socio-economic status. These schools do not have sufficient resources or even up and working laboratories where experiments can be part of everyday teaching and learning (Lubben, Sadeck, Scholtz & Braund, 2010). Most of what should occur in experimentation is done cognitively using what is generally called 'cookbook' laboratory activities or those typical of 'dry' laboratory activities (McComas, 2014). As opposed to the 'single' class experience of practical work or experimental work predominant in various schools highlighted above, McComas has suggested that the use of long term laboratory activities can show learners how science works in real life. As Lubben et al. (2010) has argued, if learners may be exposed to laboratory work as their normal school activities, '…the generation of experimental data' may'…refine students' understanding of the validity and reliability of the measurements' (p. 2158).

4.5.1 Summary:

All the findings from the above suggest the following:

1. There is a role played by the introduction of IK into the learners' science lessons.
2. There is a role played by each teaching strategy (e.g., the TEPSI and the DAI-Bridge).

3. The DAI-Bridge intervention was significantly effective in improving the learners' awareness of the ease of IK, its scientific nature irrespective of experimentation procedures and that school science could not solve all problems of the word.
4. The inclusion of IK in the learners' science lessons seemed to have protected the learners from being completely subsumed (assimilated) into the school science worldview.
5. The lack of argumentation in mediating IK seemed to have also played a role in the TEPSI learners not having had the opportunity to be exposed to the nature of IKS and its scientific character. This further seemed to have made the TEPSI learners IK to be suppressed by the dominant school science worldview to the extent of accepting that school science could solve all human problems.
6. The interventions of TEPSI as well as the DAI-Bridge did not have any effect in making the learners to have a better or improved understanding of the purpose of why experiments are conducted in the laboratories.

The following section deals with the learners' reflections on their own perceptions of the kinds of interventions that they were exposed to. The purpose of the sections below is thus to see if any of the above findings are corroborated or refuted.

4.5.2 The learners' experiences as a result of their exposure to the two interventions?

The purpose for this section was to find about the learners' experiences which were as a result of their exposure to envisage IK-integrated school science lessons as well as the associated intervention strategies. To effect the above, two focus groups of learners consisting of the DAI-Bridge and the TEPSI were compiled. Each group contained four learners made up of two learners from each of the four schools.

Three questions were developed for the focus group reflective diaries. These questions focused on the learners' awareness of and understanding of the nature of science and IKS. Each learner had to provide his/her reflection being guided by the following questions:

1. Having been involved in this programme, how important was your teacher's beliefs in influencing your attitude and beliefs about science and nature in general?

2. What are your views about science and traditional/cultural knowledge – Have you views changed and if so, do you think science and traditional knowledge are the same or different and why?
3. Did your teacher include any traditional knowledge in your science lessons and if so, did you like the teaching strategy that was used to teach the lessons?

In order to allow time for reflection, the six learners within each intervention group were pre-selected on the basis of their group leadership roles within the DAI-Bridge group as well as their interaction and vocal abilities within the TEPSI group. This selection was therefore useful in creating spontaneity in the focus group as well as the provision of broader perspectives that are a close approximation of the whole class perspectives on the questions under study.

4.6 The learners' reflective experiences in the IK integrated lessons

The purpose for this section was to find about the learners' experiences or cognitive stances n response to their exposure to the IK integrated science and associated teaching strategies. To effect the above, two focus groups of learners consisting of the DAI and the TEI were compiled. Each group contained four learners made up of two learners from each of the four schools.

Three questions were developed for the focus group reflective diaries. These questions focused on the learners' awareness of and understanding of the nature of science and IKS. Each learner had to provide his/her reflection being guided by the following questions:

4. Having been involved in this programme, how important was your teacher's beliefs in influencing your attitude and beliefs about science and nature in general?
5. What are your views about science and traditional/cultural knowledge – Have you views changed and if so, do you think science and traditional knowledge are the same or different and why?
6. Did your teacher include any traditional knowledge in your science lessons and if so, did you like the teaching strategy that was used to teach the lessons?

In order to allow time for reflection, the six learners within each intervention group were pre-selected on the basis of their group leadership roles within the DAI group as well as their interaction and vocal abilities within the TEI group. This selection was therefore useful in creating spontaneity in the focus group as well as the provision of broader perspectives that are a close approximation of the whole class perspectives on the questions under study.

4.5.1 Reflection question 1

In sourcing for the learners' responses, the learners were organized into a group and each question was read out by the researcher and explained in isiXhosa and the learners allowed to answer each question by writing down his/her views. The following boxes presents excerpts from the TEI as well as the DAI group.

Box 4.10: The TEI and DAI learners' focus group reflection responses on question 1

Question 1: Having been involved in this programme, how important was your teacher's beliefs in influencing your attitude and beliefs about science and nature in general?

THE TEI LEARNERS' RESPONSE

Learner 78 : In science I work very hard because all my teachers taught us to believe that science is is a very hard subject.

Learner 47: I believe in many things that my teacher tells us because he is the one who know about science and gives us the knowledge so that we can pass science.

Learner 5: Sometimes when my teacher teaches us he uses examples of nature or the things that he knows that we know so that we can understand

Learner 72: I don't believe in everything that my teacher believes in. The teacher is sometimes confused and I also get confused and lost interest in the lessons.

Learner 37: Most of the things I know today about science I heard from my teacher so I believe in science because of him.

Learner 88: I now believe that science is everything because my teacher taught me that everything on earth is dependent on science. Even the food we eat and the clothes we wear are made from science.

THE DAI LEARNERS' RESPONSE

Learner 84 : When we were debating in our lessons, our teacher gave us examples that were more about nature and his views make sense so I believe science is about our daily lives.

Learner 2: My teacher loves science and he teaches very well and that's the reason I love science.

Learner 36: Nature is about our daily lives so if my teacher does not respect our culture then it will be difficult for me to believe in what he teaches us, because I am what I am because of my culture.

Learner 9: Because of my science teacher there were many things that I didn't know but now I know, like the reflections, pressure and volume.

Learner 80: Because my teacher makes me see that whatever I do at home is made up of science so I that makes me believe in science at school.

Learner 53: If the teacher has a positive belief about nature I will also have a positive attitude about science.

In the above excerpts in respect of the TEI and DAI group learners, almost all the learners agreed that their attitudes about science are largely influenced by their teachers. It is only in respect of Learner 72 who argued that he does not believe in everything that his teacher tells him as he is of the view that his teacher is sometimes confused and that resulting in him also losing interest in lessons. This suggests that either way, it does not matter what teaching strategies may be employed, teachers will have a great influence in whether learners get to like or hate science.

4.5.2 Reflection question 2

The next question the learners had to express their views was about the status of traditional or cultural knowledge and school science after they had been exposed to the two intervention strategies. Box 4.11 presents the TEPSI and DAI-Bridge learners' views on the question.

Box 4.11: The TEI and DAI learners' focus group reflection responses on question 2

Question 2: What are your views about science and traditional/cultural knowledge – Have you views changed and if so, do you think science and traditional knowledge are the same or different and why?

THE TEPSI LEARNERS' RESPONSE

Learner 78 : I believe that a child or human was made by God but scientifically a foetus was made by a sperm cell and an egg cell. This makes me believe that they are different.

Learner 47: In my culture we use traditional medicine we don't believe in science.

Learner 5: It doesn't tell us about God creating us, as a Christian it is not the only true knowledge

Learner 72: Here at school I leant about how I must behave to other people and also taught that at home so I think they are the same.

Learner 37: The evolution of humans from apes is against the creation of God so I think science is against the bible and so science and traditional knowledge is different.
Learner 88: Culture and science doesn't link, culture is all about who you are. Culture you can see it everywhere you go but school science I can learn it only if I read about it

THE DAI-Bridge LEARNERS' RESPONSE

Learner 84: Because most of the time I learn something in science that I always know or I have heard before from my culture like, for example, how we can make soap from fats and blue soda.
Learner 2: Because the things I learn from science is the things that I do in my everyday life. At home we use handy Andy for dissolving black carbon which is an acid.
Learner 36: Many things I can get from science thro culture.
Learner 9: Traditional knowledge can help me understand science and also help in my culture such when we clean water with Ikalika (this is a white wash powder made from calcium carbonate or limestone).
Learner 80: Many things in science are things that happen every day at my village.
Learner 53: Some of the things we do in my culture are not the same with science, we slaughter and make amasiko (customary rituals) to get things right. Science works with chemicals from the laboratory.

In determining whether the learners' views about the notion of traditional knowledge and science it is noted that most of the TEI learners do not regard IK as being the same or being of equal status with school science. Learners 78, 5 and 37 from the TEI group associated IK with religion and that science was somehow in opposition to religion. Similarly, Learner 47 and 88 also felt that science and culture do not link together.

With respect to the DAI group, Learners 82, 2 and 80 are of the view that there is no difference between traditional knowledge and science. On the other hand, Learners 36 and 9 are of the view that traditional knowledge can help in understanding school science.

4.5.3 Reflection question 3

In the excerpts below learners were requested to state whether traditional knowledge was part of their science teaching or not and to also state where applicable whether they enjoyed the way the lessons were taught.

Box 4.12: The TEI and DAI learners' focus group reflection responses on question 3
Question 3: Did your teacher include any traditional knowledge in your science lessons and if so, did you like the teaching strategy that was used to teach the lessons? **THE TEI LEARNERS' RESPONSE** Learner 78 : Yes she did, but I was confused because I don't know how it going to be tested. Learner 47: At the beginning I did not know what was going on but understood. I can say I was happy to see that the things we do at home in my culture can also be in science. Learner 5: We enjoyed the lessons because we debated a lot, but we did not have enough time because other learners did not want to give others a chance to speak. Learner 72: Our teacher gave us examples of traditional things to discuss and see if they scientific or not scientific. We liked the exercises, but the teacher did not want to accept our answers as she said that some of that are not scientific. This discouraged some of the learners. Learner 37: At first I did not think that that it was possible to mix science and knowledge from my culture, but I enjoyed the lessons because they showed that there is science in my culture as well. Learner 88: I did not enjoy some of the lessons where we were discussing about culture and science because some of the things were not scientific, I did not see how they can link with science. **THE DAI LEARNERS' RESPONSE** Learner 84: We don't usually see the things we learn in the class so if our teacher can teach us the same way all the time and bring in our culture into the lessons, I think we can understand science better than before. Learner 2: I enjoyed the group work and debates about IK and science because I learned that black people do also know a lot of science. Learner 36: I liked the example of force using how oxen can pull isileyi (sleigh). I did not know that making isileyi (sleigh) like a triangle will reduce friction. Learner 9: The teacher used an example we know of water flowing out of a pipe to teach us about flow of electricity in a wire. I think if we can get more examples like that one it can help us to understand physical science better. Learner 80: We enjoyed the lessons too much but the time was always short and sometimes ended up disagreeing with each other in our groups. I also like the examples from our culture because it makes

us to be also proud of our culture.

Learner 53: Yes, he did, but some of the traditional knowledge I did not believe that they were the same as science.

Interrogation of the learners' reflection in box 4.12 above suggest three themes in respect of the reflection question 3. The first theme concerns the learners' like or dislike of the inclusion of IK in the lessons, the second theme alludes to the effect of the intervention and the last, on perceived challenges of attempts to include IK in the lessons. The majority of the TEI learners as well as the DAI learners have confirmed being exposed to IK integrated lessons and have all claimed that they all enjoyed the lessons.

The differences among the two groups were that the DAI group had only praise for the IK integrated lessons while the TEI group cite some challenges in terms of how lessons proceeded. They cited systemic issues relating to the teaching strategies in mediating two incompatible worldview such classroom management and lack of clarity in terms of how each worldview relate to the other.

4.6 Preliminary findings

Reflection question 1: "Having been involved in this programme, how important was your teacher's beliefs in influencing your attitude and beliefs about science and nature in general?", observations seem to suggest that:

- The majority of learners, irrespective of what intervention strategy was used, believe that their teachers' beliefs about natural phenomena has had a great influence on their attitudes towards science.

The above finding seem to be corroborated by similar findings of studies conducted by Ogunniyi et al. (1995) across various continents which stated that the learners' beliefs and attitudes about phenomena is to a large extent determined by their teachers' beliefs of what they view as valid scientific explanations. Similar findings to the above are those by Anderson (2007) who quotes Moje et al. as asserting that:

> …The discourses of classroom instruction are informed by what teachers and

students believe about the nature of knowledge in the discipline…Similarly, the ways that students take up classroom or disciplinary discourses are shaped by the social or everyday discourses they bring to the classroom (p. 15).

Reflection question 2: "What are your views about science and traditional/cultural knowledge – Have you views changed and if so, do you think science and traditional knowledge are the same or different and why?, observations seem to suggest that:

- For the TEI learners, IKS and science do not seem to hold the same scientific status as school science. IKS is somehow largely related to religion which the majority of the learners viewed as being opposite to school science. These learners thus exhibit a divergent cognitive stance where science and IK are pulling in different directions.
- As opposed to the TEI learners, the DAI learners seem suggest that both school science and IK are equally valid scientific knowledge and that IK can help in developing a more robust understanding of school science. These learners therefore exhibit a school science emergent cognitive stance.

As alluded by the TEI learners, science and IK may on the surface appear to be different because of their distinct worldview presuppositions (Ogunniyi, 2007a), but if the two worldviews were given opportunity to 'talk' together, a different conclusion may have been reached (Fleer, 1999). As various scholars have pointed, failure by any teaching and learning strategy "…to emphasise and foreground the distinctive hallmark of science is ultimately self-defeating leaving students with beliefs they are unable to justify to others (Erduran, 2006, p. 14).

Reflection question 3: "Did your teacher include any traditional knowledge in your science lessons and if so, did you like the teaching strategy that was used to teach the lessons?" In this regard, findings suggest that:

- The TEI seemed to have enjoyed the inclusion of IK into their science lessons, but seemed to have been disillusioned by the teachers' lack of IK-science mediation strategies. Some of them however had some concerns such as not knowing how IK will be tested (learner 78), not having enough time for discussions (Learner 47) and not knowing how the two link together.

- The DAI learners suggested that the use argumentation in teaching about IKS: 1. Made learning science much easier, 2. Made learners proud about their culture and the realization that their culture can also contribute to scientific knowledge.

While the TEI learners seemed to have enjoyed lessons with IK integrated lessons, the disillusionment by the learners may have been as a result of lack of mediation strategies for the integration of IKS in school science. As some of the TEI learners have alluded, Harlen & Holroyd, 1997; Papanastasiou & Papanastasiou, 2004) have attributed learners' attitudes towards school science as a result of the teachers' own lack in the subject matter. Furthermore, as evidenced by the challenges cited by some learners, it is however important that learners do not just learn to argue constructively without any groundwork being laid by the teacher (Simonneaux, 2001). In terms of some benefits that the DAI learners cited in relation to their IK-science mediation experiences, Scholtz, Braund, Hodges, Koopman & Lubben (2008) have suggested that the inclusion of argumentation in the curriculum may serve four purposes: 1. Interrogation of public claims and the strength of the associated evidence; 2. As a learning method utilizing group discussions and interactions; 3. As a means of highlighting the tentative nature of scientific enquiry; and 4. as means of enculturation into scientific discourse.

4.7 Summary:

Findings from reflection questions 2 and 3 corroborates findings in the previous sections in terms of the following:

1. The finding for reflection question 2 for the TEI learners corroborates findings in the previous section for Nosiks 1, 3, 4, 6 and 8 where the TEI learners were viewed to have adopted a dichotomous approach for IKS and school science. In other words, the TEI learners did not accord IKS a scientific status as they seem to have viewed IKS from a religious point of view as seen in the excerpts for reflection question 2. In terms of the learners' cognitive stance, parallel equipollent cognitive stances were observed which suggests that IKS and school science was divergent or incompatible. The latter is also supported by DAI comments in reflection question 2 above. The DAI cognitive stances seemed to have been convergent equipollent stances which suggests a compatibility between IKS and school science as a result of argumentation.

2. The findings about the DAI in reflection question 3 also corroborates the findings in the previous section, that IK was easily understandable and it showed that there is science embedded in IKS (Corsiglia & Snively, 2001; DoE, 200).
3. The findings about the TEI intervention in reflection question 3 above seem to corroborate findings on their rejections of universalism (Nosiks 1), laboratories as places or means of developing scientific knowledge (Nosiks 4) as well as the scientific method as a way of proving the 'truths' about nature (Nosiks 6).

-------------From here to the middle of p.178 should be in chapter 3---------------------

4.8 EFFECTS OF THE TEPSI AND DAI-BRIDGE INTERVENTIONS

The purpose of this section is to describe the conditions and the nature of the interventions that took place at the four intervention schools. The interventions took place in the first and second school terms of 2014 and the last set of data was collected in 2015. As per the Curriculum and Assessment Policy Statement (CAPS) document (DoBE, 2011) and other subject guideline documents, the first and second terms of the school calendar in South Africa is largely dedicated to the first paper of the year-end examinations. Although the first and second terms are dedicated for the Physics first paper, most introduce the Chemistry second paper towards the middle of the second term. In this regard, some topics in Mechanics, Waves, Electricity and Magnetism as well as some Chemistry were covered in some of the interventions. However, for this report three topics (Light, sound and electricity) which serves as themes for phenomena under are discussed.

4.8.1 The nature of the classroom interventions

Table 4.9 below represents an IK-based classroom observation schedule rubric with column 1 listing the criteria used with columns 2, 3 and 4 repressing the domains interrogated. In the corresponding cells, specific questions are asked and the answers are inserted in the same cells, hence the research or any research participant was provided with the above observation schedule as a rubric and a blank so as to be able to fill the cells with the relevant observational inputs. Prior to the use of the above observation schedule, the three teachers were made to be part of a workshop which was presented to a group of teachers and some curriculum advisers on how to develop socially and culturally relevant teaching and learning materials.

Table 4.9: An IK-base participatory observation schedule rubric

Intervention group: _______Lesson:_________________________Date: ______________

Criteria	**Educator roles**	**Learner roles**	**L.T.S.M**
Introduction and Lesson focus	• How does the teacher introduce the topic – thematic or topic? And focus	• Are the learners active or passive participants?	• What artifacts are used or teaching & Learning support materials are there?
Social/cultural relevance	• What worldview is dominant in the teaching.	• What worldview is prevalent in the learners' arguments	• Are the materials socially & culturally relevant?
Teaching and Learning strategies	• Are they teacher or learner-centered? • Are they discursive and argumentative?	• Are they enablers or disablers of learners' argumentation abilities	• Are the L.T.S.M in line with the teaching strategies used?
Language effects	• How did the teacher manage the language barrier issue.	• How did the language barrier issue affect the learners?	• Was there any evidence of language interventions on the teaching materials?
Time & classroom management.	• Teacher time management and classroom control	• Classroom discipline • Are learners sticking to activity time frames.	• Is there and effective balance between the use of materials in the given time?
Are lessons keeping up with pace-setters?	• Teacher effectiveness in execution of lessons.	• Are all learners keeping up with lesson?	• Are materials in line with pace-setter requirements?
Critical comments & reflections	• Key issues of the efficacy and comfort of teacher	• Reflection on learners and teacher interactions.	• Types of L.T.S.M that were used
Suggestions for further lessons	• How teachers can improve their teaching and reflexivity.	• Learner needs and inclusivity.	• Types of L.T.S.M that are relevant for IK-based lessons.

One of the three teachers volunteered to be mentored in the DAI teaching approach, while the other two volunteered to try the new IK-integrated science approach using their own teaching and learning strategies. The contents of the teacher workshops is outlined and detailed in appendix C.

Since there were a number of lessons conducted by the TEPSI teachers as well as the DAI-Bridge teacher, for the sake of duplication and time-space constraints, only one lesson from each intervention strategy will be presented and discussed. These lessons are just meant to give glimpse of the nature of the typical lessons characteristic of the two interventions. In order to provide fair and representative lessons, the teachers were given time to prime the learners and to prepare thoroughly and finally to choose which lesson they would want to observed. This was done in line with the current practice for the Whole School Evaluations (WSE) programmes such as the Qualitative Management System (QMS) which is used for the determination of teacher performances and motivation for their annual salary increases. In line with the above, the researcher observed all teachers once in the first as well as in the second term where they taught lessons in mechanics and then electricity in the second term.

4.8.2 Topics covered

As has been highlighting, the topics done under mechanics were force, impulse, momentum, work, energy and power. Since some concepts in mechanics such as force, work, energy and power are common for electricity a concept map that relates the various concepts were discussed with the two TEPSI teachers as well as the one DAI-Bridge teacher. Prior to observations, the teachers as well as learners were asked for their permission to come and observe classroom teaching. This was done by asking them to complete consent forms which were explained to them. For copies of the consent forms see Appendix D.

4.8.3 Teacher responsibilities as per the curriculum

In terms of the teachers' daily duties, the teachers are charged with the responsibility of curriculum delivery in conjunction with the stipulations set out in the Physical Science curriculum documents such as the CAPS, the year planner and subject guidelines. In terms of the terms of the educators' administrative duties, each educator must compile and keep an educator profiles which contains his/her lesson plans for each terms, learners' performance records. In addition they must also keep records of the learners' work portfolios.

Furthermore, each teacher is usually charged with the responsibility of being a class teacher where she or he has to compile progress and end of the year reports which are to inform the learners' parents about the learners' performances and conduct at school. Teachers are further tasked with the responsibility of identifying struggling and slow learners and to put in place appropriate intervention programmes for such learners and to keep such records as proof of interventions taken prior to mid and end of year examinations.

When all the teachers' educator profiles were perused, they were highly organized and showed a number of lesson plans which were planned for the two terms up to the June mid-year examinations.

4.8.4 Classroom organizations

In all the four schools, teachers had specific classrooms that they could claim as their own. In this regard, some teacher could decorate or design their wall print environment. However, because of a lack of classrooms for some teachers such as the H.O.Ds etc, teachers usually rotate and have to go to the classrooms where the specific grade and classroom is located. This is made possible by the free periods where some teachers are not having a teaching periods and thus allowing other teachers to use the classrooms.

This has led to the time required for leaners to settle down to increase when there are period changes, because teachers have to in the first instance walk to the specific classroom and secondly sometimes find the previous teacher still concluding his/her lesson and finally have to make his/her own classroom rearrangements to suit his/her lesson arrangement. The predominant classroom arrangement were that of a lecture room style as well as that of learners arranging themselves in groups of four to five depending on the class size. The learners in the TEI group were generally arranged in a traditional lecture method although they were sometimes also arranged in groups depending on the tasks to be performed. On the other hand, the DAI group learners were always put in small groups of three, four or five as the class size dictated.

4.8.5 Classroom interventions for the traditional expository pace-setter instruction group

As has been stated, Schools C and D represented the group which was taught using TEPSI intervention strategy. Two volunteer teachers taught the two classes the same content as per the pace setters using their traditional expository styles. In order to make comparisons of their teaching strategies with the DAI-Bridge strategy, the researcher did a number of visits into their classes to observe how and what they taught in their science classrooms.

On a general note, there was common thread running across all the TEPSI group lessons. The lesson which is discussed in the following section is a typical lesson characteristic of normal school science lessons which are either ‘chalk and talk’, demonstrations, group work or a combination of one or two of the teaching styles. However, the case may be, teachers were consistently at the centre of the teaching and learning process as opposed to learners being at the centre of the teaching and learning process. In other words, the manner in which lessons were facilitated by the teachers seemed to influence learners to depend on teachers as sources of knowledge. This point will be deliberated further at the discussions section for the following lesson.

4.8.6 Lesson observation for TEPSI Teacher C

The lesson which teacher C chose for observation was on electricity and the concept of flow of current. The teacher had in previous lessons introduced electrostatics where electrical charge is said to be stationary and hence no electricity. An electrical circuit apparatus was brought into the classroom. It consisted of three battery cells and holder, electrical conducting wires leading to a parallel circuit with a switch and an ammeter before the parallel circuit. The parallel circuit had a light bulb in each parallel circuit stream. The apparatus could also be set up for a series circuit where the light bulbs are connected one after another so that the electricity has to flow through all the light bulbs or if one light bulb in front of other dies (fuses) then no current can flow to the other bulbs.

The main objectives of the lesson as highlighted in the teacher’s lesson plans was to show learners that electrical charge will:

7. Flow in a conductor.
8. Needs a source of electromotive force such as a battery.
9. When current meets a junction such as in a parallel circuit, the current will split proportionally across the parallel streams and add up again after the parallel streams. In this construction, resistors (light bulbs) are current dividers and the voltage remains the same.

10. When current meets a straight line series circuit, the current will remain the same across all three resistor (light bulbs) but the voltage will be divided across each resistor.
11. Finally, the main aim of the switch is to show that current or electrical charge will not flow from the battery to the remainder of the electrical circuit if the switch is off (open).
12. The second part of the experiment was to include a rheostat which is in fact a variable resistor of known resistance. This is to demonstrate Ohm's Law which in simple words describes the relationship between the voltage and the current in an electrical circuit.

Table 4.10 below presents a summary of key elements deriving from the classroom observations of the above lesson. These observations are followed by discussions and general implications relating to nature of traditional expository instructions, their advantages and disadvantages.

When interrogating the teaching and learning strategies, the teacher used demonstrations and probing questions for learners to try and predicting what would happen when certain independent variables are changed. This was done well with the appropriate equipment which enabled the process of enquiry and discovery. However, there was no immediate evidence of whether all the learners were understanding as some learners would not naturally put up questions for fear of showing signs of being less intelligent.

As in most other lessons, the teacher relied on a later form of assessment such as class work and question time at the end of the lesson. This approach is not very effective because many learners at that time would have forgotten a whole lot of stuff and would usually say they don't understand. When the teacher asks the learners or a particular learner to indicate exactly what he or she did not understand, the learners would normally say everything or decide to say they understand. With regard to the first criteria about the focus of the lesson, there was smooth introduction of the lesson in the roles of the teacher and his learners as well as appropriateness of the teaching and learning materials.

In terms of social or cultural relevance, the lesson focused on the practical side of electricity and hence the demonstration with experimental apparatus was appropriate even though they were entrenched on traditional school science equipment and hence socially, but not necessarily culture relevant. In this regard, there are various culturally relevant analogies of river flows into separate streams which could be illustrated using water as charge, water flow as current etc.

Table 4.10: Observation schedule for Teacher C in the TEPSI cohort

Intervention group: **Teacher C**	Lesson: **Electrical current**	Date: **May 2015**	
Criteria	**Teacher's role**	**Learners' roles**	**Learning and teaching support materials**
Lesson focus: **The concept of flow of electricity**	• Provision of demonstration apparatus for the lesson.	• Learners were asked to state the purposes of each element in the apparatus	• Electrical circuit apparatus, circuit diagrams on the board, pencils and papers.
Social/cultural relevance	• Lesson on the practical application of electricity	• Learners had to hypothesis, predict and make calculations	• The materials were school science based but applicable to learners' everyday lives.
Teaching and Learning strategies	• Teacher used demonstrations and probing questions.	• A learner had to answer a a question on behalf of whole class and learners had some opportunity to debate some issues.	• Materials were useful for demonstrations in terms of the lesson focus and objectives.
Language effects	• The teacher used isiXhosa interchangeably with English, but with transliterations.	• Learners were seen to sometimes struggle and the teacher would scaffold by speaking in isiXhosa	• All the materials and worksheets were in English and hence assessment was in English.
Time & classroom management.	• More time was spent on demonstrations and less time for learners to practice.	• Since only one learner responded at a time, more time was required for all learners to participate, but class was well managed	• There was good classroom management as the focus was on the demonstrations and time was well managed.

In terms of language effect, there was evidence of some learners struggling with the English terminology concepts. This was supported by the teacher frequently using English and isiXhosa interchangeably in an unstructured manner. The lesson plan by the teacher also did not show evidence of predicting the possible language barriers and thus the preparation of corresponding electrical concepts in isiXhosa.

The implications for not planning possible language barrier interventions within the lesson plans is that teachers would find them doing unstructured code switching with foreign and unscientific isiXhosa terms which are by-products of transliteration practices (Dlodlo, 1999; Diwu, 2010). Furthermore, the assessment was in English and not isiXhosa. The implications for this again is that learners who are taught some concepts in isiXhosa usually fail to express themselves in English when the time for the English-based assessment comes.

With regard to time and classroom management, the teacher was able to control class noise and attention as he was at the centre of their attention as the demonstrator. As he had planned the lesson well ahead, he was able to stick to time for each specific activity for demonstration. The challenge however has been highlighted in the above paragraphs, it that learners did not have the larger part for themselves to explore the possible answers where the teacher could have set up the scenario and allowed each learner to spend time predicting the possible solution and again allowing learners in groups to discuss among themselves within specific time frames. In other words, demonstrations or even experimentation by learners should be preceded by enough time with learners hypothesizing, predicting and arguing possible solutions and outcomes. Experimental demonstrations should as such be at the end of a particular lesson or rather lag exploration by learners at each defined stage of enquiry.

4.3.3 Classroom interventions for the DAI group

As a mentor for the DAI teacher 2, we collaborated on developing a lesson that would be socially and culturally relevant. In addition, the lesson was designed to use a thematic approach which would cut across two or more Physical Science topics. In this regard, the concept of light was chosen.

The DAI lessons followed the following sequence:

6. A social and culturally relevant concept map incorporating all the characteristics of a thematic approach with cross-cutting concepts.
7. Individual tasks (intra-argumentation) based on the case study with questions which exhibit multiple perspectives on the phenomena under discussion.
8. Small group tasks (inter-argumentation) where learners share their individual task answers and get opportunity to defend their own views and to convince each other of possible viable solutions to the problem statements.

9. Small group presentations to other groups within the classroom leading to whole class argumentation.
10. Lesson consolidation by teacher through a process called IK-to-school science contextualization; a process where an attempt is made to make border crossing from an IK worldview to the school science worldview relatively 'smooth'.

4.3.4 The DAI-Bridge lesson observations

A typical lesson plan for the DAI-Bridge lessons is as follows. The lesson was developed to take at least three periods to introduce the concepts relating to light as a phenomenon. These introductory sessions were then followed by going into specific topics such as refraction and electromagnetic radiation. Further assessments leading to formal assessment were also conducted along the way. The lesson plan is augmented by a concept map which is used to create nodal points for activating the learners' commonsensical knowledges as well as a stimulation.

Lesson 1: Lesson focus on the refraction of light

Spend a few minutes and look at Figure 4.1 below and try to develop a map in your mind by trying to find a relationship between the sun and all other elements shown. Having done that, answer the questions below; first individually and then discuss you choice of answers in your respective groups.

Give your answer(s) as your **CLAIM** and then also provide reasons as **EVIDENCE** to support your claim. At the end of each answer please circle the source of your knowledge claims. State them as either: Personal Experience = PE, Traditional knowledge = TK or School Knowledge = SK. Note: Traditional knowledge was deemed preferable as learners were more acquainted with the term, traditional knowledge as opposed to indigenous knowledge. You have 10 minutes for answering the questions individually and another 20 minutes to discuss them in your groups. At the end of 20 minute discussions each group will be given 10 minutes to present and discuss their answers to the whole class.

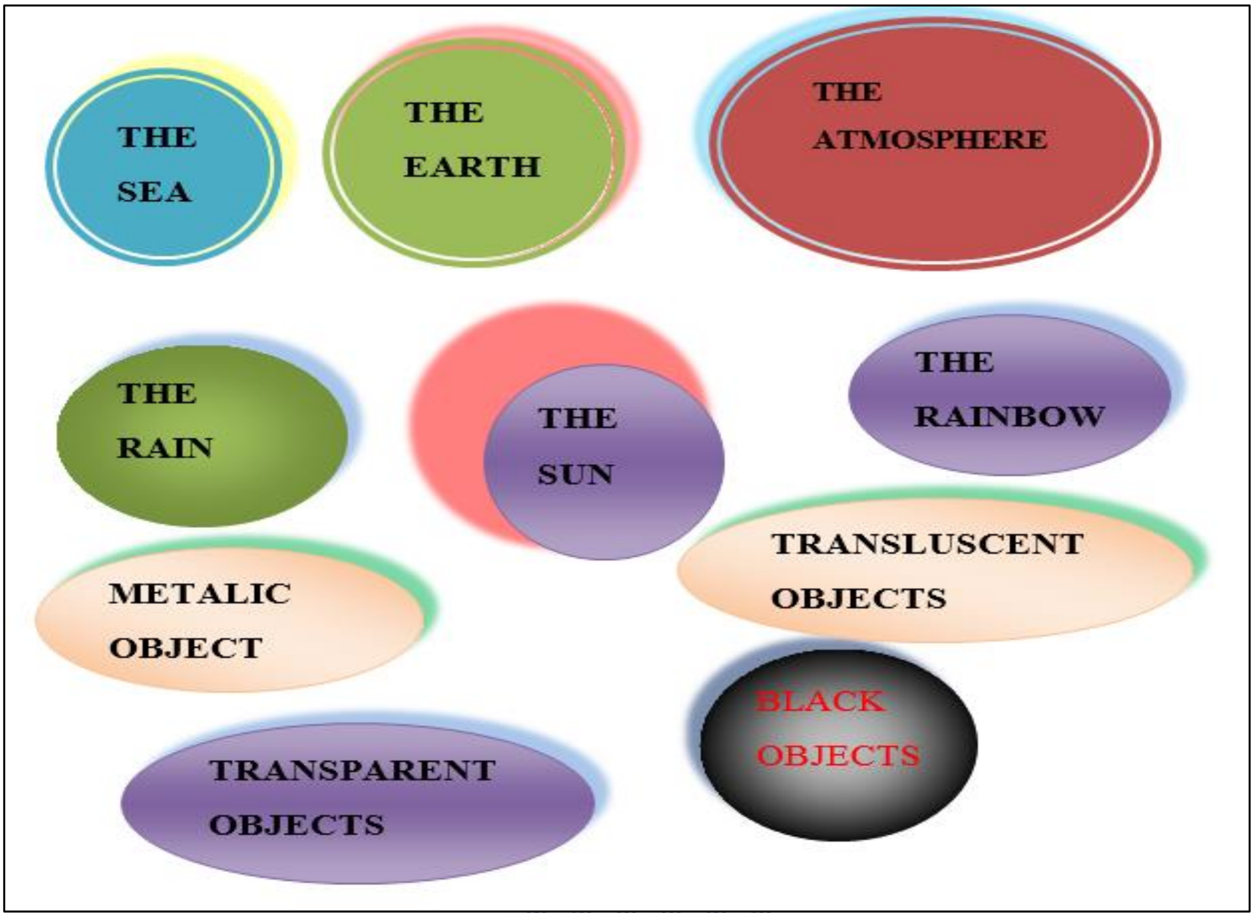

Fig 4.1: The sun and the associated earthly elements

However, since there a big number of learners, the individual task responses (for intra-argumentation) for those learners who belonged to a particular discussion group are put together and their resolution or consensus is presented in a table to save time and space. In this regard, a few excerpts of group responses and questions discussed are presented below:

TABLE 4.11: G.4 / Q.1 - Is the sun, water and air related to each other in any way whatsoever?

INDIV	CLAIM	REASONS (EVIDENCE)
L.29	Yes, the heat of the sun is what is common in them. They are not man-made (PE).	The heat of the sun warms the air and as the air warms it heats the sea water too. The see water evaporates and creates rain (SK).
L.15	They are related because they form raining (PE).	Because when the sun heat the water they form water vapour and that water vapour form clouds and clouds form rain (SK)
L.18	They all work for people	Air helps people breath, water is good for thirst. The sun can help

	and animals or they are all supportive to human beings/living beings	people see or light their way (PE).
Consensus	All support humans and animals and environment (SK).	Sun provides heat, air – oxygen, and water cooling and growth (SK).
Key: G = A group number, Q = a question number, L = a learner number,		

Observations below show learners' claims and reasons in support of their claims for each particular question stated. The provision of claims and supported with reasons is in line with the TAP. Furthermore, it should be noted that learners also indicated their sources of knowledge so that their worldview presuppositions could be identified.

As indicated by L.29, 15 and 18, have associated the sun, air and water as necessary for human survival. L.29 and L.15 related the three to the water cycle while L.18 broke each element down to what it does as a unit. For instance, she identified air as providing oxygen for breathing, water for quenching thirst and the sun as for the provision of light for vision. The discussions came to a consensus where the learners came to a conclusion that the sun, air and water are good for human survival. As one could see from the consensus, the learners cited school science and focussed on the individual attributes of the elements rather than a holistic relationship between them.

From the context of introducing the concept of light refraction by providing some of the necessary ingredients in the concept map, it is observed that the main thinking from the learners' perspectives is along the water cycle and the creation of rain using the sun. This was a nodal point to introduce the concept of the formation of the rainbow which is a phenomenon that can be explained by light refraction. In this regard, the next question asked the learners to explain where they thought the rainbow came from and how it was created. In this regard, the following excerpts from group 7 is presented below.

TABLE 4.12: G.7 / Q.2 - Where does the rainbow come from and how is it created?

INDIV	CLAIM	REASONS (EVIDENCE)
L.21	From God and rain (TK).	Because God judges his people because of sin and he decided to stop killing and created the rainbow after the flood of Noah (TK).

L.24	Rainbow comes from the refraction of water droplets and the sunrays then seven colours appears (SK).	In my cultural knowledge they believe that it's a sign that the rain has stopped (TK)
L.22	From the atmosphere (SK).	Because I can see it with my own eyes and at school we are taught about it and it comes after the rain has stopped (SK).
L.25	The rainbow comes from the rain when it falls down (TK).	It comes from the cultural knowledge because the believe is that the rain can make the seven colours called rainbow (TK).
Consensus	It is formed by the refraction of light on the water droplets in the clouds. (SK).	Because the rainbow comes after rain and sunshine and that the light is refracted through the water in the sky (SK).
Additional	God is the cause of all this (TK).	The bibles tells of Noah's story and the rainbow (TK).

Key: G = A group number, Q = a question number, L = a learner number,

Learners 21 and 25 have both derived the source of the rainbow from rain. Learner 21 cited that God caused rain to fall in the days of Noah and hence also created the seven colours of the rainbow when He stopped the rain. For learner 25, rain can cause the seven colours which he calls the rainbow. For both these learners, traditional knowledge has been the source of their knowledge.

Learner 22 however, has cited the source of the rainbow as coming out of the atmosphere. While also admitting personal experience, she states that she is taught at school that it comes after the rain has fallen. However, Learner 24 declares that the rainbow is as a result of the refraction of light, but however he also believes that the rainbow is a sign that the rain has stopped. This learner thus exhibits dual worldview presupposition; that of school science and that of IKS.

After much discussions, the learners came to a conclusion that light is refracted on water droplets in the atmosphere and hence the various colours of the rainbow are created. However, the learners also concluded that God is the main cause and they cited that the bible states so. This suggests that the learners somehow hold dual worldview presuppositions which is supported by Ogunniyi's (1988) harmonious dualism. Their conclusive responses also highlight that the learners know which context was appropriate for their report back, i.e., school science.

This is also supported by Gunstone & White (2000) who had argued that, rather that trying to change learners' preconceptions, learners should be equipped with the skills of knowing which context is appropriate and applicable for a particular situation.

Now that the learners have identified the two worldview explanations of the sources and the formation of the rainbow, the teacher was able to help the learners to have a fresh perspective on the roles of the sun (light), the rain (water) and air in the formation of a rainbow and thus the concept of refraction.

Lesson 2: Lesson focus is was on the notion of visible and invisible light

The following lesson sought to interrogate the notion of vision and infra-vision. In this regard, two questions were posed for the learners and each one is presented in each of the following tables.

TABLE 4.13: G.2 / Q.3 - In your understanding what things enable people to see objects around them?

INDIV	CLAIM	REASONS (EVIDENCE)
L.16	It is the light (PE).	Without light there would be darkness and you would not be able to see a thing (PE).
L.26	The eyes of a person, microscope, spectacles and light (SK).	It is because a microscope can help a person see what a naked eye cannot see like cells (SK).
L.22	Our eyes, nose can help see and ears can make us see (PE).	When you smell something you can imagine it in your mind. Hearing can let you think and thinking can make you imagine (PE).
Consensus	The eyes and light	L.1 & L.2 argued that light and eyes are essential for seeing an object and that the microscope is a special aid to sight.
Key: G = A group number, Q = a question number, L = a learner number,		

In summation, the three learners above cited light and the eyes as something that enables people to be able to see objects around them. Learner 16 forcefully argued that without light, people cannot see while Learner 26 also argued that eyes are equally essential in the process of sight as without them, light was useless. While the use of microscopes were acknowledged as visual aids, the learners opted for eyes and light as two apparatus that enable vision.

Having established the role of eyes as well as light in the process of vision, the teacher then ventured into the mechanisms of how light reflection and absorption resulted in the perception of different colours within the visible electromagnetic spectrum. Prior to the introduction of the invisible spectrum the following question was interrogated.

TABLE 4.14: G.3 / Q.4 - Why do you think some nocturnal animals are able to see in the dark while there is no light?

INDIV	CLAIM	REASONS (EVIDENCE)
L.9	Their iris is not the same as ours (SK).	Our people's iris are black and animals are somehow reddish (PE).
L.12	They are created to see in the dark (TK).	They stay outside all the time, so that's why they are able to see in the dark (TK).
L.17	Nocturnal animals have bright eyes (TK).	They have animal characteristics (TK).
L.31	Animal eyes are transparent so all the light can enter (SK).	Animal eyes glow at night for them to see (TK).
Consensus	The iris of animals allow more light in	Animals have bright eyes
Key: G = A group number, Q = a question number, L = a learner number,		

Since the majoring of the learners in the previous question had come to a conclusion that light was key in the process of vision, the focus of the four learners was on eyes. They all somehow decided that there must be something that enables the nocturnal animals to see in the darkness when there is no visible light. Learner 9 thought that the iris from animals must have something to do with their ability to see in the darkness as he argued that the animal iris are red while that of humans are black.

On the other hand, Learner 12 concluded that adaptation could be the explanation as she argued that since animals stay in the darkness most of the time, they must then been created for that environment. Learner 17 and 31 have respectively pointed out that nocturnal animals have bright eyes and transparent eyes. Similar to Learner 12, Learner 17 gave his reason that suggest adaptation to the environment.

However, Learner 31 suggested that the transparency of the animal eyes results in their eyes glowing at night. The learners argued among themselves until they somehow came to a conclusion that the iris from animals must be opening up at night and allowing more light to enter. This view was echoed by various other learners from other groups. Other learners held the view that animals do produce their own light at night especially when they detect some evil spirits or ghosts.

In order to extend the learners' imaginations a little bit further, the notion of the applications of cellular phones and light was introduced in the following question.

TABLE 4.15: G.6 / Q.5 - If the sunrays were not present or available, would it be possible for cellular phones to operate?

INDIV	CLAIM	REASONS (EVIDENCE)
L.1	Yes it would be able to operate (PE).	At night you can use a cell phone and you can even phone a person (PE).
L.4	It would be possible for cell phones to operate without the sunrays (PE).	Cell phones are working with electricity which means cell phones get the heat from the electricity (PE). They use heat from the electricity i.e. infrared rays (SK).
L.3	It will operate without the sun (PE).	Because at night there is no sun but still the phones can operate (PE).
L.5	It is possible (PE).	They do not use solar radiation, they use network such as Vodacom and cell C (PE).
Consensus	Phones work in the absence of visible light	Cell phones use invisible light from the sun (SK).
Key: G = A group number, Q = a question number, L = a learner number,		

Interestingly, all the learners answered the above question without any doubt and highlighted that it was commonsense that cellular phones do not need light as they operate in the darkness as well. For instance Learner 4 suggested that if there was any heat required, then it would come from electricity. He suggested that infrared rays will enable cellular phones to operate. On the other hand, Learner 5 argued that cellular phones do not need solar radiation as they operate on the network (Vodacom or cell C).

While dealing with the previous question on the ability of nocturnal animals being able to see in complete darkness, the above arguments suggests that learners the majority of learners assumed that nocturnal animals only can see only the basis of adaptation, but the notion of invisible light was still not clear. However, the above question has somewhat caused the learners to think about what could be the medium for cellular communication if visible light was not a barrier.

For example, while still incorrect, Learner 4 suggested infrared radiation (heat) which is an invisible form of light. Learner 5 suggested that cellular networks must be responsible. While the teacher probed the learners, a number of learners in the classroom could not clearly explain the nature of what they call ‘cellular networks’. These grey areas allowed the teacher to have a way of introducing the role of the various frequencies of the electromagnetic spectrum. It was interesting that the learners were however well acquainted with the electromagnetic spectrum, but they could not really relate to their everyday lifeworlds in their daily use of television, cellular phones or microwaves.

4.3.5 General discussions for the TEI and DAI interventions

Learning theories advocate for learners’ prior knowledges to be prioritised in the process of teaching and learning engagements (Ausubel, 1968). In this regard, both teachers made attempts to engage the learners in making predictions about the purpose of the artefacts used for the lessons. The teaching and learning support materials used for both groups seemed appropriate as demonstrations and experimentation were used for the TEI group while a case study and physical artefacts were brought into the DAI classroom. However, Campbell and Lubben (2000) have argued that amongst the various resources a learner bring into the science classroom is his/her own socio-cultural background which is inclusive of IKS. While the lessons in the TEI group were practical and relevant, they were more focussed on traditional school science worldview with no culturally relevant examples. As Jegede (1997) and Tobin & Garnett (1988**)** has suggested, Traditional teaching approaches usually lead learners to adopt learning strategies for the memorisation of facts. Although, teacher now know that IKS should be included in every science lesson, they however do not do so for various reasons such as not having appropriate resource materials such as textbooks reflecting indigenous worldviews of science (Ninnes, 2000).

However, an important point of note with regard to departure from prior knowledge to the main body of the lesson is the form of bridging principle used for both intervention strategies. For example, Vygotsky (1978) speaks of social constructivism where learners learn from each other and that learning is determined by what he has called the Zone of Proximal Development (ZPD) which defined as the measure of the cognitive distance traversed from the learners’ prior knowledge to the expected knowledge. The two intervention strategies were similar in terms of sourcing of the learners' prior knowledge and some engagement of learners within the introduction as well as in the main body of the lesson. There seemed to be some differences in terms of how learners traverse that ZPD.

In the TEI intervention the teacher seemed to have used prior knowledge only as means of introducing the lesson and creating interest for the learners rather than using their prior knowledge as support materials for the construction of the main body of the lesson. The general trend observed amongst other TEI group classes was that were attempts to include the learners' IK into the lessons, that was only done to introduce the lesson and to abandon the process and to go into the supposedly 'real science' in the main part of the lesson.

As Chiappetta, Koballa and Collette (1998) have succinctly put it, 'Culturally diverse students develop meaningful science understandings when they see their culture facilitating learning rather than seen as an impediment to it" (p. 51). Since the TEI learners were also observed to be struggling with language barrier issues as there were no scaffolding language materials or glossaries, teachers in this regard may deliberately avoid bringing in indigenous perspectives into the science classrooms as this may exacerbate their challenges with respect to language. Supporting this view is assertions made by Sutherland and Dennick (2004) and Rollnick and Fakudze (2008) that, communicating IK to learners will also necessitate the use of the learners' first or home languages. The implications for not planning possible language barrier interventions was that the TEI teachers were frequently observed to be doing unstructured code switching resulting in foreign and unknown words which were neither English nor isiXhosa known words (Dlodlo, 1999; Diwu, 2010).

However, though group work was observed among both groups, the one among the TEPSI group was unstructured as the teacher learners were allowed to debate and discuss without an opportunity given for each learner to first express his/her views on a particular issue. The teacher was frequently observed to be focussing and targeting more able learners. As Tobin (1988) has suggested, most teachers do this to keep momentum so as to complete the syllabus. The DAI learners were provided with individual tasks which repeated themselves over to small groups, group presentations where they also heard the other groups' views and then the whole class discussions where the teachers were also brought in.

According to Diwu & Ogunniyi (2012), the purpose of the dialogical argumentation instruction as highlighted above was to allow all the learners the opportunity to reach a cognitive consensus where it was feasible. As opposed to the DAI-Bridge group, the TEPSI teacher was leading with demonstration in highlighting some phenomenon. In this regard, the teacher could first create scenarios or case studies that would create controversy or inquisitively where the learners will automatically hypothesise even way before any demonstrations. Thus, demonstration would have serve to confirm or disconfirm their predictions and thus activate their cognitive abilities.

In terms of social cultural relevance, the concept map approach applied to the DAI group which the learners read provided some clues for learners to compare cross-cutting concepts and a multiple worldview atmosphere was inculcated. With regard to the teaching and learning strategies, more time was devoted to the learners in their individual, group and whole class discussions while the teacher only facilitated by clarifying issues as well as offering probing questions. In the process, the learners were speaking in their own home languages but using the terminology glossaries to help translating their ideas into English for assessment purposes.

As the teacher was not very much conversant with the argumentation framework as well as knowledge of IK practices, the teacher's self-efficacy and confidence was not so good as she was overwhelmed with the learners' responses and enthusiasm. This caused the teacher to side track most of the time and lost the sense of time for each individual stage in the dialogical argumentation process.

As Ogunniyi & Ogawa (2008) have argued, informing teachers about how to integrate IKS into school science is not sufficient to guarantee that they will be able to effectively integrate the two knowledge systems into their instructional practices as required by the IKS policy documents. In this regard, they highlight that a number of studies have shown that mentee teachers need to be engaged in a long-term mentoring process. In this regard, the researcher had to chip in at various times to assist as he had mentored the teacher only for a few weeks.

Of most importance, was how to bridge the learners' 'alternative' explanations with that of school science. Instead of encouraging the learners to abandon their own views, the researcher took over and assisted in a process he calls IK – to – school science contextualisation and vice versa. This ensured that while learners are able to appropriate knowledge claims (Gunstone & White, 2000), they are able to use one worldview as a place holder for a concept in another worldview and thus know when one form of explanation is necessary.

For example, in the DAI group the learners were initially engaged on their awareness of the concept of light in various contexts and then presented with a concept map to allow their cultural and personal views to be awakened. For instance, Keane (2007) suggests that, learners' worldview presuppositions are more essential for them that the normal examples of school science. She further argues that even in cases where IK examples are introduced, their introduction usually occur within a western science paradigm. Contrary to the latter, learners individually engaged with some leading questions so that they could express their own views. This is in line with what Ogunniyi (2007) calls intra-argumentation. The teacher did not take over, but facilitated the switch from individual to small group tasks so that the peer learning Vygotsky speaks about can be effected. In support of the teaching and learning processes used by the DAI teacher, Stears et al. (2003) succinctly puts this way that:

> While an individual's knowledge is personally constructed, the constructed knowledge is socially mediated as a result of cultural experiences, personal history, interaction with others in that culture, and the collective experiences of the group. This view of learning places importance on the context in which learning occurs. (p. 110).

As the last sentence in the above citation state, learning places importance on the context in which learning occurs. With regard to learners in the two intervention groups, isiXhosa has been the learners' first or home language and hence the language they can express themselves the best. It is therefore assumed that since Vygotsky was a Russian and the language of teaching and learning being Russian, social construction of knowledge may have occurred in the context of that language. In this regard, '…the way that students take up classroom or disciplinary discourses are shaped by the social or everyday discourses they bring to the classroom" (Anderson, 2007, p. 15).

4.3.6 Preliminary findings and implications on the interventions

Key characteristic and distinctive aspects of the two interventions, the challenges and opportunities they presented during the course of the observations are as follows:

- The TEI approaches seemed to be a good teaching and learning strategy geared at assisting teachers to have a uniform approach that is easily evaluated. It also helps teachers to focus and not to deviate from the key concepts specified in the syllabus. In this regard, the TEPSI approach does not need a lot of prior lesson preparations and can accommodate less experienced teachers with less subject content knowledge as much guidance is given within the text books and the subject guideline documents.

- On the other hand, the DAI approach showed that it is an approach that needs teachers to be well trained and knowledgeable in the subject. The DAI approach needed more time for lesson planning and resources preparation. Once these had been done, it showed that a large aspect of the syllabus can be covered in fewer lessons as duplication of concepts across various areas of the Physical Science syllabus are visited simultaneously. This seemed to have given the DAI more broader understanding of the concepts in unfamiliar contexts.

- The DAI approach has shown that various teaching and learning aspects such as language barriers, teaching and learning across the curriculum and the various categories of the specific aims which are normally dealt with on an individual basis can be infused in one lesson or a number of lessons in a sequence so that learners can develop a holistic rather than a dichotomized or compartmentalized view of knowledge.

- With regard to language and terminology issues, the TEI groups prioritized on English and underrated the effects of language barriers in science teaching. Implications highlighted undesirable unsystematic code switching practices which resulted in transliterations having no cognitive meanings but only served as placeholders to cover up for the teachers' language deficiencies.

4.3.7 The teacher's experiences in integrating school science and IKS

The purpose for this section was to find about the teachers' experiences in mediating and conducting of the IK-integrated science lessons in their classrooms. In this regard, the two TEI teachers and the DAI teacher were provided with guiding questions to enhance their reflective diaries. The leading questions were used as prompts and guides so that the teachers can be more specific where possible. This was also to assist the researcher in the analysis phase. The two questions were used to assist teachers in their reflection process:

1. Thinking back through the teacher workshops and the intervention lessons you conducted, how can you describe your experience and perspectives on indigenous knowledge systems and its relevance to science teaching?

2. If any, how relevant and effective do you think the intervention strategy you have deployed in the science classroom have been able to facilitate teaching that is socially and culturally relevant?

----------------- More on the outcomes of these interventions will be discussed in chapter 4.------

4.4 Summary findings and discussions

This section presents the results obtained from the reflective diaries of the three teachers that were involved in the intervention programme. Boxes 4.13 and 4.14 present the TEPSI teachers' as well as the one DAI teacher's reflective diaries. The reflective diaries are followed by discussions summary findings.

For ease of analysis, the teachers written response were categories into two main themes of challenges and opportunities/benefits as representative of the teachers experiences of both the IK integrated science as well as the compatibility or otherwise of the associated intervention strategies.

Box 4.13: The TEI and the DAI teachers' pre and post-test reflective diaries on question 1
Question 1: Thinking back from the teacher workshops and the intervention lessons you conducted, how can you describe your perspectives on indigenous knowledge systems and its relevance to science teaching? TEI Teacher C : When I first attended the workshop in 2014 I could not figure out what culture or IK had to do with science. As examples about how everyday knowledge could be used to illuminate on classroom based scientific concepts I then gradually became interested. My concern however was the issue of how I could get the kids to argue and at the same time try and keep up with the pace setters and the completion of the syllabus in time for the year end examinations. In light of this, I decided that I would try the part on how I could integrate some IK into science, but do it using my own teaching methods which I have been using over the years.

TEI Teacher D: When I took part in the workshop I was already aware of the concept of IKS as that was part of the CAPS document, but my problem was that there were no textbooks with enough IKS examples and sometimes the few examples of IKS do not cover other Physical science sections such as in Physics. This made me wonder whether it was necessary to include it in the science syllabus. In many of the lessons that I taught I tried to make the lessons more stimulating, but I had limited knowledge of IK examples and I further noted that some of the learners had no clue about IK practices that I tried to use.

DAI Teacher B: I can just start by saying that the power point slides about the workshop were very helpful because I was very skeptic about this IKS which was spoken about. I was also wondering why the Department had not provided us with workshops to explain to us what IKS was and to provide us with IKS materials. Since the workshop and when I took part in the planning of argumentation lessons I started to have interest. These argumentation planning exercises made me to dig deeper into the theory about the science content and also made me see how close it was to the normal everyday knowledge that we take for granted.

Box 4.14: The TEI and DAI teachers' pre and post-test reflective diaries question 2

Question 2: If any, how relevant and effective do you think the intervention strategy you have deployed in the science classroom have been able to facilitate teaching that is socially and culturally relevant?

TEI Teacher C: The first challenge I faced was that IK examples were in the learners' language which is Xhosa and I tried to convert these into English which was almost impossible as there were no Xhosa words which can be equated to the English concepts. I however, found that the learners were more interested in participating in the class as they could speak in their own language. The debates went on and on, but I had to cut them short because of the time as periods were shorter in other days. As part of this teaching intervention, I can say I have learnt a lot of things such as planning lesson plans which now look at how one can find examples of scientific topics that are part of the learners' prior knowledge. Although I am still not clear about IK, but I can say that IK is similar to the learners' daily knowledge about what they find at home and at their environment.

TEI Teacher D: What I have found useful for myself was to put my learners in groups so that they can discuss some of the topics. This allowed them to speak in their own languages thus getting everyone to get involved. I however found that the clever learners overpowered the weak ones. I had to intervene at some times and try and explain the concepts myself as I could see that the debates make some of the learners confused and frustrated and they feel that the period sometimes ends without them have learned anything concrete. On the overall I think, giving learners examples of science concepts that are close to their everyday experiences make science exciting and thus encourage all learners to participate. This helps to inculcate an environment of learner-centeredness and so teachers can take up roles of being facilitators.

DAI Teacher B: As I already mentioned, I found that argumentation helps one to think about the science he must teach in the classroom. Sometimes the learners asks questions that one did not think about before the lessons. It is in this aspect of lesson planning that I think the argumentation strategy is a very effective teaching method as it also made it easy for me to think about everyday examples that I can bring into the classroom. At first I thought argumentation and debating would take all my teaching time, but I realized that it gets the learners to participate early on and makes them pay attention to what is taught thus also helps in the determination of whether the learners have understood or not. I have been able to get most learners to understand the concepts on a much deeper level as well as keeping up with the syllabus although I had a lot of challenges with classroom management in the beginning, but through structured argumentation I slowly learnt that it has potential to help in content coverage.

As highlighted in the beginning of this section, the analysis of the above teacher reflective diaries is presented in two themes that is opportunities and challenges.

Observations in relation to question 1 (Box 4.13) for the teachers' reflections on their perceived relevance of IKS in the school curricular, the following main observation from the above is made:

- With respect to the opportunities presented by the IK-science integration efforts by the three teachers in their respective interventions show a common theme with regard to the their perceived relevance of IKS in science teaching; that is, 'examples about how everyday knowledge could be used to illuminate on classroom based scientific concepts.' (TEI Teacher C paraphrase)…can create interest in IKS, and that argumentation led to deeper understanding of science as well highlighting of commonalities between science and IKS (DAI Teacher B).

In agreement with the two teachers on the relevance of IKS in science teaching, Chiappetta et al. (1998, p. 51) states that:

> 'acquisition of declarative knowledge is further enhanced by when the presentation of new science content is coupled with culturally familiar objects, examples and analogies and when the students are provided with regular opportunities to interact directly with the materials being learned.

The above also seem to suggest that learning of science requires means of relating every day and traditional ways of knowledge to school science. If teachers do not have the required tools as exemplified by the DAI teacher above, then the relevance of IKS to science is nearly impossible. While the inclusion of culturally familiar objects, examples and analogies may be beneficial in illuminating the relevance of IKS in science teaching, Ogunniyi (2007) have argued that, IKS is not necessarily about artefacts, but it is about epistemologies, ontologies and metaphysical systems underpinning the artefacts.

In this regard, various challenges were cited by the three teachers in respect of their perspectives on the integration of science and IKS.

- The excerpt from the three teachers (both TEI and the DAI) seemed to suggest that training in respect of IKS integration seemed to be a challenge. Challenges included, (1). Clarity from curriculum policy documents on strategies for how to stimulate arguments in classrooms while keeping up with the syllabus, (2) Limited knowledge about IK exemplars and learners having no clue as a result of no IK supporting materials, 3. Finally, no workshops conducted in respect of IK training coupled with IKS materials.

This common theme running throughout the three teachers is consisted with the perennial challenges cited by various scholars (e.g., Ogunniyi, 2004, 2007a) on the implementation of an IK-science curriculum in South Africa. One of the main issues about the lack of exemplar teaching and learning materials to assist teachers in their attempts to infuse IK into the science lessons. For example, Ninnes (2000) have noted that, one other situation which can undermine the progress in the implementation of a Science-IKS curriculum could be the poor representation of indigenous knowledge within the school science text books

Observations in relation to question 2 (Box 4.13) on the teachers' experiences in using their respective teaching strategies in attempting to integrate IKS and school science showed that:

- In order to attempt integrating IKS within their science lessons, the TEI teachers had to think about the importance lesson planning for creating IKS exemplars (TEI Teacher C) and group work was also important to get learners to discuss IKS (TEI Teacher D).
- In her attempt in integrating IKS within science lessons, the DAI teacher, stated that argumentation helped her with planning everyday IK examples that could be brought into the classroom; getting all learners to participate first time in her lessons, their understanding of the content at a deeper level and finally, that the DAI-Bridge had a potential over time of shortening the syllabus coverage.

The TEI teachers' experiences in their attempts to integrate IKS with school science seemed to point at the need for their awareness of and knowledge of nature of both science and IKS and the appropriate teaching strategies. While argumentation and discussions coupled with exemplars in groups may enhance the learners understanding of the content, if that is not facilitated with clear argumentation rules, the content to be learned as well as the nature of the content, the learners as well as the teachers will be left confused. As Ogunniyi (2007) have stated, their allusion to the need for IKS exemplars and group work is not enough since science and IKS are premised on diverse worldview presuppositions.

Simon et al. (2006) argues that, 'science education require a focus on how evidence is used to construct explanations…' (p. 236). In support for the findings for the DAI teacher's experiences in the use of argumentation, Simon et al. continue to argue that, '…the teaching of argumentation through the use of appropriate activities and pedagogical strategies is, we would argue, a means of promoting epistemic, cognitive and social goals as well as enhancing students' conceptual understanding of science.' (ibid). As opposed to the DAI teacher whose challenges were only at initial stages of her intervention, the challenges experienced by the teachers suggest that:

- The TEI teachers had language problems as learners seemed to use an African language for IKS issues (TEI Teacher C) and classroom management as a result of long uncontrollable debates and overpowering of weaker learners by the more academically inclined learners.

The experiences by the TEI teachers are in line with studies by Sutherland & Dennick (2002) as who claimed that the background knowledge which the learner brings into the classroom is explicated in a "background language", which is the learner's first or home language (p. 4). Similar findings have been provided by Rollnick & Fakudze (2008) who also stated that the knowledge formation of IKS is directly related to the indigenous languages of those IK holders. As opposed to the TEI teaching strategy, the DAI as the name suggest, has been able to construct epistemic as well as linguistic bridges as part of the DAI-Bridge participatory action research cycle in figure 3.1 of chapter 3.

4.5 OVERALL SUMMARY

This section presents the findings which emanated from the two research questions. The research questions were discussed in terms of the broader argumentation framework consisting of Toulmin's Argumentation Pattern (TAP), Ogunniyi's Contiguity Argumentation Theory (CAT) as well as Hempel's Internal and Bridge Principle. The finding are listed in terms of the research questions under the following sections.

4.5.1 *Effects of the teaching methods on the learners' understanding of the selected phenomena*

4.5.1.1 Comparability of the learners from the four schools used in this study?

The results from the 1-Way ANOVA analysis showed that:

- The mean scores of the learners in the four schools were not significantly different and hence comparable. Out of 21 selected concepts, 18 were comparable, two showed significant differences between some of the schools and another two items were statistically invalid. Astronomy 4 (on celestial bodies versus time) and Chemistry (on heat versus cold) showed to be problematic, hence statistically not comparable. Performance scores for Sound 3 (sound dependency of weather temperature) was significantly larger than school D while the vice versa occurred for Chemistry 1 (B.P dependency on atmospheric pressure) were performance scored from school D were significantly greater than that of School A. Further interrogation of the two items of Sound 3 and Chemistry 1 showed that Sound 3 is more amenable to rural settings while Chemistry 1 to urban settings. In this regard, School A as supported by the demographics shows that the majority of their learners come form rural areas while the majority of those from School D are from urban areas.

4.5.1.2 Learners' understanding of the selected phenomena as a result of the instructional strategies and curriculum interventions.

In terms of the learners' preconceptions, the findings showed that:

- The performance scores for both the TEI as well as the DAI group were found to be statistically comparable. Performance for both groups were however found to be higher for the context-familiar phenomena (Tyndall effect, refraction and infravision) and lower for those that are context-dependent (Light 3 and Sound 3) and much lower for those that are discrepant such as Sound 5. In this regard, the learners' preconceptions on the selected phenomena were observed to been based on IK internal principles.
- The phenomena of sound presented the most challenge to learners and their response highlighted that sound largely involved context-dependent as well as discrepant concepts. These were with respect to audible sound and inaudible infrasonic or ultrasonic sounds

where audible sound was observed to be less complicated than inaudible sound. In this regard, the majority of learners' for both groups generally exhibited the substance schema of the sound model or what others have called the entity model.

In terms of the learners' interventions, the findings showed that:

- For all selected phenomena both interventions of TEI and DAI seemed to have significantly enhanced the learners' pre to post-test performances. However the DAI significantly outperformed the TEI intervention for phenomena which were more abstract such as those that were found to be context-dependent and discrepant.
- While both groups' cognitive stances were equipollent before interventions, the cognitive stances of the majority of TEI group learners were found to be school science dominant after interventions. As opposed to the TEI group, the cognitive stances of the DAI group learners were observed to be predominantly school science emergent.
- As opposed to the TEI intervention strategy, the DAI intervention strategy seemed to have explained the phenomena of border crossing in terms of the exact mechanisms they follow when they decide to cross or not cross cognitive borders. In other words, the DAI seemed not to just have enhanced the learners' abilities to provide reasons in support of their claims, but also terms of interrogating the nature of the theories underpinning particular scientific phenomenon.
- The level at which integration is possible between school science and IKS is moderated to a large extent by the nature of the internal principles as well as bridge principles inherent in a particular scientific theory or law underpinning a particular phenomenon. A related observation made was that each phenomena has internal principle peculiar to a particular worldview, hence the importance of the context of how the phenomena is presented.
- As opposed to the TEI teaching and learning approach which seemed to be dichotomizing IK and school science, the DAI teaching and learning strategy seemed to be the most appropriate intervention approach for integrating school science and IKS in a manner in a holistic manner.

4.5.2 Learners' attitudes towards the integration of school science with IKS

4.5.2.1 Teaching and learning opportunities and challenges posed by the integration of IK in the school science lessons.

- **TEI and DAI interventions**

Key characteristic and distinctive aspects of the two interventions, the challenges and opportunities they presented during the course of the observations are as follows:

- The TEI approaches seemed to be a good teaching and learning strategy geared at assisting teachers to have a uniform approach that is easily evaluated. It also helps teachers to focus and not to deviate from the key concepts specified in the syllabus. In this regard, the TEI approach does not need a lot of prior lesson preparations and can accommodate less experienced teachers with less subject content knowledge as much guidance is given within the text books and the subject guideline documents.
- On the other hand, the DAI approach showed that it is an approach that needs teachers to be well trained and knowledgeable in the subject. The DAI approach needed more time for lesson planning and resources preparation. Once these had been done, it showed that a large aspect of the syllabus can be covered in fewer lessons as duplication of concepts across various areas of the Physical Science syllabus are visited simultaneously. This seemed to have given the DAI more broader understanding of the concepts in unfamiliar contexts.
- The DAI approach has shown that various teaching and learning aspects such as language barriers, teaching and learning across the curriculum and the various categories of the specific aims which are normally dealt with on an individual basis can be infused in one lesson or a number of lessons in a sequence so that learners can develop a holistic rather than a dichotomized or compartmentalized view of knowledge.
- With regard to language and terminology issues, the TEI groups prioritized on English and underrated the effects of language barriers in science teaching. Implications highlighted undesirable unsystematic code switching practices which resulted in transliterations having no cognitive meanings but only served as placeholders to cover up for the teachers' language deficiencies.

- **The TEI and the DAI teachers' experiences**

Observations in relation to question 1 for the teachers' reflections on their perceived relevance of IKS in the school curricular, the following main observation from the above is made:

- With respect to the opportunities presented by the IK-science integration efforts by the three teachers in their respective interventions show a common theme with regard to the their perceived relevance of IKS in science teaching; that is, 'examples about how everyday knowledge could be used to illuminate on classroom based scientific concepts.' (TEI Teacher C paraphrase)…can create interest in IKS, and that argumentation led to deeper understanding of science as well highlighting of commonalities between science and IKS (DAI Teacher B).

In this regard, various challenges were cited by the three teachers in respect of their perspectives on the integration of science and IKS. Findings in this regard show that:

- The excerpt from the three teachers (both TEI and the DAI) seemed to suggest that training in respect of IKS integration seemed to be a challenge. Challenges included, 1. clarity from curriculum policy documents on strategies for how to stimulate arguments in classrooms while keeping up with the syllabus, 2. Limited knowledge about IK exemplars and learners having no clue as a result of no IK supporting materials, 3. Finally, no workshops conducted in respect of IK training coupled with IKS materials.

Observations in relation to question 2 on the teachers' experiences in using their respective teaching strategies in attempting to integrate IKS and school science showed that:

- In order to attempt integrating IKS within their science lessons, the TEPSI teachers had to think about the importance lesson planning for creating IKS exemplars (TEI Teacher C) and group work was also important to get learners to discuss IKS (TEI Teacher D).
- In her attempt in integrating IKS within science lessons, the DAI teacher, stated that argumentation helped her with planning everyday IK examples that could be brought into the classroom; getting all learners to participate first time in her lessons, their understanding of the content at a deeper level and finally, that the DAI had a potential over time of shortening the syllabus coverage.

The TEI teachers had language problems as learners seemed to use an African language for IKS issues (TEI Teacher C) and classroom management as a result of long uncontrollable debates and overpowering of weaker learners by the more academically inclined learners.

4.5.2.2 The learners' reflections on their experiences on the IK integrated lessons

Reflection question 1: "Having been involved in this programme, how important was your teacher's beliefs in influencing your attitude and beliefs about science and nature in general?", observations seem to suggest that:

- The majority of learners, irrespective of what intervention strategy was used, believe that their teachers' beliefs about natural phenomena has had a great influence on their attitudes towards science.

Reflection question 2: "What are your views about science and traditional/cultural knowledge – Have you views changed and if so, do you think science and traditional knowledge are the same or different and why?, observations seem to suggest that:

- For the TEI learners, IKS and science do not seem to hold the same scientific status as school science. IKS is somehow largely related to religion which the majority of the learners viewed as being opposite to school science. These learners thus exhibit a divergent cognitive stance where science and IK are pulling in different directions.
- As opposed to the TEI learners, the DAI learners seem suggest that both school science and IK are equally valid scientific knowledge and that IK can help in developing a more robust understanding of school science. These learners therefore exhibit a school science emergent cognitive stance.

Reflection question 3: "Did your teacher include any traditional knowledge in your science lessons and if so, did you like the teaching strategy that was used to teach the lessons?" In this regard, findings suggest that:

- The TEI seemed to have enjoyed the inclusion of IK into their science lessons, but seemed to have been disillusioned by the teachers' lack of IK-science mediation strategies. Some of them however had some concerns such as not knowing how IK will be tested (learner 78), not having enough time for discussions (Learner 47) and not knowing how the two link together.

- The DAI learners suggested that the use argumentation in teaching about IKS: 1. Made learning science much easier, 2. Made learners proud about their culture and the realization that their culture can also contribute to scientific knowledge.

CHAPTER FIVE
CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

5.1 Introduction

The aim of this chapter is to put up a synthesis of the findings which emanated from each of the research questions in the previous chapter. In order to achieve this, all preliminary findings and summaries are crystallised and presented below as the major findings from this study. Following the presentation of key findings below, the implications for the findings will be drawn. These will be followed with recommendations for policy-makers, curriculum developers, educators, curriculum advisers and teachers at large.

5.2 Findings

In major findings in this study are presented in categories as follows:

A. The context of natural phenomena as predictor of the learners' preconceptions

- Both the TEPSI and the DAI-Bridge group learners held comparable prior conceptions in 17 out of 21 selected phenomena. For both groups, their performances varied simultaneously with the nature of scientific explanations required for a particular phenomenon, thus the emergence of three typologies. In this regard, learners showed to have relatively good conceptions on context-familiar phenomena, moderate with context-dependent phenomena and very poor conceptions for those that showed to be discrepant. It was further noted that phenomena with controversial attributes could belong to any of the three typologies.

- Corresponding to the above, the learners' written responses were observed to be predominantly based on IKS worldview presuppositions for those items which are phrased using IK exemplars as well as school science presuppositions for those framed as from a purely school science perspective. The learners were observed to have performed significantly better on IK based items and poorly on school science based items. For example, for the same phenomena of invisible light, learners performed significantly better on Light 5 which used IK predicates in explaining the school science claim and poorly on Light 3 which only stated the claim made by school science without reference to IK predicates.

As various scholars (e.g. Ausubel, 1968; Campbell & Lubben, 200; Chiappetta et al. 1998; Enderstein & Spargo, 1998; Hamza & Wickman, 2007; Hewson, 2010; Hewson & Hewson, 2003; Jegede, 1996; Mohapatra, 1991; Nuno, 1988; Yip, 2001) in the field of science education have argued, identifying the learners' preconception is a necessary stage in increasing the teachers' awareness of the difficulties and barriers faced by their learners in understanding scientific phenomena (Eshach & Schwartz, 2006). In the context of this study, the learners from the four schools (A to D) were all exposed to 21 IK integrated scientific concepts. Inferential statistic (1-Way ANOVA) method showed that only in two concepts was there a significant difference between scores in two schools and results for two other concepts could be compared due to homogeneity of variances in their scores not being assumed.

However, as the above scholars have stated, the learners' preconceptions were interrogated and found to vary in line with the various phenomena. Again, as the subjects in this study are from non-western backgrounds, it was expected that their experience of school science would cause them to experience some cognitive dissonances (Aikenhead & Jegede, 1999; Chiappetta et al. 1998).

Furthermore, various socio-cultural scholars (e.g., Aikenhead, 1996, 1997; Aikenhead & Jegede, 1999; Fakudze, 2004; Jegede, 1995; Jegede & Aikenhead, 1999) proposed various situations that may arise when learners from socio-cultural backgrounds are interfaced with school science. For example, Aikenhead and Jegede (1999), have suggested that the 'smoothness' of how learners cross cognitive borders decreases with the degree of discomfort or cognitive conflict they may experiences as a result of being exposed to the culture of a different worldview.

In response to the latter, Ogunniyi (2008) highlights two deficiencies relating to border crossing. The first relates to how the learners' experiences lead to the various border crossings and the second relates to the nature of the physiological or psychological processes that brings about the smooth or hazardous border crossing. According to Ogunniyi (2009), "the context of a particular discourse plays an important role in the amount or intensity of emotional arousal experienced by the participants in such a discourse" (p. 3).

While the above findings may not have explicitly addressed the two limitations of border crossing, the finding does however show that the nature of the various phenomena may not be unrelated to how learners attempt to reconcile their worldviews with that of school science. Furthermore, as the Contiguity Learning Hypothesis (Hewson & Ogunniyi, 2008; Ogunniyi, 1995; Ogunniyi, 2008) suggest, when two distinct worldviews of IK and school science come together in the mind, they will either attract or repel depending on the context as highlighted by the various contexts as depicted in the findings. In summary these findings seem to provide some characteristic predicates for predicting possible conflicts learners may be exposed leading to various degrees of border crossing. Furthermore, in contrast to the post assessment approach by the various studies on learners' preconceptions, these findings seem to suggest that, the teachers' understanding of the nature of scientific explanations underpinning a particular phenomenon should take centre stage.

In other words, teachers should have done prior assessment of the particular concepts or phenomena they wish to teach and then reflect on such assessment as the teaching and learning process is in progress. For example, as the lack of success by learners from socio-cultural backgrounds is normally associated with their home backgrounds (Chiappetta et al. 1998), it was beneficial in this study to design questionnaires from various worldview perspectives. As has been noted, learners had high performance on context-familiar phenomena, thus consistent with Campbell & Lubben (2000) who asserted that, "contextualization improves access to knowledge and thus provides equity to disadvantaged groups" (p. 239). Previous longitudinal a and cross-cultural studies by Enderstein & Spargo (1998) in South Africa supports the notion of the role of context in teaching and learning.

For example, Fensham (1988) suggests that the introduction of discrepant events or phenomena may lead to perceptual inconsistencies among learners, thus enabling the teacher to have a reference point for measuring the learners' preconceptions and worldview presuppositions as when they arise. The latter would also apply for phenomena of controversial or socio-scientific status. As Hamza & Wickman (2007) have argued, the learners reasoning develop in response to the contingencies of a specific situation.

When these preconceptions exhibit themselves, the teacher may be in a better position to know what to do with the learners' alternative conceptions. Instead of seeing their preconceptions as blockages in the path of scientific indoctrication (Feltham & Downs, 2002; Jegede, 1997) the teacher may be able to guide the learners in being able to know which knowledge claims are valid for particular situations (Gunstone & White, 2000). As the findings of the second bullet have shown, learners' showed a better understanding on those items which were premised on IK presuppositions as a result of them being context-familiar. This has implications for teachers to have an awareness of the nature of indigenous knowledge systems as IKS has its own internal consistency (Battiste, 2002; Ogunniyi, 1988). This implies that relevance and rationality of IKS explanations are dependent upon the principles and beliefs that underpin the worldview that created its knowledge claims (Kelly, Carlsen & Cunningham, 1993; Ogunniyi & Ogawa, 2008). The latter statement thus suggest that the learners IK preconceptions will be scientific to the same extent as school that prescribed at school (Marin, Solano & Jiminez, 2001; Mohapatra, 1999).

However, when scientific concepts are culturally relevant accommodates of the learners' home languages also becomes possible. For context-familiar phenomena, the learners' home languages also plays a very crucial role in expressing one's own IK as well as linking to content to one's own lifeworld, (eg., Diwu, 2010; Kearsey & Turners,1999; Rollnick & Rutherford, 1996; Sutherland & Dennick, 2002; Wababa & Diwu, 2010; Young et al. 2005). In conclusion, the latter view has value in ensuring that the interrogation of learners' preconceptions is not for the purpose of driving and leading the learners to a particular predetermined explanation of a natural phenomenon (Keane, 2007), but to help them in building bridges between what they know and what they ought to know.

B. The dualistic nature of sound phenomena and its corresponding internal principles

- The phenomena of sound presented the most challenge to learners. This was despite having designed the phenomenon in an IK context. As opposed to its counterpart dualistic phenomenon of light, the phenomenon of sound showed that it is dominated largely by unobservable entities with the presence of very little IK observable predicates. Observable audible sound presented itself as a context-dependent phenomenon and as a discrepant phenomenon with respect to unobservable infrasonic sound. In support of the above, the majority of the learners viewed sound as a substance rather than a process.

The above findings are supported by some scholars (e.g., Eshach & Schwartz, 2007; Hrepic, Zollman & Rebello, 2002; Linder, 1992; West & Wallin, 2013; Wittman, 2003) who all arrived at the same conclusion that the concept of sound is the most problematic for learners. According to them, learners' conceptions of sound are based on a sound model that has come to be known as the substance schema or the entity model by others. The majority of the learners' written responses have also shown that language and the everyday context within which sound is used played a major role in their alternative conceptions. For example, studies by Hrepic et al. (2002) discovered that learners frequently use the same terminology which is used by scientists or experts, but often with different meanings that is inconsisted with the wave model of sound. This inconsistency is due to the fact that the everyday talk as used in the local languages of the learners does not carry the same meaning as the one used in school science vocabulary or terminology (Diwu, 2010; Kearsey & Turner, 1999; Rollnick & Fakudze, 2008; Scot et al, 2007; Sutherland & Dennick, 2002; Wababa & Diwu, 2010; B. L. Young, 1979).

The statements by the scholars above has are supportive of the learners statements who argued that inaudible sound does not exist on the account that, if it is called 'sound' then the sound must be audible. In this respect, Linder (1992) has succinctly put it when he said that the learners' perceptions of sound 'matches the everyday meaning of the word: the interpretations our brains make from a range of complex eardrum movements' (p. 262). He has further gone on to say that the learners' misconceptions on sound are such that learners are able to perform well at school without being identified and hence carry those misconceptions through to tertiary level. As West & Wallin (2013) has argued, grasping the concept of sound will involve ontological shifts from the everyday experiences of audible sound to conceptualisation of unobservable sound.

C. The effect of the DAI-Bridge principle over discrepant phenomena

- Both the TEPSI and DAI-Bridge seemed to have significantly improved the learners' performances. However the comparability of the two interventions were only in respect of context-familiar phenomena and the effectiveness of the DAI-Bridge significantly outperformed that of the TEPSI interventions for context-dependent (Light 3, Sound 3) and discrepant (Sound 5) phenomena.

In the context of the findings, the border crossing theories (e.g., Aikenhead, 1996; Jegede, 1995; Aikenhead & Jegede, 1999) states that, when learners from non-western backgrounds are interfaced with school science, they will experience cognitive dissonances to various degrees depending on the nature of the phenomenon under question. The comparability of the TEPSI and the DAI-Bridge in respect of context-familiar phenomena is not unexpected since the learners are not likely to experience much cognitive conflict (Campbell & Lubben, 2000; Chiappetta et al. 1998). However, in terms of higher order reasoning skills that were required as the concepts were more abstract or context-disembodied, the DAI-Bridge having significantly outperformed the TEPSI seemed to have developed a wide range of skills. This is in line with Specific Aims 1 (S.A 1) of the Curriculum and Assessment Policy Statement CAPS (DBE, 2011) and the Learning Outcomes 1 (L.O. 1) of the National Curriculum Statement (NCS) (DoE, 2002) which states the following: Higher order thinking and problem solving skills are required to meet the demands fo the labour market and for active citizenship within communities with increasingly complex technological, environmental and societal problems. (DoE, 2002, p. 12).

Finally, related findings by the author (Diwu, 2010) showed that, teaching and learning premised on argumentation had significantly enhanced the learners' cognitive skills on concepts that required high order reasoning than in those learners who were just exposed to traditional lecture styles of teaching.

D. The learners' cognitive shifts as a function of particular teaching strategies

- While the performances of both groups had significant improved after interventions, the cognitive stances by the majority of the TEPSI learners' shifted from initially being equipollent to those that are school science dominant. The lack of connection between the TEPSI learners' pre-test and their post-test suggest that their IK worldview was suppressed in favour of the school science worldview. As opposed to the TEPSI, those of the DAI-Bridge shifted from being predominantly equipollent to the school science emergent cognitive stances. The learners' explanations exhibited IK internal principles which were linked to that of school science using observable predicates that allowed them to make sense of the school science claims.

As has been shown, most of the scholars (e.g., Ausubel, 1968; Campbell & Lubben, 200; Chiappetta et al. 1998; Enderstein & Spargo, 1998; Hamza & Wickman, 2007; Mohapatra, 1991; Nuno, 1988; Yip, 2001) who have been interested in the learners' preconceptions have done so largely from a perspective of changing the learners' IK worldviews into that of school science. As suggested by (Feltham & Downs, 2002; Jegede, 1996), the learners' preconceptions are largely seen as stumbling blocks in the path of scientific indoctrination and hence need to be changed. These observations have been prevalent among the TEPSI learners who seemed to have abandoned their IK worldviews in favour of the school science worldview.

While it is almost impossible to replace the learners' beliefs with the school science worldview (Gunstone & White, 2000), the observations of the TEPSI learners' cognitive shifts are typical of coping mechanisms that learners use as a result of the dominance of school science. In this regard, as Jegede (1997) and Tobin & Garnett (1988) have suggested, traditional teaching approaches like the TEPSI usually lead learners to adopt role learning strategies. This means that the learners learn the tricks of mastering the school science explanations without having to believe any of them (Jegede, 1996). When situation occurs, we can thus assume that the IK explanations are seemingly incompatible to those of school science and the learners' underlying cognitive stances may be regarded as divergent.

In contrast to the above, the majority of the DAI-Bridge learners retained their IK presuppositions, but seemed to have found a meaningful point of connecting their IK to school science (Ogunniyi, 1988). The DAI-Bridge learners predominantly drew inspirations from IK internal principles, but used bridge principles to make sense of school science internal principles.

Without the understanding of IK internal principle, it would be almost be impossible to understand how learners connect two distinct worldview presuppositions. As other scholars (Marin et al., 2001) have noted, learners' explanations of scientific concepts '…might be unlinked to the content in an adult scientific logical sense'… and yet '… linked for the student.' (p. 685). In other words, the DAI-Bridge seems to have enhanced the learners' understanding of the relevance of IK and how its underlying scientific claims relate to that of school science (Kelly, Carlsen & Cunningham, 1993; Ogunniyi & Ogawa, 2008). The observations for the DAI-Bridge learners are thus consistent with what Vygotsky (1978) would call transversing the zone of proximal development or as what Ogunniyi (1997) later had called an emergent cognitive contiguity.

The implications suggests the importance of ameliorating the distorted notion about IKS and school science in the extant literature (Aikenhead & Jegede, 1999; McComas, 1998). For instance as Ogunniyi (1988, 2008) have alluded, dichotomy of IK and science is only existant in the minds of teachers since learners themselves live happily in both worlds. Various other scholars (e.g., Gunstone & White, 2000; Hewson & Hewson, 2003; Marin, Solano & Jiminez, 2001; Rollnick & Rutherford (1996); Posner et al., 1981) share this view.

E. The role of socio-cultural background on learners' conceptions of particular phenomena

- There was a significant difference between the boys' and girls' pre-test conception about the existence of infrasonic sounds transmitted by elephants. This was further verified using the t-test for independent groups. The learners' excerpts suggested that the girls presented predominantly rural experiences as opposed to those of the boys which were predominantly from rural settings.

While there has been no significant difference between boys and girls in the whole study, the above findings suggest that there may be particular school science concepts that are more amenable to either one of the gender group. As opposed to learners from westernized backgrounds where there is a general homogeneity among gender groups, boys and girls may be predisposed to certain kinds of indigenous knowledges. For instance, whilst there may be areas of commonality between girls and boys, areas of difference are also possible. For example, Rich cited in Baker (2007) argues that the concept of co-education is a misleading one since it presupposes that because girls and boys receive the same instruction in the classroom, they are therefore automatically receiving the same education. This is also true for the apartheid South African context where black women were not sent to school and their roles were to be wood gathers while boys were to go to school to secure better jobs in order to sustain households.

This phenomenon is directly linked to IKS where various groups are custodians of various indigenous knowledges (Citation Source).

- 76% and 70.8% proportions of all learners who respectively disagreed and strongly disagreed to the notion of scientism were from the rural areas and the chi square test shows that this was a significant result. The Pearson chi square test gives a significance value of $p = 0.037$.However, the t-test for comparing the boys to girls on scientism revealed that the two groups were comparable with $M = 2.65$ and $M = 2.67$ for boys and girls respectively where $p = 0.930$ and $t_{ratio} = -0.088$.

The above results which suggest that learners who are from urban contexts are highly likely to be prone to scientism are not unwarranted. Since people who live in the urban areas are largely dependent on buying almost everything and on technology for survival, it is therefore not unrealistic for them to attribute everything to science. As the findings have revealed, this is irrespective of gender.

These findings are supported by Ogunniyi (2004) who noted that, "…the mass dislocation of human population in the colonies from their familiar environments for trade, commerce on administration purposes and consequently the loss of indigenous knowledge and skills developed over centuries." (p. 290). Furthermore, the Department of Education (DoE, 2002) has also echoed the above sentiments when it stated that colonisations over a very long time (over 350 years) resulted in the loss of indigenous knowledge systems thus creating a dependency of western worldview thinking. In the meantime, despite the scientism tendencies brought about by the latter, the school science has not been able to bring complete solutions to societal ever growing problems; instead incurred a lot of disillusionment (Hodson, 2011; Jegede, 1997). Finally, it can be concluded that the socio-cultural background of learners as a context does play a role in the learners' awareness and understanding of the nature of science (e.g., Enderstein & Spargo, 1998).

F. The effect of intervention strategies on the terminology of simple and complex nature.

- Both groups seemed to have had a significant effect on the terminology of scientific concepts that were simple and context-familiar. These items were force (Terminology 6) as well as altitude (Terminology 8). However, The DAI-Bridge significantly outperformed the TEPSI intervention when it comes to terminology concepts that had represented complex ideas. These two concepts are temperature (Terminology 2) as well as energy (terminology 4).

However, to have a better understanding of the findings, the following are key linguisting principles to be born in mind. The understanding of concepts depends on a variety of factors such as the language in which they occur (Diwu, 2010; Rollnick & Rutherford, 1996; Wababa & Diwu, 2010; Young et al. 2005) and the discourse of the discipline for which they are used (Diwu, 2010; Dlodlo, 1999; Haidar, 1997; Kearsey & Turner, 1999; Rampal, 2005; Scot, Asoko, & Leach, 2007; Setati, Adler, Reed & Bapoo, 2002) as well as the conventions of the discourse in their home, mother tongue or first language (Diwu, 2010; Odora-Hoppers, 2005; Sutherland & Dennick, 2002; Young, B. L, 1979). In other words, the basic English language is a second language, thus making the school science technical language a 'third language.'

The concepts of temperature versus heat as well as energy and work are common ideas which learners are frequently exposed in their daily lives. However, these concepts are complex since their school science explanations are inconsistent with that of the learners' everyday thinking. The above issue is exacerbated by the Language of Learning of Teaching and Assessment (LoLTA) being English as opposed to being an African language (isiXhosa); which is the home or first language of the learners in this study.

For example, in isiXhosa, 'temperature' is generally called 'iqondo lobushushu' which is literaly means 'the degree of hotness' while heat is called 'ubushushu' literally, meaning 'hotness.' As one can see, both definitions are quite problematic because they are even used in isiXhosa-English dictionaries. Both definitions conflate temperature and heat as well as heat and hotness. The two definitions were frequently used by the majority of the learners and much so in the TEPSI group. The observations as was presented by most learners' is consistent with Whorf's (1956) hypothesis which suggests that, the structure of the learners' home languages determines how the learners will understand reality and also behave with respect to it. In a similar manner, Odora-Hoppers (2005) stated that:

> …language plays a crucial role in that it contains the map of the land, the relationships to the energies and the spirits of all living things – rocks, trees, plants, birds and animals. The flux in which they live is perfectly expressed in what could be termed their 'process language.' (p. 6).

As the DAI-Bridge group were involved in home language mediated argumentation discourses coupled with IK-based resource materials they seemed to have been able to develop meta-linguistic skills which acted as socio-linguistic border crosses into the scientific meanings of the concepts (Diwu, 2010). Typically of the TEPSI group, Vygotsky (1962) states that, "…memorising words and connecting them with objects does not in itself lead to concept formation; for the process to begin, a problem must arise that cannot be solved other than through the formation of a new concept." (p. 99 – 100). As opposed to the TEPSI group, the DAI-Bridge intervention was steeped in participatory action research design incorporating a terminology development loop to bridge the linguistic barriers highlight above. As Kearsey and Turners (1999) has also alluded, if bilingualism is treated as a resource instead of a barrier, then learning of scientific concepts can be enhanced.

In view of the above, Green (1995) states that language serves two basic purposes; that of external communicating with other people and the internal representations of one's own thoughts. Similar to the latter, Ogunniyi (2007) views language as first serving in the form of intra-arguments which then become externalised through what he calls inter-argumentation. As the above findings suggest, it seems that language competency may be the function of the complexities involved in conceptualisation as well as the enabling conditions. In this regard, Cummins (1980) has proposed that there are two levels of language competences; that is, basic interpersonal communication skills (BICS) as well as the Cognitive Academic Language Proficiency (CALP). The first (BICS), serves the purposes of basic communication and CALP deals with high level language use for academic purposes.

From the perspective of the findings on the TEPSI as well as the DAI-Bridge, the TEPSI learners seems to only have mastered the BICS aspect of the language which is closely related to everyday language as Green (1995) has also suggested. On the other hand, the DAI-Bridge learners seemed not to have only mastered the BICS, but also displayed CALP. In terms of the findings, the DAI-Bridge principle seem to have helped the learners through the various language factors such as, the language in which they occur (Rollnick & Rutherford, 1996; Wababa & Diwu, 2010), the discourse of the discipline for which they are used (Dlodlo, 1999; Kearsey & Turner, 1999; Rampal, 2005; Scot, Asoko, & Leach, 2007; Setati, Adler, Reed & Bapoo, 2002) as well as the conventions of the discourse in their home, mother tongue or first language (Diwu, 2010; Odora-Hoppers, 2005; Sutherland & Dennick, 2002; Young, B. L, 1979).

G. Learners' attitudes and awareness of the nature of science and IKS

The effect of an argumentation mediated IK integration towards attitudes to science:

- The findings from both the learners' attitudes to science and their own reflective narrations have shown that learners exposed to argumentation (the DAI-Bridge learners) seemed to have developed favourably dispositions towards their awareness of science embedded in IKS and its equality with school science. As opposed to the DAI-Bridge learners the TEPSI learners who were only exposed to IKS without any explicit argumentation teaching strategies seemed to have been disillusioned and seemed to have viewed IKS to be something restricted to their cultures.

- The interrogation of the learners' cognitive shifts suggested that all learners started with parallel equipollent cognitive stances where school science and IKS held different roles. After the interventions, some of the TEPSI learners' cognitive stances were observed to have remained the same while others exhibited school science dominant cognitive stances. On the other hand the majority of those in the DAI-Bridge were observed to have developed school science emergent cognitive stances.
- Furthermore, as opposed to the TEPSI intervention, the DAI-Bridge intervention showed to have significantly improved the learners' performances with respect to 'scientism'. As with the other findings where the DAI-Bridge outperformed the TEPSI group, the learners' cognitive shifts of the DAI-Bridge learners' moved from being IK dominant to convergent school science emergent cognitive stances, acknowledging the limitations of science. On the other hand, the final cognitive stances of the majority of the TEPSI learners were school science dominant.

In defining learners' attitudes, Osborne et al. (2003) states that attitudes towards science are "essentially a measure of the subjects' expressed preferences and feelings towards an object." (p. 1054). Before the interventions started, all the learners' attitudes towards science and IKS were poor as many of them seemed to have only associated IKS religion and cultural practices. Such findings are common as many other scholars (e.g., Harlen & Holroyd, 1997; Osborne et al., 2003; Papanastasiou & Papanastasiou, 2004; Ramsden, 1998) have also noted. These scholars have noted that science is often presented as a product, thus emphasis is on the acquisition of facts which become unintuitive to learners.

In the context of this study, scholars from socio-cultural perspectives have noted that the above issue becomes even more complex for learners from non-western contexts. These scholars assert that the learners' preconceptions and hence their attitudes towards science may be influenced by the fact that their lifeworlds are embedded within IKS frameworks which are inconsistent with that of school science. (Aikenhead, 1996, Corsiglia and snively, 2001; Department of Education, 2002; Fakudze, 2004, 2008; Le Grange, 2004; Ninnes, 2000; Ogunniyi, 1988; Ogunniyi & Ogawa, 2008; Phelan et al, 1991; Sutherland and Dennick, 2002,).

However, the interventions which incorporated the learners' IK was meant to change the learners' attitudes of science. As Ninnes (2000) has stated, the inclusion of the learners' IK in the teaching and learning materials makes the learners' feel enfranchised since their views on the world are valued and affirmed. However as the findings show, the simple introduction of the learners' IK into the science does not necessarily convert into the improvement of the learners attitudes towards science. Instead, the learners incurred a sense of disillusionment, where they seemed to have equated knowledge with 'science' and not viewing science as one possible knowledge (Ogunniyi, 2007b; Jegede, 1997; Fleer, 1999). In other words, as Ogunniyi (2007) have pointed out, IK is not about artefacts only, but the epistemologies, ontologies and the metaphysical systems underpinning such artefacts (p. 965), so that changes in attitudes can be accomplished. Furthermore, as Ogunniyi et al. (1995) had concluded, for teachers to be knowledgable about science and/or IKS does not that they would transmit valid views about science to their learners or even point out the limitations of the very science they teach.

In the contrary, teachers using traditional teaching approaches such as the TEPSI usually focus on keeping momentum so as to complete the syllabus (Tobin, 1988). The latter is similar to the South African examination-driven education system which, as stated by Ogunniyi (2006, p. 118) is a major source of concern. In another study (Tobin & Garnett, 1988) he noted that while teachers are chasing for the syllabus, learners are left behind thus leading them to develop rote learning and memorisation strategies. As was observed among the TEPSI classes, the learners were observed to have been demonstrating task avoidance behaviours that taxed the teachers' classroom management. In response, teachers were observed to have largely ignored the majority of learners and focussing on what Tobin & Garnet (1988) called 'target students.' In finality, the belief and practice of the TEPSI teachers seemed to have had negative shift on the learners, thus their poor attitudes (Ogunniyi et al. 1995). As observed among the TEPSI learners, their cognitive shifts resembled that of the abandonment of their own IK worldviews in order to satisfy the school science belief without any connectors.

As opposed to the TEPSI approach, the DAI-Bridge enabled the learners' own worldviews to talk to the science worldview (Fleer, 1999) in ways where the learners were afforded opportunities to engage in intra-arguments as well as in inter-arguments with others (Ogunniyi, 2007a, Ogunniyi & Hewson, 2008). Furthermore, as noted by Ogunniyi and Ogawa (2008) the DAI-Bridge group was exposed to, enabled harmonious dualism where the learners could hold two diametrically opposed worldviews without experiencing cognitive.

This is supported by a review by Scholtz, Watson & Amosun (2004) which established that intervention studies which were aimed at creating conducing classroom experiences. Learners were shown to have been able to express their ideas in open discussions with their peers. Furthermore, as a result of their discovery of science embedded within their own IK (Corsiglia & Snively, 2001; DoE, 2002; Fleer, 1999; Newton, 1999; Ogunsola-Bandele, 2009), the learners in the DAI-Bridge seemed have not only developed attitudes towards science, but also their awareness and understanding of the nature of science and IKS.

Finally, with respect to the notion of scientism, the findings have also showed that the DAI-Bridge learners did not only exhibit a significant understanding of the nature of IKS, they also resisted claims that science could solve all human problems. In this regard, the DAI-Bridge intervention also created an awareness among the learners that, the epistemic authority about the NOS rests upon its exactness, reliable methodology as well as its unbiased objectivity (McComas, 1998; Ogunniyi, 2010). As opposed to the TEPSI group, the DAI-Bridge group seemed to have grasped the complex aspects about the nature of science and IKS as a result of the DAI-Bridge context embedded activities (e.g. see Asterhan and Schwarz, 2007 and Newton, 1999; Ogunniyi, 2006). In this regard, there seems to be a consensus that argumentation as a is able to mediate the learning of school science so that the learning of school science does not create scientism among learners, but that they should be able to understand the limitations of each system of thought (Simon, Erduran & Osborne, 2006).

In conclusion, the experiences of the DAI-Bridge approach resulted in what Scholtz, Braund, Hodges, Koopman & Lubben (2008) have called 'inclusive argumentation' where the learners seemed able to harmonise their IK worldviews with that of school science This is in agreement with Gunstone & White (2000) who argued that when learners are taught science in an appropriate manner which recognises multiple worldviews they may be in a better position to know when one worldview is appropriate over another.

The implications of the above findings suggests that, while the presentation of scientific concepts using familiar and culturally oriented objects, artefacts, examples and analogies may be of some value in enhancing the learners understanding and attitudes (Chiappetta et al., 1998; Keys, 1997; Ninnes, 2000), they are however not enough to enhance the learners' awareness of the nature of both science and IKS. Again, as Ogunniyi et al. (1995) have stated, IK introduction in terms of everyday knowledge and practical artefacts and examples will serve to be of great value only when their epistemic, ontological and metaphysical beliefs are unearthed. Furthermore, in order to evaluate the learners' comfort or discomfort, their cognitive shifts will have to be evaluated in order to understand their final cognitive stances as have been established for the TEPSI as well as the DAI-Bridge groups. The findings have thus pointed out that favourable attitudes towards science with respect to the status of IKS would point to either learners attaining to parallel equipollent cognitive stances on issues of non-compatibility (e.g., God and science) or emergent cognitive stance where both IK and science complement each other. In this regard, non-compatibility would refer to situations where the issues at stake do not intersect, but run concurrently alongside each other.

The effect of IK integration towards the learners' attitudes to science:

- As has been revealed from the interrogations of the learners' responses as well as their reflective narratives in both groups, the TEPSI as well as the DAI-Bridge learners' exposure to IK integrated lessons seemed to have created much enthusiasm among the learners. The introduction of IK seemed to have shielded the learners from being completely subsumed by the harsh western Eurocentric scientific worldview. In this regard, the introduction of IK in the science lessons seemed to have been effective in swaying the learning from: (1) 'universalism' (Nosiks 1), (2) the notions that knowledge is developed in laboratories (Nosiks 4) and (3) the notion that the scientific methods is a means of proving the 'truths' about nature. Finally, the findings seem to suggest that the introduction of IK in the learners' lesson seem to drive the learners' cognitive shifts towards school science emergent cognitive stances.

The above findings are interesting in that they seem to have been largely as a result of the introduction of the IK content than how it was mediated. For instance, for all three items depicted in the findings, both the TEPSI as well as the DAI-Bridge learners' post-test performances had significantly improved. A further point of note is that there was no significant differences between the two groups' performances, thus suggesting that the two teaching strategies were statistically comparable. The second point of interest is that the items on the effect of argumentation seemed to have focussed on the nature of IKS while the three above seem to focus on the nature of science. The findings regarding the effects of the introduction of IK seem to confirm findings by Chiappetta et al. (1998, p. 51) who argued that:

> Acquisition of declarative knowledge is further enhanced when the presentation of new science content is coupled with culturally familiar objects, examples and analogies, and when the students are provided with regular opportunities to interact directly with the material being learned. (See also, Keys, 1997).

The above thus seem to explain, why the TEPSI learners may not have developed sufficient awareness of the nature of IKS, but significant awareness relating to the nature of science. A further corroboration to the latter statement is depicted by the findings which showed that the cognitive shifts of the learners were from IK dominant to school science emergent cognitive stances. Combining the effects of TEPSI learners' responses and performances on items relating to the status of science and those discussed above, one conclusion seem to suggest that, "culturally diverse students develop meaningful science understandings when they see their culture facilitating learning rather than seen as an impediment to it." (Chiappetta et al., 1998, p. 51).

While the TEPSI learners seem to have enjoyed the IK integrated lessons, they however were in dilemma regarding its scientific status. In other words, the TEPSI learners seemed to regard IK as serving a different role and science another – which is scientific; as have been noted regarding scientism among the TEPSI learners. However, as the above findings have shown regarding the inclusion of IK, it is almost impossible to obliterate the learners' views or beliefs about their IK no matter how much hegemonic school science may have been (Hewson, 1988; Hewson & Hewson, 1988, 2003; Posner et al. 1982).

The implications for the inclusion of IK into school science towards the learners' attitudes to science suggests that lessons which are not mediated by argumentation may lead seeing learners viewing IK and school science as serving two different roles. This is consistent with concerns raised by Cobern & Loving (2001) regarding the hegemony of school science and its prestige in society. The latter scholars proposed that IK and science should be accorded equal, but different status, while other scholars (e.g., Finley, 2009) raised a question regarding the scientific status of IKS. In other words, premised on the view that there is 'lost knowledge' as a result of the marginalisation of IKS, he raises concerns about how one could identify the lost knowledge and hence evaluating its validity or otherwise. The latter has also been echoed by Onwu (2009) who claimed that the issue of including IK into school science still remains a murky one. Finally, with regard to the findings among the TEPSI learners, we can conclude that the efforts of integrating science and IK failed to address, "…the engaging tension perhaps, amongst learners in our schools, between indigenous and scientific ways of knowing with the possibility of each stimulating and supporting the other in our classroom contexts."

The role and purposes of conducting experiments in the laboratory

- Both groups seemed to have exhibited poor attitudes towards their understanding of the role of experiments in the laboratory. This suggests that the inclusion of the learners' IK nor an argumentation framework may not necessarily illuminate the role of experiments in the laboratory. The cognitive shifts of both the TEPSI as well DAI-Bridge starting with school science dominant cognitive stances and remained the same till after their respective interventions.

The above findings are not uncommon to the rest of the world. As McComas (1998) points out, some of the myths about science are most likely caused by the explicit inclusion of faulty ideas in textbooks while others are as a result of omissions in text. To illustrate the latter statement, a statement from the Curriculum and Assessment Policy Statement (CAPS) document (DoBE, 2012, p. 122) have this to say about what an experiment is and its purpose:

> Practical investigations should use performances at different levels and a focus on process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts. The difference between practical investigation and an experiment is that an experiment is conducted to verify or test a known theory whereas an investigation is an experiment that is conducted to test a hypothesis, i.e. the result of outcome is not known beforehand.

From the above, it is not very difficult to see the contradictions which may be a source of confusion to teachers and hence trickle down to learners (Ogunniyi et al., 1995). The quotation states that an experiment is different from an investigation in that an experiment is conducted to verify or test a known theory, while an investigation is also defined as an experiment whose purpose is to test hypotheses. The first point in the policy statement regards testing of theories and hypotheses which Alexander (2009) sees as problematic. He states that, "If you were to ask me what scientific idea I think is most destructive, then I would say the idea that in science we have to test to explain is hugely problematic (Alexander, 2009, p. 1).

The second point is that there is a very fine line between an experiment and a practical investigation since the two terms are generally used interchangeable in schools as well as by scientists in their day to day activities. For example, scientists usually repeat experiments not for the purpose of verifying theories, but rather to verify findings from other scientists' investigations. The third point is that learners in schools are usually taught to state their hypotheses in the process of conducting their experiments. In contrast to the latter, the policy statement reserves hypothesizing for practical investigations. The fourth point is that the term 'hypothesis' has three meanings. According to McComas (1998) (citing Sonleitner), a hypothesis can either refer to an 'explanatory hypothesis' which might become a theory, a generalizing hypothesis which might become a law or just a prediction if it is intended to be a forecast (p. 56).

Fifth, is the issue of verification and testing of theories with respect to experiments and the issue of hypothesizing in respect of investigations. As already highlighted, hypotheses with respect to theories are explanatory hypotheses. It is in this regard, that McComas suggested that the term hypothesis should be replaced by predictions, explanatory hypothesis with regard to provisional theories or generalizing hypotheses with regard to trial laws. As opposed to the findings by both learner groups as well as the CAPS policy statement, McComas, (2014) has suggested that laboratory experiments should be used to introduce lesson rather than using them to emphasize the known that is the verification of 'known theories.'

To illustrate the confusions about experimentation activities in schools, McComas (1998, p. 64) made the following statement which speaks to what may be seen a worldwide issue of concern:

> Throughout their school science careers, students are encouraged to associate science with experimentation. Virtualy all hands-on experiences that students have in science class are called experiments even if they would more accurately be labeled as technical procedures, explorations or activities. (p. 64).

To be able to help learners overcome such misconceptions in order to enhance their attitudes about science with regard to experimentation would require some understanding of the philosophy of science in addition to their understanding of the nature of science.

As Lubben, Sadeck, Scholtz & Braund (2010) have noted in studies which also looked at the role of small groups in experimental tasks, many schools do not have sufficient resources or even up and working laboratories where experiments can be part of everyday teaching and learning. Most of what should occur in experimentation is done cognitively using what is generally called 'cookbook' laboratory activities or those typical of 'dry' laboratory activities (McComas, 2014). As opposed to the 'single' class experience of practical work or experimental work predominant in various schools highlighted above, McComas has suggested that the use of long term laboratory activities can show learners how science works in real life. As Lubben et al. (2010) has argued, if learners may be exposed to laboratory work as their normal school activities, '…the generation of experimental data' may'…refine students' understanding of the validity and reliability of the measurements' (p. 2158).

5.3 Limitations

5.3.1 Syllabus and pacesetters

Teachers are expected to abide by weekly pacesetters which are guided by the syllabus, hence a challenge with regard to the choice of ideal topics for this study. To counter this, an action research design was adopted and hence classroom interventions were designed according to the pacesetters in the particular research periods.

5.3.2 The nature of content orientation (Science-IKS)

Some school science topics are not as easily amenable to integration with the learners' IK. This has been as a result that there are no IK-science textbooks readily available to enhance the incorporation of the learners' IK in the classrooms. In turn this had an effect of destabilizing the preparation time for lessons that needed to be conducted in a particular intervention week. This has been a strain for the TEI teachers as well as they had never been trained in the IKS worldview.

5.3.4 The language of teaching and assessment

Whilst the content of the lessons was bilingually structured and requiring learners to use whichever language they choose to express themselves, it became a challenge for learners to want to use isiXhosa as they were concerned about examinations which required English as opposed to isiXhosa. Teachers in both interventions had to make attempts to use isiXhosa to try and elicit or to communicate IK to the learners as IK is predominantly explicated in the learners' languages – which is isiXhosa in this case. Despite all the attempts to try a develop some content-specific terminologies for the teachers, the process taxed all the participants as some teachers as well as learners were not acquianted with the newly coined terminologies. This forced the participating teachers to adopt additive bilingual or mother tongue-based bilingual techniques to enhance the learners' metalinguistic skills. As was noted in the learners' demographic profile, some of the learners were non-isiXhosa speakers and hence they had to rely on their limited language skills.

5.3.5 The nature of intervention strategies

As learner were not used to the dialogical teaching and learning strategies, they tended to want to argue more than it was required for them to do so, thus impacting on classroom as well as time management for each lesson. This contributed to learners having a difficulty in completing worksheets which were meant for data collection. The mentee teacher was not exposed to the DAI approach for an adequate period of time, hence her confidence was not at its optimum.

5.3.6 School programmes

The school programmes such as sports days, school time destabilisations as a result of boycotts and whole school evaluations etc. had impact on the destabilisation of weekly intervention plans which necessitated some rescheduling or redesign of intervention lessons to comply with the teaching content for the particular week.

No doubt, this crisis created an anomalous setting for me and hence constitutes part of the limitations of this study. But as Ogunniyi (1992) has ably argued, research in the social sciences (including education) are fraught with a congeries of extraneous variables such as history, maturation, high mortality rate, unpredictability of humans who often act and react to contextual changes, lack of universal theories about human behaviours, problems associated with formulating terms or variables with precise operational definitions etc.

5.4 Implications of the findings

The primary focus of this study has been in classroom-based research in a select high schools of low economic status. Furthermore, the central focus of the research has been on the perennial problem facing the effective implementation of an IK integrated curriculum in South Africa.

In this regard, the findings from this study have implication for curriculum development, teacher training and instructional practices. Again, the findings have thus re-affirmed the importance of classroom research as a critical aspect of curriculum implementation. It is one thing to design a new curriculum but another matter to see it work in the classroom setting. An important lesson that can be drawn from this experience is that there is a wide gap between curricular idealization and implementation. Secondly, the current school and classroom context warrants a closer consideration by curricular planners. Thirdly, a new curriculum development without adequate teacher preparation is not likely to succeed at all (Jansen & Christie, 1999; Kyle, 1989). The following issues are worth of scholarly attention:

- Teachers, curriculum advisers, curriculum planners and Education Management District Coordination (EMDC) officials will need retraining.
- In order to reach the ideals of an IK-integrated science curriculum as stipulated for Specific Aims 3 of the CAPS document, curriculum planners and policy makers should review, redesign and make amendments to guide the mechanisms of how teachers can incorporate the learners' IK in the science lessons.
- In conjunction with the above, institutions of higher learning will also need to re-align their teacher education programs to develop teachers that have an awareness of and understanding of the natures of both school science and IKS. As findings have shown, all the above would need to be supplemented by systematic or structured bilingual terminology training to inculcate systematic code-switching as opposed to haphazard code-switching (see, Dlodlo, 1999).
- Since school science and IKS are premised on different worldview presuppositions (Ogunniyi, 2007a) and that learners in non-westernized contexts are viewed to be crossing borders to and fro between their home and school cultured, a bridge to merge the two worldviews will need to be part of the teaching and learning materials.

- While training of teachers on the natures of both science and IKS may enhance their awareness of the limitations of the two worldviews, they will still need to be trained in the DAI-Bridge principle so that they will be able to erect cognitive bridges between school science and IKS. The DAI-Bridge principle is an intervention mechanism that is premised on the view that the integration of IK and science has the potential of creating cognitive conflicts among the learners.

- The DAI-Bridge principle, as stated above, presupposes that the teachers do not only have an awareness of the natures of both science and IKS, but that they should be well versed in scientific laws and their underpinning theories. This implies an understanding of science and IKS internal principles and their corresponding bridging principles.

- Teacher training on the DAI-Bridge principle will also enable them to be in a better position to transfer the skills on how to deal with the distinct intern principles of school science and IKS so as to enhance the Learners' ability to negotiate the chasms of science and IKS. This will help the learners to develop the scientific skills, knowledge, values and attitudes and hence their understanding of how science works and is developed (Ogunniyi, 2008).

It seems evident from the above observations that an argumentation framework in the form of the DAI-Bridge principle have the following implications for curriculum planning as well as lesson planning for teachers:

- The DAI-Bridge principle could be used as a tool to guide the material developers in creating culturally and socially-relevant teaching and learning materials. In this regard, helps in analyzing the internal principles governing the scientific concepts and the identification of connectors or predicates for the corresponding IKS. This is based on the view that IKS has its own internal consistencies.

- For the classroom lesson planning, the DAI-Bridge principle can be used to identify the nature of scientific concept to be taught and hence analyse their internal principle so as to also identify the corresponding IKS internal principle so as to start a lesson fully prepared to help learners in navigating the chasms between the distinct worldviews of science and IKS.

- The DAI-Bridge principle also have implications for not assuming that the learners would easily abandoned their entrenched beliefs and attitudes as a result of a series of well implemented classroom lessons (Ogunniyi & Hewson, 2008; Ogunniyi et al., 1995). Instead, these perceived misconceptions or alternative conception are to be seen as the building blocks for filling the gap between the learners' IK-based conceptions and school science. In this regard, the DAI-Bridge principle could prove to be indispensable in calculating the Zone of Proximal Development (ZPD) (Vygotsky, 1978). Anything in contrary to this view would promote a conceptual change teaching and learning approach which requires a dramatic restructuring of the learners' existing base knowledge (Feltham & Downs, 2002).

It seems obvious from the above that the DAI-Bridge principle as a dialogical argumentation framework as a mediation and bridging strategy pre-supposes adequate training on the part of all stakeholders. These will include teachers who in turn will have to equip their learners with the necessary skills to use the framework in the process of making sense of the nature of IKS and science and hence connect knowledge claims between the two. The disadvantages of the bridging mechanism and argumentation as a mediation strategy are dependent on a number of factors. These factors that can lead to the DAI-Bridge Principle not working efficiently as depicted below:

- If teachers are not well trained on the DAI-Bridge model, on the nature of science and IKS coupled with the adequate content knowledge content knowledge, then any attempts to apply the model can prove to be a delucive exercise (Jansen and Christie, 1999, Kyle, 1989).
- If teachers use a method of teaching in which they lack necessary skills as was the case in the TEPSI group, then learners' awareness about and understanding of the NOS and NOIKS will diminish instead of being enhanced (Ogunniyi & Ogawa, 2008).
- Similar to the issue of the distinct worldviews of IK and science, if the issue of language and terminology development is not part of the process, then the efficiency of this teaching strategy might be undermined as IKS is largely underpinned by language.
- The method of the DAI-Bridge will need a lot of preparation for each task. If preparation is poor, then the efficiency of the method will again be undermined (Diwu, 2010; Stone, 2009).
- Finally, if the learners' prior knowledge based on IKS is not recognized as part of learning, then the DAI-Bridge principle will be redundant since it is designed to be a bridging strategy

to facilitate the process of learning by finding a contiguity between IK to school science (See, Ogunniyi, 1988; Ogunniyi, 1995).

In conclusion, an argumentation framework based on the DAI-Bridge principle can prove to be a very crucial teaching and learning tool such that teachers' confidence in mediating IK integrated science classes can be enhanced. Furthermore, when learners are also inducted to the same protocols, there may be high possibilities for learners being able to develop and apply scientific knowledge in a responsible manner. When situations requiring informed decision-making on socio-scientific issues arise, they will be in a better position to take necessary steps than depend on the gut feeling or trial an error approaches. (Erduran, 2006; Kyle, 1989; Ogunniyi, 2007a;).

5.5 Conclusions

The Dialogical Argumentation Instruction Bridge (Bridge) principle incorporating the Contiguity Argumentation Theory (CAT) as well as Hempel's Bridge Principle has proved to be an innovative lesson planning and an instruction method that requires thorough pre-thinking and careful preparation. In this regard, the findings (Classroom observations, teachers' and learners' reflective narratives) strongly suggested that, teachers without thorough training in the subject matter knowledge, the nature of science (NOS) and the nature of IKS (NOIKS) will hardly be in a position to: 1. Plan and develop authentic IK integrated science lessons that are of high scientific rigour, 2. Mediate the incongruities that would normally arise among learners as a result of the incompatibilities between school science and IKS.

Without the DAI-Bridge principle, it would have probably been not possible to: 1. Gain a further understanding of the mechanisms by which the various border crossing models are possible (e.g., see Aikenhead, 1996; Jegede, 1995, Aikenhead & Jegede, 1999). This include other phenomena such as the 'harmonious dualism' which has noted that science and IKS are not mutually exclusive of each other (Ogunniyi, 1986), 2. Understand and describe the learners' conceptions of the phenomena of light and sound accurately, since "ideas that are unlinked to the content in an adult scientific logical sense may be linked for the student" (Marin et al., 2001: 685), 3. Develop a model for determining the complexities involved in integrating particular school science and IK scientific concepts. For example, the incompatibilities usually observed between science and IKS (Ogunniyi, 2007) are as a result of the internal principles underpinning each thought system internal consistencies (see, Battiste, 2002; Hempel, 1966; Keane, 2007; Kelly et al., 1993; Ogunniyi, 1988; Ogunniyi & Ogawa, 2008).

To make an example, the observations from the TEPSI classrooms suggest that, while the teachers and learners were enthusiastic with the inclusion IK in the science lessons, their enthusiasm however turned into a disillusionment and frustrations among the learners. This was because learning for the TEPSI learners was not designed to be within the personal meaning and experiences of the learners (Wallace, 2003). With respect to the DAI-Bridge principle, the search of prior knowledge was not about whether the learner ideas were correct or not correct, but finding out why the learners think or exhibit certain ideas which seemed not to be linking to the content. In this regard, the DAI-Bridge principle utilized dialogical/discursive activities which enabled the learners to provide reasons in support of their conceptions, thus contributing as co-producers of their own knowledge (Aleixandre, 2002).

Although the intervention was for a very short time (first two school terms), the DAI-Bridge principle as a lesson planning and an instruction method seemed to be working even for shorter periods. The above finding is further vindicated by the fact that, the learners and teachers in the DAI-Bridge groups though not used to this method of teaching still showed enthusiasm and support for it. The other important conclusion to be made is that, the DAI-Bridge seemed to have enhanced the learners' scientific rigour than watering it down. In fact, the learners seemed to have exhibited attributes that show understanding rather than conceptual change learning based on the subjugation of the learners' prior conceptions. In conclusion, although there were intervening variables as explicated in the section on limitations, the study was not without some positive indications. In terms of the purpose of the study and the research questions, the findings suggest that this study fulfilled its objectives.

5.6 Recommendations

In the light of the implications and conclusions of this study there were many issues relating to the inclusion of IKS into the mainstream school science syllabus. Some of the issues are as follows:

- While the call to include IKS into the mainstream school science is without question an essential one, however, the call somehow underrated the diverse nature of epistemic authorities underpinning school science and IKS. In the light of this view, the RNCS/NCS as well as the CAPS policy documents will have to be revisited to clearly and unequivocally spell out the role of IKS in science teaching. That is, the purpose of IK teaching, assessments and examination, the issue of what aspects of IKS could be examinable (See, Finley, 2009; Mosimege and Onwu, 2004 and Onwu, 2009) and what possible classroom mediation strategies could be proposed.

- As a results of the above observations, many teachers during the workshops which were conducted for introducing this study including the participant teachers were complaining that there are no textbooks or Learning and Teaching Support Materials (LTSMs) to help them in their attempts to comply with the CAPS document. They further noted that examinations had very little IK related questions and thus questioned the importance of even trying to waste time talking about IKS. These observations generally led the TEPSI teachers to view and to use the learners' IK as only as a means of creating contrasts between the learners' conceptions and the intended scientific conceptions. Recommendations based on the findings of this study would suggest that, the learners' prior conceptions should be interrogated for their scientific status (Corsiglia & Snively, 2001; DoE, 2002; Ogunsola-Bandele, 2009) using IK internal principles as opposed to the school science internal principles. As stated by Kelly et al. (1993) as well Ogunniyi & Ogawa (2008), the relevance and rationality of any worldview explanation are dependent upon the principles and beliefs that underpin the worldview that created its knowledge claims. In other words, IKS cannot be evaluated using western science internal principles as it has its own internal consistencies (Battiste, 2002).

If we look at countries like Japan which are now at the forefront of scientific innovation, we would see that they had also been in the same situation as South Africa at some stage. For instance, Ogawa as cited in Ogunniyi et al. (1995) has argued that:

> The Japanese never lost their cultural identity when introducing western science and technology, because they introduced only the practical products of western science and technology, never its epistemology or world view.

Firstly, my understanding of the above statement seems to echoed the sentiments echoed by Wallace, 2007) who argued that learners who are endowed with more constructivist learning beliefs and awareness of and the knowledge of the nature of science may feel epistemologically empowered "…to create their own questions, connections, and knowledge claims"... and that "… those who believe that science is a body of correct knowledge to be learned may feel disempowered to create their own scientific ideas." (p. 2). Secondly, is in accord with the assertions made by McComas (1998) where he cites Dunbar as drawing similarities between science as practiced in traditional societies as analogous to 'cookbook science' and explanations or epistemologies as theoretical science. He argues that traditional people observe the patterns or laws of nature and then apply the rules without necessarily knowing why nature operates in the manner that it does.

In conclusion, while the above analogies are very much illuminating for the problem at hand, the analogies overlook one point; that is, when traditional people apply the rules of nature they are informed by IK internal principles which underpin the observations of natural occurring events and never the western science epistemologies. In this regard, the DAI-Bridge Principle provides the corresponding explanations for the "cookbook science."

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APPENDIX A: ***PERMISSION TO CONDUCT RESEARCH IN WESTERN CAPE SCHOOLS***

Directorate: Research

Western Cape Government
Education

Audrey.wyngaard2@pgwc.gov.za

REFERENCE: 20130222-6447

ENQUIRIES: Dr A T Wyngaard

Mr Christopher Diwu

2 Michelle Avenue Mandalay 7785

Dear Mr Christopher Diwu

RESEARCH PROPOSAL: EXPLORING SCIENTIFIC AND INDIGENOUS KNOWLEDGE SYSTEMS WORLDVIEW OF GRADE 10 LEARNERS EXPOSED TO TRADITIONAL AND DIALOGICAL EXPOSITORY INSTRUCTION ON FERMENTATION

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. **The Study is to be conducted from 20 January 2014 till 30 September 2014**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.

9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.

10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.

11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

The Director: Research Services Western Cape Education Department Private Bag X9114 CAPE TOWN 8000

We wish you success in your research.

Kind regards. Signed: Dr Audrey T Wyngaard

Directorate: Research DATE: 05 December 2013

Lower Parliament Street, Cape Town, 8001 tel: +27 21 467 9272 fax: 0865902282 Safe Schools: 0800 45 46 47

Private Bag X9114, Cape Town, 8000 Employment and salary enquiries: 0861 92 33 22 www.westerncape.gov.za

tel: +27 021 467 9272 Fax: 0865902282 Private Bag x9114, Cape Town, 8000 wced.wcape.gov.za

APPENDIX B: RESEARCH ETHICS APPROVAL FROM THE UNIVERSITY OF THE WESTERN CAPE

OFFICE OF THE DEAN
DEPARTMENT OF RESEARCH DEVELOPMENT

UNIVERSITY of the
WESTERN CAPE 16 January 2013

To Whom It May Concern

I hereby certify that the S Research Committee of the University of the Western Cape has approved the methodology and ethics of the following research project by: Mr C Diwu (Education)

Research Project: Exploring scientific and indigenous knowledge worldviews of Grade 10 learners exposed to traditional expository and dialogical argumentation instruction on fermentation.

APPENDIX C: ***CONSENT FORM: Teacher***

CONSENT

I hereby give my express permission to participate in this study and to conduct classroom based intervention lessons, attending any briefing sessions or interviews in order to give feedback to inform the study. I understand that I am also participating freely and without being forced in any way to do so. I also understand that I can stop participating at any point should I not want to continue and that this decision will not in any way affect me negatively.

I understand that this is a research project whose purpose is not necessarily to benefit me financially except for my professional development.

I ________________________________ (Name) give my express permission to participate in this study entitled, "Exploring scientific and Indigenous Knowledge Systems worldviews among grade 10 learners exposed to Traditional and Dialogical Expository Instruction on fermentation"

……………………………..

Signature of participant **Date**:…………………..

I hereby agree/disagree__________ to the tape/video-recording of my participation in the study.

……………………………..

Signature of participant **Date**:…………………..

APPENDIX D: ***CONSENT FORM: Learner (IsiXhosa version not appended)***

CONSENT

I hereby agree to participate in the intervention lessons on the concept of fermentation as (including our beliefs and practices) as understood from a school science perspective as well as that of indigenous knowledge. I understand that I am participating freely and without being forced in any way to do so. I also understand that I can stop participating at any point should I not want to continue and that this decision will not in any way affect me negatively.

I understand that this is a research project whose purpose is not necessarily to benefit me financially but to enrich my understanding of what we learn in science at school and what we do at home.

I ________________________________ (Name) give my express permission to participate in this study entitled, "Exploring scientific and Indigenous Knowledge Systems worldviews on grade 10 learners exposed to Traditional and Dialogical Expository Instruction on fermentation"

……………………………..

Signature of participant **Date**:…………………..

I hereby agree/disagree__________ to the tape/video-recording of my participation in the study.

……………………………..

Signature of participant **Date**:…………………..

APPENDIX E: ***PRE-ARGUMENTATION APPETISER***

INTRODUCTION TO AN ARGUMENTATION-BASED DEBATE

PREAMBLE: Study & Show yourself Approved by God (2 Tim 2:15)

Watch your life and doctrine closely. Preserve in them, because if you do, you will save both yourself and your hearers. **(1 Tim 4:16)**
They want to be teachers of the law, but they do not know what they are talking about or what they so confidently affirm. **(1 Tim 1:7)**
Turn away from godless chatter and opposing ideas of what is falsely called KNOWLEDGE, which some have professed and in so doing have wondered from the FAITH. **(1 Tim 6:20-21)**

TITLE: Science and God – Is God and science

Atheist Science Professor vs Christian & Science Student

An atheist professor of philosophy speaks to his class on the problem science has with God, The Almighty.
He asks one of his new students to stand and…

THE PROFESSOR STARTS

Prof: So you believe in God?
Student: Absolutely, sir.
Prof: Is God good?
Student: Sure.
Prof: Is God all-powerful?
Student: Yes.
Prof: My brother died of cancer even though he prayed to God to heal him. Most of us would attempt to help others who are ill. But God didn't. How is this God good then? Hmm?
Student is silent
Prof: You can't answer, can you? Let's start again, young fella. Is God good?
Student: Yes.

Prof: Is Satan good?

Student: No.

Prof: That's right. Tell me son, is there evil in this world?

Student: Yes.

Prof: Where does Satan come from?

Student: From… God…

Prof: Evil is everywhere, isn't it? And God did make everything. Correct?

Student: Yes.

Prof: So who created evil?

Student does not answer

Prof: Is there sickness? Immorality? Hatred? Ugliness? All these terrible things exist in the world, don't they?

Student: Yes, sir.

Prof: So, who created them?

Student has no answer.

PROFESSOR PRESENTS SOME BACKINGS

Prof: Science says you have 5 senses you use to identify and observe the world around you. Tell me son… Have you ever seen God?

Student: No, sir.

Prof: Tell us if you have ever heard your God?

Student: No, sir.

Prof: Have you ever felt your God, tasted your God, smelt your God? Have you ever had any sensory perception of God for that matter?

Student: No, sir. I'm afraid I haven't

Prof: Yet you still believe in Him?

Student: Yes.

NOW THE PROFESSOR MAKES HIS CONCLUDING REMARKS ABOUT GOD

Prof: According to empirical, testable, demonstrable protocol, science says your GOD doesn't exist.

What do you say to that, son?

Student: Nothing. I only have my faith.

Prof: Yes. Faith. And that is the problem science has.

NOW THE CHRISTISTIAN STUDENT TAKES HIS TURN TO DIRECT QUESTIONS

Student: Professor, is there such a thing as heat?

Prof: Yes.

Student: And is there such a thing as cold?

Prof: Yes.

Student: No sir. There isn't.

The lecture theatre becomes very quiet with this turn of events.

Student: Sir, you can have lots of heat, even more heat, superheat, mega heat. But we don't have anything called cold. We can hit 458 degrees below zero which is no heat, but we can't go any further after that. There is no such thing as cold. Cold is only a word we use to describe the absence of heat. We cannot measure cold. Heat is energy. Cold is not the opposite of heat, sir, just the absence of it.

There is pin-drop silence in the lecture theatre.

Student: What about darkness, Professor? Is there such a thing as darkness?

Pro: Yes. What is night if there isn't darkness?

Student: You are wrong again sir. Darkness is the absence of something. You can have low light, normal light, bright light, flashing light… But if you have no light constantly, you have nothing and it's called darkness, isn't it? In reality, darkness isn't. If it were, you would be able to make darkness darker, wouldn't you?

THE PROFESSOR ASKS FOR CONCLUDING REMARKS

Pro: So what is the point you are making, young man?

Student: Sir, my point is your philosophical premise is flawed.

Prof: Flawed? Can you explain how?

STUDENT PRESENTS HIS REBUTTAL TO THE PROFESSOR'S ARGUMENT

Student: Sir, you are working on the premise of duality. You argue there is life and then there is death, a good God and a bad God. You are viewing the concept of God as something finite, something we can measure. Sir, science can't even explain a thought. It uses electricity and magnetism but has never seen, much less fully understood either one. To view death as the opposite of life is to be ignorant of the fact that death cannot exist as a substantive thing. Death is not the opposite of life: just the absence of it.

STUDENTS PRESENTS BACKINGS

Now tell me, Professor. Do you teach your students that they evolved from a monkey?

Prof: If you are referring to the natural evolutionary process, yes, of course, I do.

Student: Have you ever observed evolution with your own eyes, sir?

Prof: *The professor shakes his head with a smile, beginning to realize where the argument is going.*

Student: Since no one has ever observed the process of evolution at work and cannot even prove that this process is an on-going endeavour, are you not teaching your opinion, sir? Are you not a scientist but a preacher?

The class is in uproar.

Student: Is there anyone in the class who has ever seen the Professor's brain?

The class breaks into laughter.

STUDENT MAKES HIS CONCLUDING STATEMENT

Student: Is there anyone here who has ever heard the Professor's brain, felt it, touched or smelt it? No one appears to have done so. So, according to the established rules of empirical, stable, demonstrable protocol, science says that you have no brain, sir. With all due respect, sir, how do we then trust your lectures, sir?

THE PROFESSOR REPLIES AND CONSENSUS IS REACHED

Professor: *The room is silent. The professor stares at the student, his face unfathomable.*

I guess you'll have to take them on faith, son.

Student: That is it… The link between man & God is FAITH. That is all that keeps things moving and alive.

Source: www.patrish.com/atheist.html adapted

APPENDIX F: INTRODUCTORY WORKSHOPS FOR TEACHERS AND OFFICIALS

CLASSROOM BASED INTERVENTIONS[1]: 2014

THEME:

Delivery of IK-contextualised Physics lessons using argumentation as a vehicle of instruction

Presented By: Mr Christopher Diwu
PhD Candidate – Science Education, UWC

Promoter: Prof. Meshach Ogunniyi

Diwu, C. (2014). Exploring scientific and indigenous knowledge worldviews of high school learners exposed to Traditional/Dialogical expository instruction on selected school science topics. Unpublished PhD Thesis. The University of the Western Cape.

Senior Professor of Science Education
School of Mathematics and Science Education
The University of the Western Cape, RSA

PART 1: ORIENTATION INTO SCIENTIFIC ARGUMENTATION

All scientific claims are based on some beliefs, evidence from experimental data and observations. From the history and philosophy of science, all such premised upon which scientific claims are based are what make the scientific enterprise an argumentative exercise. To understand the nature of science as well as IKS, the lessons adopts argumentation as a tool for validating scientific claims by breaking down and describing all elements that support such claims. Argumentation is also a tool that shows explicitly the link between the specific aims 1, 2 and 3, competencies and values that lead to the development of critical thinking skills and the awareness of and understanding of the nature of scientific enquiry.

While there are other argumentation frameworks, the frameworks that have been found to be most useful for science education in the extant literature are those of Toulmin (1958) and Ogunniyi's (2002) **Contiguity Argumentation Theory** (CAT). **Toulmin's Argumentation Pattern** (TAP) is a framework purely following school science logic. While also employing a logical approach of the TAP, CAT further seeks to explain the apparent reasons for the learners' shifting argumentation positions. This is a good attribute for reflexive learning so one might learn to distinguish between different scientific contexts. For instance, in mechanics we talk of a force F acting on rigid bodies of mass M while in electrodynamics or electricity we talk of a force V acting on a charge q instead of a mass M.

Table 1: Elements of Toulmin's Argumentation Pattern

Claim	A scientific statement proposing a conclusion or articulation of a belief.
Counter-claim	An scientific statement proposing an alternative conclusion without opposing the claim or belief articulated above
Evidence	Reason, facts or data presented in order to support the claim or counter-claim given.
Qualifier	A contingent condition upon which the claim or counter-claim is valid
Warrant	Statements used to establish and to justify the relationship between the evidence and the claims or counter-claims made.
Backings	Implicit assumptions or generalizations that serve as support for the claims/counter-claims.
Grounds	A collective terms for all statements that support a claim or counter-claim (e.g. evidence, warrants and backings).
Rebuttal	A single statement that can prove any of the grounds to be false, thus making the claim or counter-claim to be false as well.

By way of example and illustration, let us consider the structure of the following scientific statement to see how TAP can be used for analyzing and understanding of scientific statements.

EXEMPLE 1 - CHEMISTRY: For most known liquids, experimental results conducted at sea level have shown that water is have the highest boiling point where it boils at the temperature of 100^{o} C.

Claim	The normal boiling point of water is 100^{o} C.
Counter-claim	The boiling point of water is not always 100^{o} C.
Evidence	The atmospheric pressure must be 1 atm
Qualifier	Measurements must be at sea level
Warrant	When the vapour pressure is 1 atm the water will boil at 100^{o} C
Backings	The pot should be open to the atmospheric pressure
Rebuttal	Any condition not met above results in rejection of the claim.

EXAMPLE 2 - PHYSICS: Scientific investigations have showed that all bodies near the surface of the earth or within its gravitational field will fall freely towards the centre of the earth with an acceleration of 9.8 m/s^2. Complete the following as in example 1 above.

Claim	All bodies near the surface of the earth or within its gravitational field will fall freely towards the centre of the earth with an acceleration of 9.8 m/s^2.
Counter-claim	
Evidence	
Qualifier	
Warrant	
Backings	
Rebuttal	

Table 2: Ogunniyi's Contiguity Argumentation Theory (CAT) worldview cognitive categories.

Dominant ideas	Those ideas or statements of belief that lead to a particular position or claim
Suppressed ideas	With a change of context, a used-to-be dominant idea can be suppressed by the very idea that it had dominated.
Assimilated ideas	These are those current cognitive ideas which are challenged by a new idea to such an extant that they are modified to a more plausible mental state.

Emergent ideas	These are ideas which are new to the learners and thus have no rival or opposing from the learners' previous experiences or knowledge.
Equipollent ideas	Those competing ideas that exert comparable equal intellectual or emotional force on the learners' cognitive structure.

Let us go back to example 1 and 2 and imagine that in your classroom you have a mixture of learners from the planet earth that your in and other learners from mars also trying to understand the Physics and Chemistry you are teaching.

Question: Which learners do you think will struggle to grasp the scientific concepts you are teaching and why?

____
____

Comment: Despite their validity, it is most likely that the validity or 'truthfulness' of the claims made by examples 1 and 2 might be vigorously challenged by learners coming from mars and will not accept them thus causing cognitive dissonance.

Using the Contiguity Argumentation Theory (CAT), there are various situations that can occur with the learners from mars.

1. They could either decide to memorize the claims made by example 1 and 2, thus their Mars worldview being suppressed in favour of the exam favourable earth centered worldview.
2. Refuse to accept what is being taught and opt to drop out from science as a subject or
3. Be assimilated to the earth-centered view by adjusting their Mars-centered worldview with the earth-centered worldview concepts.
4. If there is no water or gravity in Mars, then the concept of water and gravity can be emergent unopposed ideas for the Mars learners.
5. Having been in Mars and now on earth, the idea of 'no gravity' on mars and 'gravity' on earth could be equipollent ideas as a result of the Mars learners' dualistic experiences.

Finally, it should be noted that, the CAT helps us to understand what science learning barriers learners could be experiencing by analyzing their right as well as wrong answers or what we would normally want to call 'misconceptions'. The CAT will for most times show us what alternative conceptions our learners hold. The CAT also reveals issues of beliefs which learners might use in backing up their scientific claims.

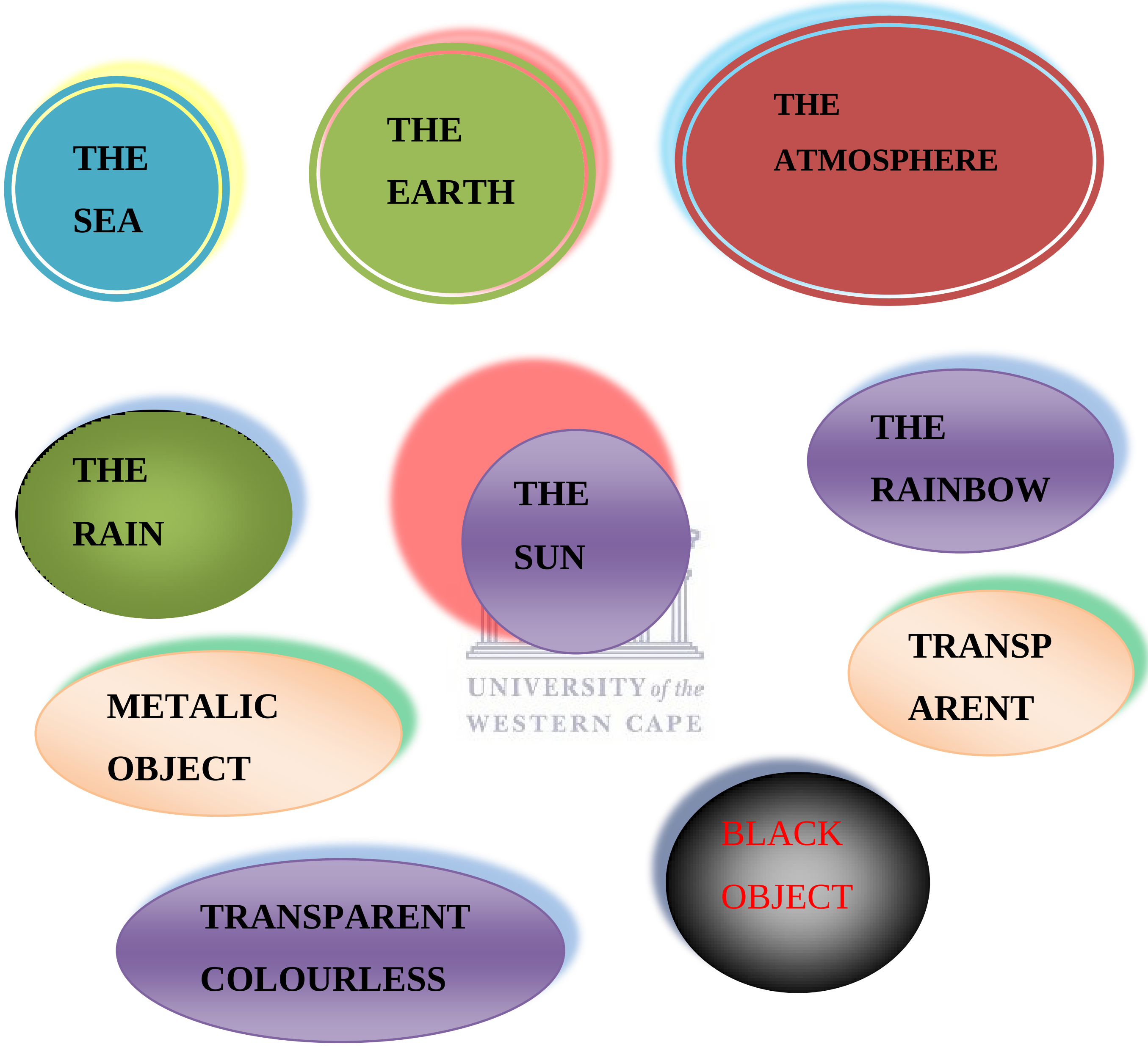
CLASSROOM ACTIVITIES

Lessons in Physics using the argumentation framework model

<u>THEME:</u> The phenomena of light

TOPIC : Geometric optics – Refraction, reflection and Snell's Law			
WHAT:	**PURPOSE:** **SPECIFIC AIMS AND SKILLS TO BE ACQUIRED**	**How: Teaching and learning sequence and time frames**	**WITH WHAT: LTSM'S**
Note: Specific Aims, skills, learning objective and content are aligned to the CAPS			
LEVEL: Grade 10, 11 & 12 **CONTENT TO BE TAUGHT:** ✓ Understanding of the nature of light. ✓ Understanding the electromagnetic spectrum. ✓ Understanding of the terms: incident, reflected, absorbed and refracted ray ✓ Understanding the concept of visible and invisible light. ✓ Understanding the concept of a black body. ✓ Understanding the concept of primary and secondary colours of light. ✓ Understanding the formation of the rainbow. ✓ Understanding internal reflection and the concept of the critical angle. ✓ Understanding and the application of Snell's Law.	**S. A: 1, 2 & 3** **SKILLS that learners should develop:** ✓ **Practical reasoning** skills as a means of argumentation. ✓ **Notions of validity** of a claim based on warrants to justify evidence. ✓ To **develop respect** for alternative or different interpretations based on various beliefs, moral values and attitudes. ✓ Understanding the concept of light. ✓ Applying the knowledge by constructing demonstration investigations and associated calculations. ✓ Demonstrating an understanding of the NOSIKS and its impact of society, technology and the environment.	✓ **Introduction** (5mins) Explaining the rules and activities to be done. **SESSION 1:** **Activity 1** (10 mins) Learners individually answer questions ✓ **Activity 2** (20 mins) Learners in groups of 4 record their answers and starts to critique each other's claims ✓ **Activity 3** (5mins) Group leaders records group consensus for group presentations ✓ **Activity 4** (20mins) Each group presents their claims. ✓ **Activity 5** (20mins) Whole class discussion **SESSION 2:** ✓ **Activity 6** (15mins) Teacher consolidates whole class discussion and mapping IKS back to school.	o Argumentation terminology. o Worksheets and pens. o Demonstration materials like glass, stone, metals, water etc. o Group work charts for presentation of group arguments and consensus.

Fig 1: The sun and the associated earthly elements



<u>SESSION 1:</u> SEARCH FOR LOCAL KNOWLEDGE AND EXPERIENTIAL KNOWLEDGE (10 mins).

Spend a minute to look at figure 1 and try to develop a map in your mind by trying to find a relationship between the sun and all other elements shown. Having done that, answer the question below.

<u>ACTIVITY 1:</u> INDIVIDUAL TASK (5 minutes)

At the end of each answer please circle the source of your knowledge claims. State them as either: Personal Experience = PE, Traditional knowledge = TK or School Knowledge = SK

1. According to your own knowledge, list a few important functions of the sun in our daily lives. Give your answer(s) as your **CLAIM**

____

____

Source of Knowledge: PE TK SK

2. (a) In your understanding, what things makes people to be able to see objects around them? Write your answers as your CLAIM.

____

____

Source of Knowledge: PE TK SK

(b) Give **reason(s)** or **grounds** to your CLAIM above as your **EVIDENCE** for saying what you said

____

____

Source of Knowledge: PE TK SK

3. (a) To your knowledge, what makes people to hear each other? Give your answer(s) as a **CLAIM**

____

____

Source of Knowledge: PE TK SK

(b) Give **reason(s)** or **grounds** to your CLAIM above as your **EVIDENCE** for saying what you said

____

____

Source of Knowledge: PE TK SK

4. (a) Is the sun, water and air related to each other in any way whatsoever? If so, in which way? Write your answers as your CLAIM.

____

____

Source of Knowledge: PE TK SK

(b) Give **reason(s)** or **grounds** to your CLAIM above as your **EVIDENCE** for saying what you said

____

____

Source of Knowledge: PE TK SK

5. (a) To your knowledge where does the rainbow come from and how is it created? Write your answers as your CLAIM.

____

____

Source of Knowledge: PE TK SK

(b) Give **reason(s)** or **grounds** to your CLAIM above as your **EVIDENCE** for saying YES or NO.

____

____

Source of Knowledge: PE TK SK

ACTIVITY 2: SMALL GROUP TASK (20 minutes)

In your group, discuss each others **CLAIMS/COUNTER-CLAIMS** and **EVIDENCE**. Discuss each other's sources of knowledge and If you disagree, write the **reasons for your disagreement** as your **REBUTTAL** in row with the name of the person(s) you are disagreeing with.

GROUP NO: ___ QUESTION NO: ____

NAME	CLAIM/COUNTER CLAIM	REASONS/GROUNDS	REBUTALS

<u>ACTIVITY 3:</u> GROUP PRESENTATION (20 mins at 2 mins per group)

Let someone with good presentation skills present your group claims, grounds and rebuttals noted in your group.

<u>ACTIVITY 4:</u> Whole class argumentation (20 mins)

Group	CLAIM /COUNTER CLAIM	REASONS/GROUNDS	REBUTALS IN CLASS

<u>SESSION 2</u>: MAPPING OF IK BACK TO SCHOOL CONTEXTUALISATION

<u>ACTIVITY 5</u>: IKS-TO-SCIENCE MAPPING (15 mins)

Let us look at questions 1 to 5 once more again and try to find some links between the local, known and the commonly known scientific facts. Is there any science in the everyday and local contexts with respect to those questions? Discuss in your groups and try to map the local to the school science textbook claims.

THEME: THE PHENOMENA OF LIGHT AND VISION		
Specific Aims: APPLY KNOWLEDGE OF PHYSICAL SCIENCES IN NEW AND UNFAMILIAR CONTEXTS Skills required is that learners must: Analyze and evaluate knowledge and apply this to new and unfamiliar contexts.		
LESSON :.The concept of refraction and its implication to natural observations		
Issues of interest	**Meanings, beliefs and practices in everyday contexts**	**School contexts, practices and explanations**
1. The Sun		
2. Water		
3. The Air		
4. Transparent objects		
5. Transluscent objects		
6. Opaque objects		

7. The rainbow		

<u>SESSION 3</u>: Main lesson content

At this stage, what the science textbook states as important learning outcomes should now become more clearer and understood in the context of all scientific statements evaluated in terms of Toulmin's Argumentation Pattern as well as IK philosophical premises of non-logical arguments. As the Contiguity Argumentation Theory suggests, the previous introductory sessions helps in mitigating the assimilative approach of school science so that learners can freely choose how to adopt and accommodate the western science worldview alongside their IK worldview understandings and where possible pick up the emergent school science scientific perspectives. We can now go to page 41-42 (Sources of biological compounds) as well as page 43 (How the digestive systems works).

APPENDIX F: RESPONSES ON THE LEARNER PERCEPTIONS OR VIEWS OF SCHOOL SCIENCE: PRIMARY & COMPARATIVE COHORT INDIVIDUAL TASKS ONLY

DAI GROUP

	Agreement:	Assertion which the learners have to respond to
Q.4	SA/A/D/SD	**It is easier to learn cultural knowledge than school science knowledge**
L		
L.1	A - Sup	I learn respect easier from my culture
L.2	SA - Sup	Because in culture we learn it from birth and we experience things differently in science
L.3	SA - Sup	My cultural knowledge is who I am and science is hard with complicated problems to solv
L.4	SA - Sup	Because in science you are calculating or using numbers
L.5	SA - Sup	In most cases we grow up doing cultural things and hearing it.
L.6	A - Div	For example, me – I believe in traditional things
L.7	A - Sup	Because I see my cultural knowledge everyday
L.8	D - Ass	I don't know nothing about culture
L.9	A - Sup	Cultural knowledge is only taught in special occasions and it is easier to learn. School science needs to be practiced
L.10	SA - Sup	Because it is easier to understand your cultural knowledge
L.11	SA - Sup	Because in culture it does not take years to learn everything
L.12	A - Sup	The cultural knowledge is easy because its what I grew up being taught about
L.13	D - SD	Because I concentrate at the science class and I learn easier
L.14	A - Sup	Because many things in culture are easier
L.15	D - Conv	The things I learn in school are physical, I see them happening in real life
L.16	SA - Sup	Because I can see what is being done in my culture than in science
L.17	A - Sup	Because science got laws and equations, but cultural knowledge is what we grew up with
L.18	A - Sup	Because it shows that the cultural knowledge is easy to learn than school science
L.19	A - Sup	Because you see I cannot write notes on my culture
L.20	A - Sup	Because sometimes my science teacher get too much hard to come up with an answer
L.21	A - Sup	School science is hard to understand and cultural knowledge we grow up knowing it
L.22	D - SD	It is easy to learn science at school if you concentrate on it
L.23	SA - Sup	Because some things in my culture I know by myself and science knowledge I must get by my teacher
L.24	SA - Sup	Because our cultural based on how to dance and music
L.25	SD - SD	Sometimes it is hard to catch up with cultural knowledge, but it is better at school to catch up with science
L.26	SA - Sup	Cultural knowledge is how we live but science is what I just know about
L.27	A - Sup	Cultural knowledge is an indigenous knowledge for all
L.28	D - Ass	Cultural knowledge is difficult because people believe in many things, I get confused

L.29	A - Sup	Our culture is always specific and science needs to be practiced and read.
L.30	A - Sup	In my culture there are things that I know without learning it and there are no notes that you have to read
L.31	A - Sup	Cause you can see it everywhere you go but school science I can learn it only if I read about it
L.32	A - Sup	Because you have to study more about science, but in culture they do practical work in other things
L.33	D - Em	Both are not easy because there will be hard times while learning
L.34	SA - Sup	In my culture we do prove some things we learn
L.35	SD - SD	I always have books to remind me about school science and I didn't grow up in rural areas
L.36	A - Sup	Your cultural knowledge must be learned from you grand parents
L.37	A - Sup	You don't have to pass cultural knowledge, it happens naturally
L.38	D - Em	Because some things in your culture can be hard to know
L.39	SA - Sup	Because cultural knowledge is easy to understand than science
L.40	SA - Sup	Because culture is something we do in our daily basis and gain experience
L.41	A - Sup	Because your family tells you more about cultural than your school teacher

Q.5	SA/A/D/SD	**I believe in science in the same way I believe in my culture**
L		
L.1	D - SD	Because many things I know I get from school
L.2	D - Ass	I don't believe in my culture
L.3	SD - Ass	I feel strongly about science and some things in my culture I believe to be myths
L.4	D - SD	I believe in science more than in my culture
L.5	D - Div	I do not believe in any of those things because they both opposite to the bible
L.6	A – Sup	Example, I believe in cultural things
L.7	D - Sup	Because I believe that my culture is me and it is my roots
L.8	D - 0	No reason
L.9	A - Eq	They will both help me in some way or other
L.10	A - Conv	Because science shows something that you do in your everyday life
L.11	D - SD	Because there are things I do not believe on culture
L.12	SA - Conv	Because I believe in both that they are true
L.13	SA - Eq	Because science can take me to where I want
L.14	SA - Conv	Because everything I learn in science and in my culture are true
L.15	A - Eq	My culture and science are both important to me, they guide me through life
L.16	SA - Eq	Because it (science) is very important and useful in the future
L.17	D - Sup	Science is throughout and hard to notice (i.e. complex)
L.18	A - Em	Like doing something e.g. Sounds and waves are things that uses an ear.
L.19	A - Conv	Body parts and stomach its about science and nature
L.20	A - Eq	Because its about science everywhere we go

L.21	D - Sup	Science can be trick but my culture can or is understandable than science
L.22	D - Sup	Because science can't solve your personal problems
L.23	A - Conv	Because some things we do in science are the same as in my culture
L.24	A - Em	Because I must know the new technology
L.25	A - Eq	I grew up learning science as I grew up with my culture
L.26	A - Eq	Science help in many ways like my culture
L.27	SA - Eq	We are living with science and it makes our lives easier
L.28	A - Eq	I do believe in my culture because I grew up being taught about my culture.
L.29	D - Sup	Some other things are very different from my culture
L.30	D - Sup	It is easy to learn cultural knowledge than science knowledge
L.31	A - Eq	Science can help me deal with other things and also help in my culture
L.32	A - Eq	Because it is important to know about my culture as well as about science
L.33	SA - Conv	Because science helps you to know about nature
L.34	SD - Div	I do not even believe in science because it works with things already created
L.35	D - Conv	Because I always learn science almost everyday
L.36	A - Eq	I like science as I like my culture
L.37	D - SD	Science is what I have been taught and not my culture
L.38	A - Conv	Because science tells us how things are done as well as those that are done in my culture
L.39	SD - Sup	I believe more in my culture than science because science cannot make things possible
L.40	D - Sup	I only learn about science, but I am not experiencing it
L.41	D - Div	Because these things are totally different

COMPARATIVE COHORT		
	Agreement:	Assertion which the learners have to respond to
Q.4	SA/A/D/SD	**It is easier to learn cultural knowledge than school science knowledge**
L		
L.1	A – Sup	Because they taught us things that are easier
L.2	SA – Sup	It's easy to know something that you grow up doing at your home than what you get to know at an older age
L.3	SA – Sup	It is easy to learn cultural than school science because culture is culture
L.4	A – Sup	Because my cultural knowledge is done physically, practiced
L.5	A - Sup	There are things that are being made like African beer without going to the laboratory
L.6	A – Sup	Because I know about it
L.7	A – Sup	Cultural knowledge is easy
L.8	SA – Sup	Because in science we must communicate in English while in our culture we use isiXhosa which is easy to understand

L.9	D – SD	Because you cannot make things quickly as in science
L.10	SD – 0	No reason
L.11	SA – 0	No reason
L.12	SA – Sup	Culture is what I believe in and it describes the way I live my life therefore if it is difficult to adjust my life to be related with science
L.13	A – Sup	In the cultural knowledge you can learn to cook but in science there are experiment that you can't do without being taught
L.14	D – Conv	I think it's the same
L.15	SA – Sup	In science everything needs to be proven
L.16	D – SD	Because science lessons are easier and can help in future as compared to cultural
L.17	A – Sup	Because is something I learnt from the books and culture I learnt from my parents
L.18	SA – Sup	Science make things much more complicated.
L.19	A – Sup	Because it is where we grow up and we able to focus without any distractions
L.20	A – Sup	Because things happen easier in my culture than in science
L.21	SA – Sup	To mix medicine/chemicals in an African way
L.22	SA – Sup	Ngoba apha eskolweni uye ungakwazi umamela ncam ngoba kukho bantwana abaye bazenze bhetele kunawe, ngoku uphele uzijongela phantsi kanti kwiculture yam siyalingana [Here at school there are other learners who makes themselves better than others and yet in my culture we are all equal and I can understand better].
L.23	A – Sup	In school there are many technics but in my cultural knowledge you learn about things that you know
L.24	A – Sup	Because my culture is the one that I understand than school knowledge
L.25	A – Sup	Because it is sometimes difficult to understand about school knowledge because those are the rules overseas
L.26	D – 0	No reason
L.27	A – Sup	To cook at home is more easy than when you learn cooking at school
L.28	A – Sup	Because in science we do not learn things as we do in our culture
L.29	A – Sup	In culture we most do things in practical, we learn about things we see with our eyes
L.30	A – Sup	We are not beaten like here at school.
L.31	A – Sup	Because cultural knowledge is about the will to know your culture.
L.32	SA – Sup	More cultural things are done practically and at school it is mostly written
L.33	A – Sup	Parents will tell us stories about long time ago and you will be interested
L.34	A – Sup	Because I feel science is more difficult than learning cultural knowledge
L.35	A – Sup	Because esikolweni asinazo izinto ezininzi [At school we have limited resources]
Q.5	SA/A/D/SD	**I believe in science in the same way I believe in my culture**
L		
L.1	D – Div	I don't believe in science because my culture is the best one
L.2	SA – Eq	I believe that ancestors are alive hence it's the bones of the dead people, the same way in

		science
L.3	D – Div	Because in my culture they did not believe in science
L.4	SA - Eq	Because I love my culture as much as I love science
L.5	SD – Div	Instead it keeps us or make us not believe in our culture
L.6	A – Eq	Because my culture is very important to me and science can help again
L.7	SA – Eq	Because science can help us and so is our culture
L.8	SD – Div	Because science says there is no God while I believe there is God
L.9	A – Conv***	Things done in science are done in culture
L.10	SA – Eq	The process of making African beer is being given more details in science
L.11	SA – Eq	Because science make me wiser about things that are happening around the world
L.12	SD – Sup	Science is very complicated,physicians or scientists don't say the same thing so my culture is easy to understand
L.13	D – Sup	Sometimes I memorise science but cultural information stays ever in my brain
L.14	SA - Eq	Because I take everything that I am taught by my parents and my teachers
L.15	A – Eq***	Sometimes science can help for instance when you are sick and culture can also help when you are sick (traditional medicines)
L.16	SD – 0	No reason
L.17	SD – Eq	Because some of the things I believe from my culture are different from science
L.18	A – Eq***	Because they work hand in hand
L.19	A - Em	Because science is more researched
L.20	A – Em	Because I have to know the things in the world
L.21	SA – Eq***	They both heal, e.g. traditional healer and doctors
L.22	SA – Conv***	Ngoba iculture yam yile indibangele ukuba mandikwazi ndibenalo ulwazi nge science
L.23	A – Em	It's beause I love knowledge
L.24	A – Conv***	because they show the same things but they happen different when it comes to understanding
L.25	A – Eq	Difficult to explain this questions
L.26	A – Eq**	Ngoba kwezinye izinto iyandinceda
L.27	D – Ass***	In my culture these are things that are not real in life
L.28	SA – Eq***	Because they both feed my knowledge
L.29	A – Em	In science when we learn we sometimes even do examples
L.30	A – Eq***	Kuba zonke izinto ezithethwa yiscience zikhona nezi zeculture yam zikhona
L.31	SA – Conv	Some cultural believes are proven by science
L.32	SD – Ass	Science mostly prove the thing its facts and culture is about history
L.33	D – Div	I don't believe the same
L.34	A – Eq	Because science can solve some problem of the world and culture can do the same in some people
L.35	SA – Conv***	No difference it's the same

SOME FURTHER SUPPORTIVE PAPERS

The current situation in teaching and development of technical corpus in isiXhosa

Most isiXhosa-speaking teachers are faced with the challenge of having to explain, define and provide equivalent terms in isiXhosa for certain scientific text and terminologies with which they have to deal in their everyday science classes. The inferior quality of education, among other things, that was attained during the times of the apartheid government failed to equip most African language teachers with the proper language skills in either their home language or in English, their L2, for enabling them to cope with the unique proficiency skills that science teaching demands.

As a result, most teachers find difficulty with dealing with scientific English registers, which makes the teaching of science and mathematics concepts and terminology in English extremely challenging. Therefore, most of the time the teachers concerned have to resort to the direct borrowing of most of the science terms that they use from the English language, which terms they then incorporate in their isiXhosa vocabulary. Such teaching practice is problematic for learning and teaching. Kishindo (cited in Pfaffe, 2000:p. 113) finds that many lexicographers simply assume that most learners understand the concepts behind the terms, regardless of whether they are in their native language form or in English. Such an assumption is unfortunate.

Despite borrowing providing an easy route out of the terminology conundrum, it does not solve the conceptual problem. Borrowing directly from the European languages by means of phonetic transcription should be avoided, since such borrowed words do not initially convey any meaning. Such methods merely tend to produce clumsy-sounding 'scientific' words in the vernacular (Dlodlo, 1999: p. 324). Most teachers tend to adapt and borrow scientific words directly from English without trying to explain them in the learners' home language, as can particularly be found in the case of teaching conducted in isiXhosa.

Such borrowing, as that alluded to by Kishindo, becomes very problematic for most isiXhosa-speaking learners, as it hinders their scientific literacy through limiting their conceptual understanding and cognitive development.

Most learners learn without fully understanding the concepts and terminology used, leading to rote learning and the likelihood of having to memorise scientific content without proper understanding of the concepts and terms involved. Heugh (2003) related that “when I have asked the pupils to tell me what they understand of these sentences, they cannot. They cannot, with accuracy, relate the English sentences to the content of the lesson in which they have just participated through isiXhosa.”(p. 29). In the former DET schools, one can clearly detect such a lack of understanding in the intermediate phase. The learners in this phase come from the foundation phase, where the language of teaching and learning was their home language.

In the intermediate phase they suddenly have to adapt to English as the medium of instruction, being taught by teachers who are uncomfortable with teaching in English alone. The corollary to the unequal role allocation of the two half LoLTs was teachers’ use of code-switching and code-mixing. The project team “found that the simultaneous oral use of isiXhosa and English in the Science classroom was widespread, intuitive, unsystematic, at times resourceful and yet fraught with problems” (Brock-Utne *et al*., 2004:159).

Such a practice has resulted in the subtractive approach, in which much unsystematic alternating between the languages concerned exists, with most learners being stronger in isiXhosa than they are in English, their L2, in which they tend not to be well grounded in terms of their proficiency skills. Schutte and Orr (1992) found that the difficulties that readers of science texts face are exacerbated for those for whom English is not L1.

Apart from remarking on the unfair use of English as the medium of teaching, Rampal (1992: 229) observes that most science terminology was adapted by English from other European languages in the first place: “While the discourse of science chose to use dead words to suppress unwanted associations, it also adopted a ‘deadpan’, or detached and disembodied, tone to obliterate any reflections of subjectivity.” Rampal states that, even though the language of science was created out of dead languages, such as Latin: “Its terminology became finely differentiated and its theory sought precise definitions for the fine-grained concepts it evolved.”

For instance, as concepts in mechanics developed, the science of ‘movement’ was gradually differentiated into a fine spectrum of precise, unambiguous terms, such as ‘velocity’, ‘speed’, ‘momentum’, ‘inertia’ and ‘kinetic energy’, with each term having a meaning quite distinct from its everyday connotations. So, the terminology which is used in the teaching of the sciences is the language with which even the native speakers of English are not familiar. The mastery of such terminology is even more difficult for African language speakers, for whom the English language, as a whole, sounds foreign.

Rampal’s (1992:231) assertion that science uses the terminology of dead language(s) is correct, in that, the etymology of most science terminology lies in Latin or Greek roots. However, as most teachers are not directly involved with the development of terminology they tend not to be aware of such roots.

Rampal (1992:235) further indicates that most scientific words or terminology were created to be precise in meaning and unambiguous. The question arises as to whether it is possible to teach sciences and mathematics in isiXhosa without ambiguity. This is indeed so, despite the fallacies that the African languages are not capable of expressing scientific concepts, due to their lack of precision. Such fallacies lead to stereotyping of the languages concerned, such as when Machungo (1998:32) points out that “African languages as vehicle of science and technology is a goal far from being achieved”. Such a myth needs debunking, as the natural sciences will, indeed, be able to be taught effectively through the medium of the African languages, once the corpus has been sufficiently well developed.

Literature review on Terminology Development.

Systematic attempts to develop and expand terminology have been under way since the late 1920s, leading to the establishment of several language committees (Mahlalela et. al 2002:15). The strategies and mechanisms used in developing scientific concepts and terms in isiXhosa, despite having been in use for some time, have not yet been explored in relation to what works best in isiXhosa with specific reference to the lower educational levels. Many other languages have dedicated language academies or institutes that have been outstanding in the development of terminology.

For instance, the Académie française, apart from its involvement with the field of science and technology, has also attempted to keep French free of foreign borrowings, particularly any from the English language. Similar in intent to such a body is the Real Academia of Spain, whose objective it is to clarify, purify, and glorify the Spanish language (Onyalo, 2004).

A number of studies have been undertaken around the issue of developing scientific terminology in the African languages. Legere (2005) refers us to "the experiences of the terminology/specialised vocabulary development project for Mbukushu (Namibian language) in which no barrier is acknowledged that can prevent the expression of scientific and mathematical concepts in an African language". Scholars such as Carstens (1993), Bamgbose (1987), Mwansoko (1990), Dlodlo (1999), Shembe (2000), Antia (2000), Van der Walt (2005) and Mahlalela and Heugh (2002) all share the same ideas about the use of an African language in the teaching of content subjects. None of these scholars see the issue of terminology development in an African language as problematic; rather, they regard the issue as posing a challenge that can be overcome by means of collective effort aimed at elevating the status of such languages. The LANGTAG report (1996) also recommends developing the vocabulary needed for the expansion of functions possible in terms of the new language dispensation.

The Actual process of Terminology Development

Introduction

The process of developing terminology entails many facets or dimensions. The concept of terminology development does not by any means connote an absence of content knowledge in Mathematics and Sciences as some Western science proponents believe. The other problem or challenge that needs to be overcome is that of that of western science hegemony over the epistemological authority of what science is or what counts as science. To a large extent, most terminologies in Africa are developed through a process of translating from colonial languages into African languages which then create challenges for terminologists having to decide between "coining" and "borrowing". In the light of the above it is also important to note Rampal (1992:231) assertion that, science uses "dead languages" in its terminology, since the etymology of science and even mathematics letters or variables are Greek. Examples would be the word, **"Photosynthesis"** for science and **"decimal"** for mathematics. The word photosynthesis uses the word **"Photo"** which means light and synthesis which means to build, make or put together and on the other hand the word "decimal" contains in it, the prefix or word **"deci"** meaning one tenth. In the same vein, we have similar words or terms in isiXhosa which can be used to develop our own terminology. In isiXhosa the equivalent word for “photo/photon” or “light” is “Imitha/umtha” or “ukukhanya”. The same goes for the word “deci” – one tenth which in isiXhosa is “isishumi”. To be precise and unambiguous in our terminology development as Rampal (1992: 235) puts it, it also then becomes incumbent on those involved in terminology to understand our indigenous knowledge systems as well as the history and philosophy of the maths and sciences. The nature of science is also a very crucial aspect as it will help us present a more accurate view of science in the terminology that is to be developed. Another illustration of the use of indigenous knowledge systems at work in science was in the development of an equivalent term for lightning and electricity in isiXhosa. In isiXhosa the two scientific terms have one word “umbane” in isiXhosa. The question is, who told indigenous people that electricity and lightning were two related scientific phenomena. Again who told indigenous people that the word current means something moving rather than something stagnant or stationary? In isiXhosa current means “umsinga”. When we see someone moving in a particular direction we say “usingise phi” i.e. in which direction are you heading. In science we talk of **electricity** as the **flow of charge**, because electricity is a word signifying the motion of electrons; similarly in isiXhosa we also talk of **umbane** as “ukuqukuqela kwezibaneki”. We also extend the meaning of “umbane- electricity” to the word “isibane – lamp”. Indigenous people apply the term “isibane - lighter” to a wider context to include everything that makes light. The term “umbane – electricity/lightning” is understood in various contexts – whether light is visible in the case of lightning, electric bulbs, paraffin lamp/wood fire or invisible as in a case of a fan. In the case of paraffin lamp/wood fire, the rational for calling them isibane is that indigenous knowledge has it that there can be no light without a flow of something. For terminology to develop, indigenous knowledge has to be revived. The New National Curriculum Statement of the Department of Education (2003a) states:

Now people recognize the wide diversity of knowledge systems through which people make sense of and attach meaning to the world they live. Indigenous Knowledge Systems in the South African context refer to a body of knowledge embedded in African philosophical thinking and social practices that have evolved over thousands of years. The National Curriculum Statement Grades 10 – 12 (General) has infused indigenous knowledge systems into the Subject Statements (p. 9).

According to Naidoo and Savage as cited in Ogunniyi pre-publication Book 1, Nature of

Science:

> …a better use of existing resources" is needed in science education which should "Be cheap enough for all educational institutions, thus promoting equity. Be more soundly based on current learning theories, thus promoting understanding rather than rote learning. Empower students to contribute better to personal, community and national development and participate more actively in the democratic process. Present a more accurate view of science than traditional courses portray (Ogunniyi, 2008:94).

The citation alluded to in the above quotations stresses that reinventing of the wheel is a waste of time and a waste of resources imbedded in indigenous knowledge systems with leads to a deviation to current learning theories that encourage that teaching should use learners pre-knowledge as a premise so as to promote a learner-centred approach. The other problem envisaged is that local knowledge become assimilated, hence leading to a less accurate view of science as alluded to by Ogunniyi. To make an illustration of the application of the above is to make an example of a current endeavour to find a term for a blue colour in isiXhosa.

For instance, in Physics the concept of colour is the expression of different wavelengths of light. In isiXhosa a blue as well as a green colour has the same term/word – (iluhlaza – green). To some researchers, this observation led them to believe that African people are either colour blind with regard to a blue colour or that a word or term for something blue does not exist. The truth is, it does exist. In isiXhosa a blue colour and a green colour are seen to be close and hence qualifiers are used to specify that a blue colour is, "as green as". Translated literally we say a blue colour is **"as green as the sky"** and not as **"as blue as the sky".** A blue colour is also seen as another shade of a green colour and not that it being blue is not recognised or that there is no term for it. Most plants have green leaves with blue pigmentation and flowers that are red, yellow, blue and violet. Names for all those colours exist. The problem is that in the process of terminology development cognisance of Indigenous Knowledge Systems should not be underestimated. In science a green colour and a blue colour are neighbouring wavelengths of while light. In many instances, due to the hegemony of "western science", when developing terminology we resort to coining strategies when it is not necessary to do so. In many cases when trying to find a word for blue in isiXhosa, some terminologists have suggested the word "ibhlowu"- for blue in an attempt to conform to the Afrikaans term, "blou" forgetting that it is also borrowed or stolen from English. Generally, no attempt is made to question why there is no "distinct" word for "blue" in isiXhosa. In the table below we will try and give a number of examples that highlight a number of scenarios and criteria that are important in developing terminology.

The process and mechanisms of developing terminology/or vocabulary

TABLE 1: The three dimensions of terminology development

COGNITIVE (content part) (Deals with accuracy in describing concepts)	**LINGUISTIC PART (Looks at correctness of the language)**	**COMMUNICATIVE PART (Including IKS) (Looks at standardization of terms)**
Is the term that is developed accurate? 1. E.g. lets assume that we are trying to develop a term for **BODMAS** in mathematics. How would we start giving a **term** to it? We would firstly have to unpack its meaning – a mathematical code or formula for arithmetic operational sequence. For example, (2 + 5 x 10 / 2) = 27 and not 35 or 50. Here we explain **BODMAS** in isiXhosa, but leave the acronym intact in its English format. **Other examples are:** Decimal place Fraction	*Do we all agree on grammatical writing of the term used or developed?* 1. **BODMAS** = BHYPDT – **B**iyela, **H**lalutya, **Y**ahlulahlula, **P**hindaphinda, **D**ibanisa u**T**habathe. **Note:** we cannot use acronyms in different languages, so we have to keep BODMAS as acronyms are university. uphawu lwesishumi iqhezu	*This is a process of accepting terms by speech communities or people who speak the language.* 1. A term should give meaning to people who speak that particular language otherwise the whole process of **terminology development** will be a waste of time. Is there any evidence of **BODMAS** exemplification in IKS? – Surely there is. In live stock farming indigenous people had a lot of live stock. In counting, different live stocks are always counted separately using different stones – representing variables. They always have different **kraals** representing **brackets** in mathematics. In

Tenth (1/10) Number (12) Digit/figure, HTU Place value/holder Unit Integer Prime numbers Even numbers Odd number Natural numbers Whole numbers, Counting numbers	isishumi inani inani-mvo HTU isigcinindawo senani, umvo inani Oonozahlule Oonombini Oononqakathi Amanani endalo Amanani ephelele Amani obalo	operating or "counting", division always came first in the form of **dividing** the like terms/same stock. In the case of cattle, Bulls, cows, castrated males, pregnant females and young off springs etc are grouped together. Before addition comes, pregnant females are counted twice signifying **multiplication** and then **addition** comes. To get to the final answer, subtraction will come in the form of discounting those that form part of "inqoma" – those that were borrowed; hence one would be able to say how much live stock one has accumulated. When communicating BODMAS to learners we translate it to BHYPDT – **B**iyela, **H**lalutya, **Y**ahlulahlula, **P**hindaphinda, **D**ibanisa u**T**habathe for understanding of meaning.
2. In science we can think of the three phases of matter and the phase transitions. For example a **liquid** is called "**ulwelo**" – a noun.	2. Ulwelo = liquid(n) Ulwelo = liquefy (v) Ulwelwiso = liquefaction (a)	2. Derived from a process of separating **chaff (ikhafu)** from grain using wind which in one word is called – **ukwela - verb.** The process is called **"ulwelo-adjective"** and consequently also used for the term "liquid –

A solid A gas Air wind Tornado Hail Storm 3. Another **Maths/Science** term is **"Power".** In Maths it signifies the number of times a singular number is multiplied by itself, e.g 2 to the **power 3** written as $2^3 = 2 \times 2 \times 2 = 8$. In Science it refers to the **rate** of doing **work.** This can be put another way as the amount of work done in a given time. In summary the more the power for a number the bigger it is and similarly the more power machine has the more work it can do in a particular time. 4. We also have a term, **"to precipitate"** in dual	siqina -'**umoya**' (igesi). -'**umoya**' (esiwuphefumlayo) -'**umoya**' ovuthuzayo -Isitshingitshane -Isichotho -Isaqhwithe 3. In isiXhosa "iqondo" refers to a level or degree and ukuphindaphinda refers to "to multiply" thus **iqondo lophindaphindo** in mathematics context while "ukusebenza" means, "to work" and hence **iqondo lokusebenza** in the science context.	**ulwelo -noun"** because it flows. To elaborate more: **To cross** – "ukuwela" **Crossing over wind** – "ukwela". The central rational is that of **"flow"** when **crossing** as well the **flow of grain.** 3. To indigenous people the term, **"Iqondo"** refers to a level or degree of something and is derived from **"qonda or ukuqonda"** which means a level of understanding relative to a common base. Another term in everyday use of power is **"amandla"** which refers to strength. This definition is close to that used for mathematics in the amount of times that a number is multiplied. A stronger person is expected to be able to do more work than someone with less strength or vice-versa someone seen to be doing more work than someone else is deemed to have more power than his/her counterpart. 4. The amaXhosa people have long time developed the term **"ukuchothoza - precipitation"**

contexts – water vapour to ice (in the case when water vapour condenses directly into solid ice rather than liquid rain and the other scenario – ions forming an insoluble chemical, hence falling out of a solution, e.g $CuCl_2$ (l) + H_2SO_4(aq) = **$CuSO_4$ (s)** + 2HCl. In this case **Precipitation** is called **"ukuchothoza**". The copper sulphate	4. The rain that comes with stones is called "**isiChotho"**, hence the term "**ukuchothoza".**	

The actual process of terminology development.

These dictionaries are written in three official languages of the Western Cape Province to promote its language policy in education, to enhance accessibility of the content to both teacher and a learner in their home languages, to counter act against the myth that African languages cannot teach in areas of science and mathematics because they do not have concepts and terminology, and to raise awareness around the use of African languages as languages of learning and teaching (LoLT). These dictionaries are intended for teachers and learners in the intermediate and senior phase of primary schooling as teaching and learning resources.

The key objectives of these dictionaries are:

- To aid teachers and learners in multilingual classrooms, by providing science and mathematics terms and definitions in three languages, isiXhosa, Afrikaans and English.
- To create technical/ scientific vocabulary in isiXhosa in particular, so that it would be possible to teach and assess in former marginalized African languages.

SELECTION OF TERMINOLOGY

Three important things to look at

1. **Level of Instruction:** The level of language used in terminology should match the learners' grade level - terms for primary teaching should be more descriptive than those of secondary schooling which need definitions.

2. **Nature of Subject:** There should be a difference between terminology of different disciplines or areas of teaching, e.g. mathematics or physical science terminology. For instance power for mathematics is different from power in science.

3. **Level of Learners:** It is important to grade the terminology according to age or level of learners, learners should gradually get deeper in definition of terminology as they move up to upper grades. E.g. intermediate or senior phase

Principles of Devising New Terminology

Transfer of concepts: This a very important one, because without proper transfer of concepts there could be no application of terminology in our real daily lives. A concept must **have a clearly defined meaning**, in a **precise application of usage** for that **particular subject field**, particular domain e.g. science, art, trade. Literal translation should be avoided because it could be misleading.

Priority of Internal resources: The terminologist should start looking at everyday language used by their communities before going out for coining new terms or borrowing from other languages e.g. Old Bantu Education Terminology

Brevity: Too long or sausage terms should be avoided, because terms are expected to be easy memorable e.g. for this term: Kinetic energy, motion energy- Amandla **e**ntshukumo or do we say Amandla-ntshumo

Consistency: We maintained consistency for coined terms to mean a particular concept. This was quite difficult as there is plethora of synonyms in isiXhosa that people want to keep. We had to retain one or at least one other to be scientifically specific in our definitions e.g. Magnet = isitsalane (something that uses its power to attract objects) or umazibuthe (means to collect) or a borrowed term which is = imagnethi. We settled for 'isitsalane) because it is a term that we all agreed it is scientific accurate.

Coining as a terminology development strategy.

- **Simple equivalence:** These are the terms consisting of only one stem without affixes e.g Kwiswahili term for Chest- kifua – isifuba (Xhosa)

  Stem- shina – isiqu

  Water- maji- amanzi

- **Composition:** Two or more words joined to form a new lexical item e.g girrafe- indlulamthi = dlula+ mthi (verb+noun) (taller than a tree)

Borrowing as alternative strategy:

When new terms cannot readily be coined in a language through the processes discussed above, the alternative is to borrow them from other languages

e.g French, Greek , Latin, English and we can even from other African languages e.g Kiswahili.

borrowed term : Enzyme - enzayime

- **Semantic Extention:** involves the expansion of the meaning of an existing word in order to embrace a new meaning.

  e.g isiXhosa , Xhathisa – balance (v) Unzinzo esikalini – balance (n)

  Yoruba , Iyefun 'pollen' iyefun 'flour'

  Hausa, Raga 'grid' raga ' net'

<u>The following terms are some of the challenges in which you can get during a process of developing terminology.</u>

Term No. 1: A gas

For example let us take the term 'gas' some people prefer to call it 'igesi' some call it 'irhasi'. They explained it as ' Into efana nomoya kodwa engeyo likhwidi okanye into eqinileyo' that is something that looks like air which not a liquid or something solid. Generally speaking a gas is known in two ways by our communities (1) A gas which we breathe that is ' oxygen'. (2) a house hold gas which is used to burn our stoves.

How the problem was resolved

This we resolved by highlighting the fact that, this would be extremely confusing to the learner cognitively because in Science we refer to Air as a gas, the household gas are two different things. We resolved this by referring to gas e.g oxygen as ‘Igesi’ and the household gas as ‘Irhasi’.

Term No. 2: A Liquid

Another problematic term was ‘Liquid’. They defined it as ‘Into ebumanzirha’ something that looks like water. Others felt that referring to liquid as ‘Amanzi’ that is water would give cognitive problems to the learners, because water is not the only liquid. Apart from their differences about the definition of the term ‘liquid’ they also spent a lot of time thinking about the specific term a ‘liquid’.

How the problem was resolved

We resolved the debacle by reminding teachers that there is existing term in isiXhosa for ‘liquid’ viz ‘Ulwelo’ but people are not aware because it is not frequently used. They also suggested that both terms ‘Ilikhwidi’ and ‘Ulwelo’ be simultaneously used.

Term No. 3: An electrical current

There term ‘Electrical current’ also gave some problems, teachers defined it as ‘ Umsinga wombane’ and they all agreed but differed with the explanation of the concept i.e. some were saying ‘Ukuhamba kombane okanye ukubaleka kombane.

One teacher felt that the word ‘Ukuhamba’ would confuse the learners, he mentioned that; in this context we are dealing with Science, so we need to be accurate in our definition because the word ‘Ukuhamba’ is colloquially used to mean ‘walk’.

How the problem was resolved

This problem was resolved by introducing the word for ‘flow’ that is ‘ukuqukuqela’, so the term ‘electrical flow’ in isiXhosa it is ‘Ukuqukuqela kombane’. The experienced teacher knew this term and they were very excited because they had heard of the term in the past but couldn’t associate it with Science.