

**Full Thesis submitted in fulfilment of the requirement for
the degree:**

Masters in Science Education

TITLE OF THESIS

Effects of using a dialogical argumentation instructional model to teach
grade 11 learners some concepts of sound by means of indigenous

musical instruments



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DECLARATION

Declaration

I declare that “**Effects of using a dialogical argumentation instructional model to teach grade 11 learners some concepts of sound by means of indigenous musical instruments**” 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.

DANIEL A. ANGAAMA

SIGNED: DATE: NOVEMBER, 2012



ACKNOWLEDGEMENTS

I would like to thank the Lord Almighty for His abundant grace, surprises and blessings manifested through the wonderful people and opportunities He placed along my path.

The person one to whom I owe so much as far as this work is concerned is my supervisor, Professor Meshach Ogunniyi. Prof, I am grateful for your kindness, patience and fatherly rebukes. Thank you for making me to start thinking in multiple dimensions. Thank you for being such a father, friend, and a role model in the pursuit of knowledge and of a practical, disciplined Christian of life.

I am grateful to all members of the Science and Indigenous Knowledge Systems Project (SIKSP) family; true comrades-in-arms in the battle for knowledge. In particular, I would like to thank Mr Keith Langenhoven, Doctors Emmanuel Mushayikwa, Funmi Amosun and Elizabeth Rasekoala for the crucial comments and recommendations. I am grateful to Mrs Ruth Stone for supplying me with didactic materials and musical instruments for this research. To Dr Samuel Kwofie and Mr Shafiek Dinie, I say thank you for very useful comments and advice in times of need.

My appreciations go to Simasiku Siseho for the academic and material support and for taking off the tension when I got confused as I encountered setbacks in the field of research. His statement: “That’s research” has done so much to calm me down time and again. Thanks to Chris Diwu for the academic support. My deep appreciation also goes to Philip van der Linde and Frikkie George for the practical intervention they made, without which this study could not have been possible. May God reward you!

Thank you Loide Shifula, Vicky Thandokazi, Dominic Awah and Constance Shey for making invaluable contributions to enable me to get through with this research. I appreciate Clement Buasoyi and Prof R. Madsen for the statistical analysis.

I wish to express my appreciation to all colleagues of the Physics department for being such an encouragement. In particular, I would like to thank Prof Delia Marshall for her very useful assistance and advice, as well as Dr Mark Herbert, Mr

Joash Ongori, Mr Trevor and Ms Honji for their contributions in shaping my instruments. Finally, I wish to thank Prof Linder, whose work on sound acted as an inspiration in this study.

Dr Bernice Abi nee Egoh was such an encouragement in persuading me to come to South Africa and to enrol at the University of the Western Cape. Thank you so much for the efforts you made to contribute to my career development. May the Lord bless you! Thank you, Abi Henry for encouragement and support that spurred me on.

I would like to express my appreciation to the respective authorities of the Faculty of Education for academic support given during the period of studies. In particular, I would like to express appreciation for a financial support in 2010 and for academic assistance through various postgraduate assistantship programmes. I owe much to the University of the Western Cape for all the facilities put at my disposal to enable me carry on this work.

I cannot express enough appreciation to you, Winnie, for the bold step of faith that you took to persuade me to leave my job and come for further studies. Thank God for giving me such a farsighted lady as wife. To my family back home, I want to thank each of you for your prayers and for enduring the absence of a father, brother, uncle and more. Finally I want to thank all members of Balm of Gilead Ministries for their prayers.

ABSTRACT

Two grade 11 classes of two high schools in Cape Town were taught some concepts of sound by means of indigenous musical instruments. The purpose was to find out the relative effects (or none) of two instructional strategies. Toulmin (1958)'s Argumentation Pattern, Ogunniyi (1997)'s Contiguity Argumentation Theory and Reiner *et al.* (2000)'s Substance Schema formed the theoretical framework.

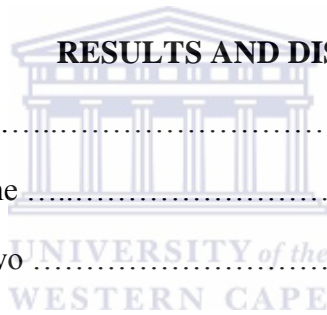
A pre-post-test quasi-experimental design was employed and data collated using questionnaires, a sound conceptual test, argumentation worksheets, and classroom observation schedules. One teacher taught the experimental group using dialogical argumentation while another teacher taught the comparative group using lecture-demonstration method, coupled with the use of ICTs for duration of four weeks. Data were analysed using a mixed (quantitative and qualitative) methods approach.

The findings revealed that many the learners held some scientifically valid conceptions of sound prior to formal instruction. However, the learners also held many scientifically invalid conceptions in relation to the speed of sound in air, sound propagation, and sound produced by stringed instruments. The alternative conceptions of learners in the C group remained largely unchanged after instruction, while those of the E group changed appreciably, but not completely. The E group learners changed the alternative conceptions that were worked into structured argumentation activities better than those which were not. Also, the learners in both groups seemed to hold indigenous beliefs in relation to sound which did not seem to change after instruction. Most learners had a positive attitude towards the use of indigenous knowledge in the science class. No significant difference was found between male and female learners with respect to conceptual understanding of sound, indigenous beliefs, and interest in the integration of science and indigenous knowledge.

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ABBREVIATIONS USED IN THE STUDY

TAP	Toulmin's Argumentation Pattern
CAT	Contiguity Argumentation Theory
DoE	Department of Education
SIKSP	Science and Indigenous Knowledge Systems Project
SIKSQ	Science and Indigenous Knowledge Systems Questionnaire
SAT	Sound Achievement Test
WCED	Western Cape Education Department
DAIM	Dialogical Argumentation Instructional Model
EMDCs	Education Management and Development Centres



KEY TERMS

Toulmin's argumentation pattern

Contiguity argumentation theory

Reiner *et al.*'s substance schema

Dialogical argumentation

Dialogical argumentation instructional model

Alternative conceptions

Conceptual understanding

Indigenous musical instruments

Indigenous beliefs

Sound propagation



CHAPTER ONE

INTRODUCTION TO THE STUDY

1.0 Introduction

The notion of making science more relevant to learners as a means of arousing and sustaining learners' interest in science has become a point of concern to many science education researchers as well as education policy makers (American Association for the Advancement of Science [AAAS], 1990; Millar & Osborne, 1998). Consequently, one of the objectives of secondary school physics in Cameroon has been to relate, as far as possible, the physics principles to local applications in order to make it more relevant and interesting to the learners.

In line with this objective, some learners were asked to bring local musical instruments to school during the Youth Week (a period during which learners engage in many extracurricular activities in Cameroon). The learners brought many of the instruments – xylophones, talking drums, harps, horns, flutes, and so on. Using these musical instruments, the teachers discussed the physics principles behind their proper functioning. Many of the learners became excited about the topic (sound), and some of them remarked that physics had come 'closer to them'. Although physics concepts and principles with regard to sound had been demonstrated using laboratory equipment like ripple tanks, tuning forks, slinky coils, and so forth, the learners did not relate to them as much as they did with the musical instruments. Thus using local materials that were familiar to the learners to illustrate the same principles of sound had a very positive effect on the learners' perception of physics.

The positive impression of the above-mentioned incident has left a permanent mark in my experiences as a teacher, and was one of the underlying reasons for choosing to investigate on the use of indigenous or traditional musical instruments in this study. It was hoped that using indigenous musical instruments in teaching the concepts of sound might have many positive effects on learners' attitudes towards the topic of sound. In a related study carried out in a rural secondary school in Limpopo Province of South Africa, Lesiba (2006) found that learners' interest in the topic of sound increased when indigenous musical instruments were used to teach it.

In that study, thirty grade 10 learners were taught some concepts of sound and waves using three traditional musical instruments – African drums, thumb pianos and Kudu horns. The results showed that the learners were very active in class and also showed great excitement and motivation to learning the lesson. Furthermore, the learners were able to appropriate, with relative ease, more abstract concepts such as associating pitch with frequency, and loudness with amplitude.

The present study, as well as that of Lesiba (2006), falls in line with the South African government policy to integrate science and indigenous knowledge in the science classroom as a means of enabling learners to appropriate scientific concepts. This aspect is one of the key issues of the post-apartheid government policy in promoting science teaching and learning in the context of multicultural and multiracial classrooms that have emerged after the fall of apartheid where classes reflected racial identities.

1.1 Background

In 1994 the political landscape of South Africa changed from the repressive, racially segregated apartheid regime to a democratic racially inclusive government. In 1997 the new South African government launched a new curriculum to match the new context of multiracial classrooms in the post-apartheid era. This new curriculum, called Curriculum 2005 (C2005), had many significant changes as compared to the former one under the apartheid government. Among the changes contained in C2005 were demands for a shift from teacher-centred methods of teaching to learner-centred ones, with the teachers playing the role of facilitators.

Learning was also expected to take the learners' background knowledge into consideration by including indigenous ways of knowing into the science classroom alongside the school science practices that had been in place all along. These themes could be seen within C2005 itself, its revised versions such as the Revised National Curriculum Statement (RNCS – Grades R - 9) and the National Curriculum Statement (NCS – Grades 10 – 12) (Department of Education, DoE, 2002), as well as the Curriculum and Assessment Policy Statement (CAPS) (Department of Basic Education, DoBE, 2011).

The implementation of C2005 met stiff criticism and resistance from both teachers and other stakeholders (Jansen, 1999). In an attempt to resolve the controversies surrounding C2005, the Department of Education in 2002 introduced the Revised National Curriculum Statement (RNCS) – (Grades R – 9) and the National Curriculum Statement (NCS). The RNCS and NCS outlined certain Learning Outcomes and Assessment Standards, among which was Learning Outcome 3 which demanded that science teachers integrate Indigenous Knowledge (IK) with school science.

The demand to integrate IK with science was based on the argument that IK has been sustaining its users and their environments for centuries (Snively & Corsiglia, 2001) and was therefore useful for sustainability of indigenous communities in South Africa despite its denigration by European colonialists (DoE, 2002). However, due to past neglect and other shortcomings such as poor documentation of IK, much of it had been lost during the past centuries of colonisation. This argument is reflected by Ogunniyi (2007a) in the following statement:

IKS reflects the wisdom about the environment developed over centuries by the inhabitants of South Africa, and much of this valuable wisdom believed to have been lost in the past 300 years of colonization now needs to be rediscovered and utilized to improve the quality of life of all South Africans(p.963).

The problem of integrating IK with science is further complicated by the situation that despite the intent of government policy to implement a science-IK curriculum, there has been a mixture of doubt, indifference, resistance and confusion on the part of teachers who had to carry on with the practical implementation of such a curriculum in the science classroom (Ogunniyi, 2005, 2007a, 2007b; Onwu, 2009). In an attempt to explicate teachers' opposition to the new curriculum, Ogunniyi (2007a) advances the following reasons:

- 1) Teachers were schooled in western science and hence were more familiar with that worldview than that of IKS.
- 2) The new curriculum demanded new instructional approaches and goals in terms of contextualization and indigenization rather than the old status quo of the mastery of scientific information for examination purposes which they were used to.

3) The top down approach in which the curriculum had been implemented seemed to underrate the teachers' role in curriculum planning and implementation. 4) The lack of clarity on how a Science-IKS curriculum could be implemented (p. 964).

1.2 Motivation for the study

Personal experiences often have long-lasting impressions in one's career as a science teacher. Three of such experiences directly influenced this research in various ways. First, the experience with using local musical instruments to teach the physics of sound as mentioned in the introduction; second, my involvement in the Science and Indigenous Knowledge Systems Project (SIKSP) at the University of the Western Cape (UWC), and thirdly, my experience with undergraduate students of a conceptual physics course at UWC.

Having previously outlined the first experiences above, I will proceed to give an outline of the encounter at the SIKSP. The SIKSP has been equipping both in-service and pre-service teachers to integrate science and IK in their classrooms. This is accomplished through innovative teaching strategies based on a dialogical argumentation framework (Ogunniyi, 2007a, 2007b). To accomplish this task, bi-weekly seminars and workshops are organised. During the bi-weekly workshops, teachers share their classroom experiences and also engage in practical activities aimed at enhancing their argumentation skills as has been reported by various researchers (Kwofie, 2009; Langenhoven, 2009; Ogunniyi, 2007a, 2007b, 2009, 2011).

I was exposed to dialogical argumentation as a teaching strategy through the SIKSP workshops. Furthermore, I became aware of the significance of expanding my understanding of science from the narrow Euro-centric perspective in which I was nurtured to a wider view that also considered indigenous ways of knowing as scientific in their own right. The group discussions and the exposure to the nature of science (NOS), as well as the dialogical argumentation platform enabled me to see the tentativeness of scientific laws and to acknowledge that school science worldview is just one way of explaining experience.

The experience in the undergraduate physics class enabled me to have a direct encounter with students who just completed high school. The course was designed to

assist students whose background knowledge of physical science was less than the minimum required for direct university admission.

Difficulties encountered by many of these learners on the topic of sound and waves seemed to indicate that their understanding of sound at high school was probably inadequate. This experience just seemed to confirm the findings of earlier studies that concluded that sound is a difficult topic (Linder, 1992; Wittmann *et al.*, 2003).

The topic 'sound' is often considered a simple example of wave physics, in particular and an example of a longitudinal wave. Although it is not considered as difficult as other topics such as electricity or mechanics, many studies suggest that sound is a conceptually difficult topic (Linder, 1992; Linder & Erickson, 1989; Wittmann *et al.*, 2003). Many alternative conceptualizations of sound concepts occur at all levels of learning. That is primary to tertiary.

The Nature of Production of Sound

Sound is a form of energy that requires a material medium for propagation. Although all sound is caused by vibrations, learners do not often attribute it to vibrations unless they see the source of sound vibrating (Driver, Squires, Rushworth & Wood-Robinson, 1994). Moreover, most learners often fail to understand that the vibrations are transmitted to the surrounding air. The studies cited below suggest the enormous difficulties learners might be facing at all levels of science learning.

Sound propagation

The propagation of sound is associated with the compressions and rarefactions produced in the medium in which the sound is propagated. Although the wave moves across the medium, the particles of the medium do not move along the wave pattern. However, studies have established that learners of various backgrounds hold many alternative conceptualizations of sound propagation (Chang *et al.*, 2007; Linder, 1992; Linder & Erickson, 1989; Periago, Pejuan, Jaen & Bohigas, 2009).

Driver *et al.* (1994) found that only learners from 16 years old could think that sound travels in air. For many learners, sound was conceptualised as "a material, invisible substance with dimensions flowing through empty space" (p. 135). Other difficulties

encountered by learners include the notion that sound can be trapped in a sealed container.

In this conceptualisation, sound in a sealed glass container cannot escape, unless there are holes. In some cases the learners believe that the holes may be microscopic, hence invisible to the eye (Chang *et al.*, 2007).

Speed of sound

The manner in which learners conceptualize the speed of sound has revealed many alternative conceptions. The speed of sound in air or any medium depends only on the properties of the medium. However, many learners often believe that wave properties such as the frequency, and amplitude of vibration would affect the speed (Chang *et al.*, 2007). In some cases, the speed of sound has been construed as dependent on the amount of obstruction provided by the particles of the medium (Linder, 1993b). The speed of sound is thought to be lower in solids than in air because the particles in the solid offer more obstruction. On the other hand, the speed of sound would be greater in a vacuum because there is nothing to obstruct the movement of the sound. The next section presents the study problem.

1.3 Problem Statement

In response to the post-apartheid challenges, and in line with trends all over the world with regard to science-ITK integration, the Department of Education (DoE) mandated that science teachers should relate science and technology to learners' socio-cultural environments. This mandate is clearly spelt out in Learning Outcome Three of the C2005 policy document. It is also articulated in the subsequent curriculum policy documents such as Revised National Curriculum Statement (RNCS), the National Curriculum statement (NCS) and the Curriculum Assessment Policy Statement (CAPS).

This means that learners are expected to be able to explore and evaluate scientific ideas in terms of their life-world experiences, and compare and evaluate the uses and values of scientific and technological products in terms of their impact on the environment and society. They are also expected to be able to compare the influence of different beliefs, attitudes and values on scientific knowledge (DoE, 2002). These changes in the science curriculum are in accord with trends in many parts of the

world, for example, Japan, Canada, Australia, Malawi, Mozambique, just to name a few (Castiano, 2009; Ogunniyi & Ogawa, 2008; Phiri, 2008; Snively & Cosiglia, 2001).

Organizations such as the United Nations Educational, Scientific and Cultural Organization (UNESCO) have adapted policies in line with the integration of indigenous knowledge (IK) with mainstream science because of the potential benefits of such endeavours in securing a more sustainable environment (International Council for Science, 2002; Snively & Cosiglia, 2001).

Despite the potential advantages of a science-IK curriculum and requirement by policy that the science teachers should integrate the two knowledge corpuses, practical implementation has been slow. Some teachers are still hesitant or confused about integrating science and IK because they do not know exactly how such integration could be done (Ogunniyi, 2007a; 2007b; Onwu, 2009). The practicing science teachers involved in the study of Onwu (2009) complained that they lacked models of how to integrate IK. Since they were schooled in the school science worldview alone, they also complained of a “Lack of knowledge/proficiency concerning teaching strategies to cope with IK issues” (p. 25). This group of teachers might just have been speaking on behalf of thousands of teachers throughout the country. There is a dire need for multiple attempts at integrating science and IK so that science teachers can find examples to both challenge and help them to do the same. The next section outlines the study rationale.

1.4 Rationale

Ausubel (1968) made this powerful declaration that seems to be most relevant to all teaching strategies underpinned by constructivism: “The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly” (p. VI). Throughout the years science educators have stressed the importance of prior learning in the construction of new knowledge in the science classroom. From the social constructivist point of view, learners’ prior knowledge which is obtained from everyday experience and home culture serves as the starting point for further knowledge construction (Driver, Asoko, Leach, Mortimer & Scott, 1994; Stamovlasis & Tsaparlis, 2006). Redish and Steinberg (1999) are in agreement with the above researchers. They assert that the experiences

learners bring to the physics classroom greatly influence the manner in which they hear and interpret the material presented to them by the teacher. This implies that the cultural influence of the home cannot be completely disregarded in a constructivist classroom. Consequently, learners' cultural background knowledge, which is the lens through which they interpret experience, ought to form part of the science classroom discourses.

In the case of non-western learners of science, such as those found in most South African classrooms, several studies have shown that the knowledge they possess from their home background experience may greatly hinder them from learning school science in a meaningful way (Aikenhead, 1996; Aikenhead & Jegede, 1999). These difficulties are greater when their traditional and indigenous interpretations are very different from those of school science that explain the same phenomenon. In order to reduce these difficulties, many science educators have suggested that learners' cultural values be appreciated and incorporated into the school science curriculum (Aikenhead, 1996, 2001; Aikenhead & Jegede, 1999; Jegede & Okebukola, 1991b; Ogunniyi, 1988, 2005b).

Ogunniyi (2005b) goes further to argue that science and technology are aspects of culture, and as such, cannot be taught and learnt in a socio-cultural vacuum. Consequently he contends that the assessment of the outcomes of any science curriculum cannot be regarded as culturally valid if the learners' socio-cultural backgrounds are disregarded. In line with this cross-cultural perspective, Garoutte (1999) recommends that learners be exposed to an elaborate indigenous model of inquiry where possible; and this can be reflected in song, dance, story-telling, and so on. Following this recommendation, Jegede and Aikenhead (1999) suggest specific instructional strategies for science teachers to bridge traditional knowledge and school science where teachers should use a variety of materials and resources, including those familiar to the learners.

In a similar vein, Onwu and Mosimege (2004) make suggestions on the type of IK that could be included in the curriculum. They suggest that IK should be used productively in the science classroom. They argue that IK should not only serve as a starting point for the exploration of science, but also for many benefits beyond the introductory stages, given its wide scope. The authors suggest that the similarities

and differences, strengths and weaknesses of the two systems (i.e. science and IK) should be articulated and explored during instruction in the science classroom. However, extant literature indicates that IK has been largely used in the form of examples, analogies or just as an anecdote to some science concept (Castiano, 2009). Very few studies have used IK as a main context or platform to teach school science.

This study therefore sought to investigate the effects of a dialogical argumentation instructional model (DAIM) to teach some concepts of sound using indigenous musical instruments. It was hoped that by using indigenous musical instruments as the main teaching materials for teaching sound, the learners from such backgrounds would most probably appreciate science better than when conventional science equipment alone is employed. One of the advantages of such a method is that learners from such cultures would come to realise that science is embedded in every culture and that it cannot be portrayed in the light of western culture only.

The topic of sound was chosen because it is part of the junior secondary school science syllabus. It is usually taught after the concept of waves because the conceptual understanding and interpretation of the different characteristics of sound are often explained using wave properties. Although many people think that this topic does not usually pose the kind of difficulties encountered in mechanics and electricity, research has shown that sound is a conceptually difficult topic (Hrepic, Zollman & Rebello, 2002; Linder, 1992, 1993; Wittmann *et al.*, 2003). Sound as a topic is a good starting point to teach more abstract concepts since sound is commonplace. It was thought that the many diverse applications of sound such as music, communication, medicine, architecture, and so on, could generate interest in learners.

1.4.1 Learners' Prior Conceptions of Sound

A review of literature indicates that several studies have been carried out on sound conceptions. These studies have consistently established that many concepts of sound are not readily understood and that many alternative conceptions of sound are held by science students at all levels of learning - primary, secondary and tertiary. Likely, the same studies have indicated that both practicing and prospective science teachers also hold many alternative conceptions of sound that are not consistent with the scientifically accepted views. I will present below some of these studies.

Mazens and Lautrey (2003) studied children's alternative conceptions or naïve representations of sound using a sample of eighty-nine children aged between six and ten. The purpose of the study was twofold: (1) to determine if the naïve knowledge of children about sound was fragmented and unorganized or structured around core principles.(2) To determine the mechanism of conceptual change. In-depth semi-structured interviews were used and the children had to predict, justify, observe and explain the outcome of the experiment. The results indicated that: (1) the younger children attributed sound to a substance more than the older ones.(2) Substantiality was attributed to sound more than weight and permanence; and finally. (3) Conceptual change took place gradually through a process of belief revision.

Driver, Squires, Rushworth and Wood-Robinson (1994)'s study on children's ideas about sound drew inspiration from the work of earlier researchers such as Watt and Russel (1990). In that study, Driver and colleagues concluded that children's explanations as regards sound production were mainly in terms of the physical properties of the source of sound. These explanations could include the physical attributes of the objects such as the size or shape.

Other explanations were given in terms of the force used in producing the sound, or in terms of the vibrations observed as sound was being produced. Driver and colleagues, referring to earlier studies, also noted that children hardly associated sound with vibrations unless they could see the object producing the sound vibrating, and very few children understood that the vibrations were transferred to the surrounding air. They also noted that only children who were at least 16 years of age believed that sound travels in air. However, they conceptualized the sound as 'a material, invisible substance with dimensions flowing through empty space' (p. 135). On their part, Chang *et al.* (2007) carried out a study of primary and secondary learners' physics concepts in Taiwan. The results of the study showed that 58% of the learners could correctly associate sound with waves while 25% of learners thought that sound could be blocked by a sealed container. On the other hand, 10% thought that sound could penetrate the wall of a container while 5% of the learners thought that sound was carried by air and could only penetrate the container walls through tiny holes.

The study of Eschach and Schwartz (2006) involved ten middle school (8th grade) learners who had never been taught sound concepts formally. In-depth open-ended clinical interviews were carried out for 25 to 40 minutes with the aim of finding out if Reiner, Slotta, Chi, & Resnick (2000)'s substance schema was present in their thinking, and how they used the schema's properties. They found that the learners perceived sound to be "pushable, frictional, containable, transitional (that is able to move and be moved), but viewed it as different from ordinary substances with respect to stability, corpuscular nature, additive and inertial properties" (p. 4). They also reported that learners' conceptualization of sound lacked internal consistency and global coherence. To them, learners' conceptualization of sound resembles diSessa (1993)'s loosely connected, fragmented ideas. In their view, the pre-conceptions of the learners were not strongly committed to the substance-based conceptualization of sound.

Chu and Treagust (2008) investigated the concepts of velocity, resonance, reflection and the motion of the pendulum using ten undergraduate physics students enrolled in a general physics course. In addition to a pre-test questionnaire, weekly interviews were used to collect the data over a period of twelve weeks. Most of the naïve physics students experienced difficulties in developing their conceptions into scientifically acceptable ones after this period of instruction. At the end of the study, only two out of ten students developed acceptable physics conceptions.

Linder (1992) investigated difficulties faced by students studying sound. He laments that sound is often hurriedly covered in tertiary physics as an example of wave physics because it is erroneously assumed to be straightforward; whereas studies show that students usually had misconceptions about sound concepts. He further notes that even though students could solve physics problems using mathematical approaches, they did not understand many basic concepts about sound. He notes that the use of analogies and illustrations in physics, if not well thought out, could lead to more confusion or reinforcement of students' misconceptions. In conclusion, recommends a more observational, conceptual approach to teaching of physics that takes into consideration students' prior conceptions.

The examples just mentioned are an indication of the difficulties faced by learners when they study sound. The prior knowledge of most learners often differs from the scientifically acceptable conceptions of sound. Hence different instructional methods are needed to help them understand the difference between what they hold concerning a particular sound concept and what science holds. By differentiating between the two worldviews, the learners would be able to choose one or the other explanation based on the context and supporting evidence. That is where dialogical argumentation as a teaching strategy seems to have an advantage over others such as the lecture-demonstration method.

1.4.2 Meaningful learning of science

Many researchers have investigated the behaviour of non-western learners in science classrooms (for example, Aikenhead, 1996; Aikenhead & Jegede, 1999). Most of these researchers agree that learners from non-western backgrounds tend to face more barriers than their western counterparts in the attempts to learn school science. The explanation they provide is that these barriers are due to cultural differences between the science worldview and their inherent worldview as this presents a cognitive barrier. Hence, these researchers tend to adopt different ways of crossing these barriers and negotiating their learning within the cognitive and cultural domains; as further elaborated in chapter two). Since school science, which is embedded in the western thought system, cannot easily replace the indigenous knowledge (IK) in which many Africans grow up (Ogunniyi, 2004), many learners of science from African and non-European backgrounds as a whole, tend to switch between the two systems of thought, depending on their surrounding circumstances (Aikenhead, 1996; DoE, 2002). A personal example may illustrate this point further.

In 2008, after teaching form one (grade 8) learners the introductory concepts of science such as carrying out investigations in science through experiments, we got involved in a whole class discussion about the differences between science and IK (referred to as 'superstition' in the textbook which we were using). Many of the learners were of the opinion that some of their traditional beliefs were the truth, contrary to what the textbook was trying to make them believe. After much debate, one learner said that she would just write what the textbook says only to acquire a pass mark in a test.

This learner was convinced that her traditional beliefs were the truth and not myth. Her comments just seemed to have externalized what might be going on in the minds of many learners of science from non-western cultures. Many of them write what the science teacher demands at school just for the sake of obtaining a pass mark but go back with their indigenous conceptions intact. Although they study and pass the science subjects at school, they do not see science as relevant to their daily experiences. In this regard, many studies done in connection with the influence of traditional beliefs on the learning of science by children of non-western backgrounds have concluded that some of these beliefs may constitute an obstacle to the learning of school science if not well managed (Aikenhead, 1996; Jegede & Okebukela, 1991; Kesamang & Taiwo, 2002).

Aikenhead (1996) contends that science has a culture and that the manner in which learners cross from the subcultures of their peers and families to the subculture of school science can constitute a formidable barrier if not well managed. When the learner's life-world is congruent with that of school science, the transition from the home culture to that of school science is smooth; when the two are different, the transition needs to be managed. When life-world culture is very different, the transition tends to be hazardous; and when the two are highly discordant, the learners tend to resist change; and transition from the home culture to that of school science becomes virtually impossible. Such learners find the learning of science very difficult or almost impossible.

In order to assist learners cross cognitive borders less hazardously, Aikenhead (1996) has suggested that school science teaching should be regarded as cultural transmission that can be supportive or disruptive to the learner's life-world subculture. In view of this, a majority of learners in South African schools who are from black (indigenous) backgrounds, for example, need to cross the cultural borders into the subculture of school science. Integrating indigenous knowledge (IK) into the science curriculum would make science more relevant to them, and hence will facilitate smooth border crossing into the school science sub-culture (Aikenhead, 1996; Aikenhead & Jegede, 1999).

1.4.3 Dialogical argumentation as a teaching strategy

Dialogical argumentation involves learners making claims in the science class on the basis of evidence while other learners are free to question the claims or the evidence. According to Ogunniyi (2007a),

Argumentation is a statement or constellation of statements advanced by an individual or a group to justify or refute a claim in order to attain the approbation of an audience ... or to reach consensus on a controversial subject matter such as integrating science and IKS (p.965).

A dialogical argumentation-based classroom provides learners with the opportunity to express their views freely as well as clear their doubts. Viewed from this perspective, dialogical argumentation enables learners, in their attempt to construct knowledge, to actively participate in class by making claims and using evidence to justify such claims, while other learners make counter-claims or rebuttals. Hence, rather than just accepting scientific information as given by the teacher, the learners in an argumentation-based classroom interrogate it before reaching a conclusion. In the dialogical argumentation instructional model (DAIM) which was used in this study, each learner first makes claims and provides grounds on a given task individually. Next the learners present their views in small groups while others scrutinize, question and rebut some of the claims and/or grounds. Finally group representatives present the group conclusions to the whole class while the other learners question and provide rebuttals (Kwofie, 2009; Ogunniyi, 2011). The teacher acts as a facilitator rather than the sole authority. By examining various views in a science class, learners are able to arrive at a more valid conclusion as well as develop critical thinking- a critical aspect of the scientific form of reasoning (DoE, 2002, p. 10-12). The next section articulates the purpose of the study.

1.5 Purpose of the study

The purpose of this study was to investigate the effect of using the DAIM (an instructional strategy that takes the learners' indigenous knowledge background into consideration) to teach some concepts of sound to grade 11 learners. The use of indigenous musical instruments in teaching sound concepts was deemed suitable as a way of introducing the learner to science through a familiar cultural context. In this

way the indigenous knowledge (IK) dimension would be integrated into the science lessons, as demanded by the curriculum (Learning Outcome 3 and the Specific Outcome 3 of the CAPS).

1.6 Research Questions

In order to investigate the problem in a coherent manner, the study sought to find answers to the following questions:

1. What concepts of sound do grade 11 learners hold before and after being exposed to a dialogical argumentation instruction involving the use of indigenous musical instruments?
2. Is there a difference between the learners' conceptual understanding of sound by those exposed to dialogical argumentation instruction and those not exposed to it? Is learners' conceptual understanding of sound affected by gender or age?
3. a) What IKS-based conceptions of sound do the learners hold? b) What are the learners' attitudes towards the integration of IK and science? Are learners' attitudes towards the integration of science and IK affected by gender or age?

1.7 Theoretical Framework

Several theoretical frameworks exist, depending on the nature and goals of the study. A theoretical framework is made up of one or several interrelated theories or concepts relevant to the intended study. The theoretical framework guides a study by giving it some form and direction. It enables the researcher to avoid getting into confusion in the process of the study since there may be many things worth including. It acts as the lens through which the researcher views the whole study. The theoretical framework acts as road map or building plan guiding the research design, procedures of data collection, analyses and interpretation. In this regard Maxwell (2005) affirms that

The function of the theory [theoretical framework] is to inform the rest of the study – to help you assess your purposes, develop and select realistic and relevant research questions and methods, and identify potential validity threats to your conclusion (p. 25).

In the light of these considerations of a theoretical framework, this study was informed and guided by three interrelated theories within a dialogical argumentation framework. These theories include Toulmin (1958)'s Argumentation Pattern (TAP) and Ogunniyi (1997)'s Contiguity Argumentation Theory (CAT).

In addition, it was deemed necessary to use Reiner, Slotta, Chi and Resnick (2000)'s Substance Schema of conceptual change to analyse the learners' alternative conceptions. Essentially, these theoretical constructs, to some extent, are in agreement with socio-cultural constructivism as espoused by Vygotsky (1978) and personal constructivism as espoused by Piaget. Constructivism is premised on the notion that knowledge is not transferred from the knower to the learner, but actively constructed by the learner, drawing from prior experience (Ausubel, 1968; Driver, Asoko, Leach, Mortimar & Scott, 1994).

In line with the aforementioned views on theoretical frameworks, I found the three theories mentioned above relevant to shaping and guiding this research. These theoretical constructs -Toulmin (1958)'s argumentation pattern (TAP), Ogunniyi (1997)'s contiguity argumentation theory (CAT), and Reiner *et al.* (2000)'s substance schema complement each other.

Toulmin (1958)'s argumentation pattern has been used by many researchers in science education to promote scientific discourses in the science classroom because it is more amenable to inductive-deductive logical forms of reasoning prevalent in most science discourses. Since the study also involved the inclusion of IK which involves metaphysical, and both logical and non-logical reasoning, the CAT which is amenable to both thought systems was also relevant. Reiner and colleagues' substance schema was necessary as a tool for evaluating the nature and validity of reasons given in justification of claims made by the learners. The evaluation was done in terms of the scientific context of conceptual change, which neither of the preceding theories could handle. An elaboration of each of these theories will be outlined in the subsequent sections.

1.7.1 Toulmin's Argumentation Pattern

The TAP is one of the tools in science education that has enabled both teachers and learners to immensely understand the nature of science (Ogunniyi & Hewson,

2008). Toulmin (1958) stressed that the structure of the argument is the same across different domains, though the quality of an argument depends on the context. That is, the structure (which consists of data, warrants, backing, claim,) is generic across different domains. However, the warrants which link the data to the claims depend on the context (Acar, 2008; Driver *et al.*, 2000).

To take an example that is relevant to this study: if a learner makes a statement that “The speed of sound will increase because the drummer is playing the drum with more force than before” such statement will sound very right in everyday reasoning. TAP will have no problem with such a statement because it is syllogistically correct. The validity of this statement can therefore only be determined by applying a theory which would take into consideration the relevant theories relating the speed of sound to the force producing it. Toulmin himself admitted that the warrants justifying the claim from the given evidence were field-dependent. Therefore, learners with a good knowledge of the content of the science topic would produce better arguments than novices (Sadler & Fowler, 2006).

Many science education researchers agree that students have to master the structure of the TAP as an analytic tool for reasoning, implying that learners need to be explicitly taught argumentation in order to be able to effectively use it as a tool to construct knowledge (Kuhn, 1993; Osborne *et al.*, 2004). However, research has also established that the quality of the argument depends on the learners’ content knowledge in order to be able to cite the necessary data to back a claim, and adequate warrants to justify the connection with it (Acar, 2008, von Aufschnaiter *et al.*, 2008; Sadler & Fowler, 2006).

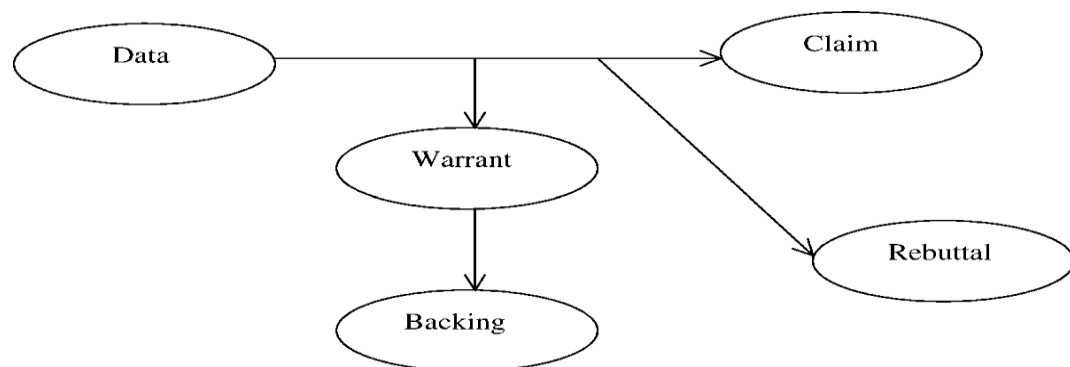


Figure 1.1 The Structure of Toulmin’s Argument Pattern (Erduran, Simon & Osborne, 2004)

The structure of TAP is framed in six basic elements – claims, data, warrants, backings, qualifiers, and rebuttals.

According to Toulmin (1958):

A claim is ‘a conclusion whose merit we are seeking to establish’ (p. 97). A claim can be a statement expressing a conclusion from a deductive argument or a statement of belief expressing one’s opinion in a given situation.

Data refers to ‘the facts we appeal to as a foundation for the claim’ (p.97). Data may take the form of experimental evidence collected in the laboratory, or some other form of empirical evidence that can be measured or examined for desired qualities.

Warrants are ‘rules, principles, inference-licenses’ which justify why the data counts as evidence in support of the claim (p.98). Since these rules and principles or theories are field-dependent, strong warrants would need a good knowledge of the specific content of the subject area in science.

Backings are the underlying or implicit assumptions in support of the warrant. They may be drawn from scientific theories or from common knowledge. This implies that to elicit backings of good quality in support to the warrant, content knowledge is required.

A qualifier is a special condition under which the claim holds true or the special conditions under which the warrants validly lead to the claim. For example, suppose someone makes the statement: Since the water is boiling, its temperature is 100°C. This statement is not entirely true because water boils at 100°C only when certain conditions of pressure and purity are met. Thus these conditions need to be included in a qualifier: Since the water is boiling, its temperature is 100°C, provided the water is pure and the pressure is atmospheric.

A rebuttal is a counter statement or a different view that contradicts some stated claim, data or warrant (Ogunniyi, 2007a). According to Toulmin (1958), rebuttals, warrants and backings depend on the field of study. Consequently, one can conclude that strong warrants, rebuttals or backings require requisite content knowledge to engage in arguments of high quality.

One criticism that was levied against TAP was the difficulty in distinguishing between data, warrant and backings as some of these elements were not explicitly put in an argument (Erduran et *al.*, 2004).

In order to resolve some of the difficulties faced by the learners and teachers in identifying the various elements of TAP, Erduran, Simon and Osborne (2004) called the data, warrants and backing collectively as ‘grounds’ (Erduran et *al.*, 2004, Ogunniyi, 2009). In this study I used this simplified version of the TAP. While TAP is more useful in an inductive-deductive classroom discourse, the Contiguity Argumentation Theory (CAT) is more applicable to the case of IKS-science integration since the CAT deals with both logical and scientifically valid arguments as well as with the non-logical and metaphysical phenomena of IKS (Ogunniyi & Hewson, 2008).

Table 1.1 Levels of TAP’s arguments in classroom discourse

Quality	Characteristics of an argumentation discourse
Level 0	Non-oppositional
Level 1	Argumentation involves a simple claim against a counter claim with no grounds or rebuttals.
Level 2	Argument involves claims or counter claims, with grounds but no rebuttals.
Level 3	Argument involves claims or counter claims with grounds but only a single rebuttal challenging the claim.
Level 4	Argument involves multiple rebuttals challenging the claim but no rebuttal challenging the grounds (data, warrants, and backing) supporting the claim.
Level 5	Argument involves multiple rebuttals and at least one rebuttal challenging the grounds.
Level 6	Argument involves multiple rebuttals and at least one rebuttal challenging the grounds.

Source: Ogunniyi, 2009 (modified after Erduran, Simon & Osborne, 2004).

1.7.2 The Contiguity Argumentation Theory

The CAT is draws from the Aristotelian notion of the interaction of ideas in a person’s mind as he/she attempts to resolve a conflict. CAT construes such interaction of ideas as an attempt to attain cognitive harmony or equilibrium through a coupling process akin to that of competition, accommodation, integrative

reconciliation and adaptation (Ogunniyi, 1988). At the stage when cognitive harmony is attained (what Ogunniyi calls the a-ha! moment or the state of consciousness), some learning has taken place-even if it is for a short duration of time. The whole process is dynamic and in a state of flux, depending on the arousal context which triggers the whole process of learning (Ogunniyi, 2007a & b; Ogunniyi & Hewson, 2008).

A fundamental assumption of the CAT is that claims and counter claims on any subject matter or across fields (such as science and IKS) can only be justified if both systems of thoughts are initially accorded the same status until one is found to be inappropriate for a given context (Ogunniyi, 2007a; 2009; Ogunniyi & Hewson, 2008).

Also, there should be valid reasons to place the two distinct worldviews side by side within the same dialogical space, which facilitates the process of the re-articulation of the different worldviews. For students to integrate the two distinct worldviews, they must be able to make sense of their combined effect. The CAT asserts that conceptions can move in at least five cognitive stages within the learner's mind or between learners involved in dialoguing on science and IKS-based conceptions. The cognitive states are the equipollent, dominant, suppressed, emergent and assimilated states. These concepts in the five categories are in a dynamic state of flux in the learner's mind. As stated in Ogunniyi and Hewson (2008, p.162):

- A cognitive stage is dominant if it is the most adaptable to a given context.
- A cognitive stage becomes suppressed by one that is more adaptable.
- A cognitive stage becomes assimilated into one that is more adaptable than itself.
- An emergent cognitive stage occurs when one is exposed to a phenomenon for the first time, with no previous knowledge of it.
- An equipollent mental stage occurs when two opposing ideas or worldviews exert approximately equal intellectual forces on the person.

Ideas in the equipollent stage tend to co-exist, without possibly resulting in any conflict (Ogunniyi, 2007a; Ogunniyi & Hewson, 2008). For example, the belief in Darwin's theory of evolution and the story of creation as stated in the bible can co-exist in a learner's mind, and used in school or personal contexts without any conflict.

However, two types of equipollent ideas seem to exist in the learner's mind – one in which the equipollent ideas are clearly distinguishable to the learner and the other in which the two co-existing ideas are indistinguishable. In the distinguishable condition, the learner holding the science and IK explanations of the same phenomenon knows the differences between these two explanations. Thus such a learner knows the context in which the scientific explanation can be used and the context in which the IK explanation is more valid. In the preceding example, if such a learner goes to the church, he or she will know that the context warrants the creationist view, and evolution is immediately suppressed.

On the other hand, the same learner in a biology class would answer the questions according to Darwin's theory and not according to the biblical account because the context has changed.

When the equipollent ideas are indistinguishable, the learner would use either the science or IK worldviews even when the context demands the use of the other. For example, a learner with such ideas would fail to give only the explanations that are in agreement with Darwin's theory in the science class but would see nothing wrong in using creationist views in the science classroom. Learners with this kind of thought patterns seem to be more prone to carrying their alternative conceptions into the science classroom. Such misconceptions cannot be easily corrected through normal instruction. During argumentation, such learners may benefit as they express their thoughts and clarify their ideas (Ogunniyi & Hewson, 2008).

It should be noted that these cognitive stages are always bipolar in nature, implying that when one thought system is dominant, there is another thought system being dominated (suppressed or assimilated), suggesting that the determinant of whether a thought system is dominant, suppressed, assimilated, or the two are equipollent depends on the context (Ogunniyi, 2004). The assimilated worldview differs from the suppressed in that whereas the suppressed may become dominant in a different context, the assimilated remains subservient to the dominant worldview even when the context needs it to assume a dominant role. For example, a learner whose IK worldview has been assimilated by the science worldview would always explain a phenomenon like the origin of life in terms of the scientific explanation based on evolution or the big bang and ignore or dismiss the religious creationist explanations

as superstitious, although he/she cannot prove his/her own supposedly scientific theory.

1.7.3 Reiner *et al.* (2000)'s Substance Schema

An analysis of the quality of arguments on conceptions of sound for example, based on the TAP would enable one to know the learners' levels of argumentation while the CAT categorization would give the picture of the dynamism of cognitive states involved in the process of argumentation. The role of claims and counter claims in shaping the course of an argument cannot be ignored i.e. an arguer is not only concerned about the logicity of his viewpoint but that of a possible opponent (Leitao, 2000). These analyses would inform one about nature and structure of the arguments.

Despite the insight provided by TAP, it fails to capture the complete picture of an argument since the nature and validity of the evidence provided in the warrants is not taken into account. Likewise, though CAT has shown the dynamism of the cognitive process involved in argumentation, the actual mechanism involved in knowledge revision on account of an argument will still require a deeper investigation perhaps beyond the scope of psychological analysis. For the same reason Ogunniyi (2007a) has pointed the need to explore possible contribution that the field of neural science can provide to this subject matter. However, that discourse is beyond the scope of this exploratory study. Neither TAP nor CAT has explicitly shown how the framework proposed applies to conceptual understanding in science.

To provide a more complete evaluation of the argumentation, the nature and validity of the evidence needs to be considered in order to judge if it is indeed consistent with the scientific theory in the topic (McNeil, 2011; Sandoval & Millwood, 2005). In order to encapsulate the scientific content of the arguments, it was thought worthwhile to include Reiner *et al.* (2000)'s substance schema. This schema analyses the quality of an argument or a statement in terms of the underlying conceptual understanding involved.

Many studies have shown that learners often attribute properties of materials to abstract concepts and processes, and as a result, the learners develop many

misconceptions about the said phenomena (Chi, 2008; Chi, Slotta & Leeuw, 1994; Reiner *et al.*, 2000; Slotta, Chi & Joram, 1995). Reiner *et al.* (2000) have come up with a list of properties which characterize such mental misconceptions in learners as shown below:

1. Substances are *pushable* (able to push and be pushed).
2. Substances are *frictional* (experience “drag” when moving in contact with some surface).
3. Substances are *containable* (able to be contained by something).
4. Substances are *consumable* (able to be “used up”).
5. Substances are *locational* (have a definite location).
6. Substances are *transitional* (able to move or be moved).
7. Substances are *stable* (do not spontaneously appear or disappear).
8. Substance can be of a *corpuscular nature* (have surface and volume).
9. Substances are *additive* (can be combined to increase mass and volume).
10. Substances are *inertial* (require a force to accelerate).
11. Substances are *gravity sensitive* (fall downward when dropped).

(Source: Reiner, Slotta, Chi & Resnick, 2000, p. 34-35).

This schema was used to analyse the content of arguments advanced by learners in the appropriate areas of sound concepts. The following section outlines the significance of the study.

1.8 Significance of the study

It was anticipated that this study would contribute to existing knowledge in science education by:

- 1) Documenting the degree of alternative conceptions of sound prevalent in the learners in the sample under study.

- 2) Comparing the relative effectiveness or otherwise of dialogical argumentation instruction and the teacher-centred method in ameliorating the conceptual understanding of learner on sound. More specifically, the relative effectiveness in altering learners' alternative conceptions to the scientifically acceptable alternatives.
- 3) Enabling or challenging science teachers in South Africa to consider seriously the potential usefulness of integrating science and indigenous knowledge in their classrooms.
- 4) Highlighting the learners' opinions with respect to the use of indigenous knowledge in the science classroom.
- 5) Documenting the existence or otherwise of IKS beliefs held by the learners.
- 6) Raising the awareness of both teachers and curriculum developers about dialogical argumentation as a potentially useful tool in implementing a science-indigenous knowledge curriculum, as demanded by policy.
- 7) Examining if there are differences or otherwise in the learners based on gender.

1.9 Operational definitions

This section provides a good understanding of the key concepts as actually used in this study.

a. Indigenous musical instruments

Indigenous musical instruments are musical instruments that are common to the local African people, and fabricated by craftsmen within these communities. They are mostly made out of dry wood and leather, or strings attached.

b. Indigenous Knowledge (IK):

Indigenous knowledge is an all-inclusive knowledge that covers technologies and practices that have been and are still used by indigenous people for existence, survival and adaptation in a variety of environments. Such knowledge is not static but evolves and changes as it develops, and is influenced by both internal and external circumstances and by interaction with other knowledge systems... (Onwu & Mosimege, 2004, p. 2).

c. Dialogical argumentation

Dialogical argumentation involves one making a claim, and using evidence to logically back one's position. It also involves people proposing alternative views, challenging the claims made by others, and finally coming to a consensus through convincing evidence.

d. Sound

Sound is a form of energy which comes about as a result of longitudinal wave propagation and which can be detected by the human ear, if it falls within the audio frequency range.

e. Curriculum 2005

C2005 was the new South African curriculum that was introduced by the ANC-led government in 1998 after it took over from the apartheid government. It was known as Outcomes Based Education (OBE), and was a radical departure from the former curriculum which was teacher-centred.

f. Misconceptions

Misconceptions include all incorrect descriptions, misinterpretations, or inaccurate explanations of a scientific concept created by the learner (Yip, Chung & Mak, 1998, p.320).

g. Integration of science and IK

The consideration of both science and IK as equally valid sources of explaining observed phenomena.

h. Culture

Culture is the overall lifestyle of a society and the way it deals with reality (Ogunniyi, 2005). More specifically this includes the norms, values, beliefs, worldview, skills, behaviour, and technologies (artifacts and know-how) of a group of people (Phelan, Davidson, and Cao; cited in Aikenhead, 1996).

i. Cultural border-crossing

This refers to the transition between a learner's worldview and the science worldview of natural phenomena (Aikenhead, 1996; Aikenhead & Jegede, 1999).

j. School science

The science that is taught and learnt at school using standard texts derived from European or Western backgrounds.

1.10 Scope and delimitation of the study

There are so many indigenous musical instruments in use in Cape Town, but in the scope of this study the following instruments were used: guitar, harp, drum, xylophone (marimba), and a *vuvuzela*. These were chosen because they were familiar to the learners and represented different types of musical instruments - stringed, percussion and wind instruments. Although there are many properties of sound worthy of investigation using musical instruments, the study was limited to the scope of the syllabus in that particular grade.

Due to several limitations such as finances, time, lack of teachers capable and willing to implement the study, the research was limited to two modestly resourced schools in predominantly middle and lower class areas in the North District of the Western Cape Educational Department.

1.11 Thesis outline

Chapter one serves as an introduction to the study. Chapter two is a review of relevant literature in the areas of conceptual change, argumentation and teaching of science in multicultural contexts. Chapter three presents the research design, the research processes, and the methods of data analysis employed in the study. In chapter four the results are presented, followed by discussions. Chapter five comprises the conclusion of the research, followed by some implications and recommendations for various stakeholders – science teachers, curriculum advisers, and so on.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

In this chapter, the literature related to the study is explored. The chapter begins with theoretical considerations while the practical ones based on actual studies are presented later. In view of the role that alternative conceptions and conceptual change play in the learning of sound concepts, this chapter begins with a critical review of issues related to conceptual change. This review examines several criticisms leveled against the conceptual change theories of learning and then presents more recent instructional practices which seem to address the shortcomings of the previous conceptual change methods.

Of special note are the methods used in teaching and learning science to non-western learners. Within the constructivist paradigm in which this study falls in, the learner's background knowledge is very important, and cannot therefore be left out. Given the multicultural nature of the learners in most South African science classrooms, the chapter would next examine arguments and theories involved in teaching science in multicultural contexts or to non-western learners. The next concept to be examined in this review is argumentation as a learning tool in science education.

Science learning has been strongly associated with argumentation (Driver *et al.*, 2000; Kuhn, 1993), hence the instructional method (the DAIM) used for the intervention in this study was argumentation-based. Argumentation was also preferred over other methods because it was a versatile tool that could handle many different aspects of the new science curriculum in South Africa. Moreover, it seems to be a cost effective method if well managed. The following section discusses the concept of alternatives conceptions and its relevance to the present study.

2.1 Alternative conceptions

A fundamental constructivist view of learning holds that learners do not come to the science class *tabula rasa*, but do hold their own ideas of how the world works (Ausubel, 1968).

However, many science education researchers agree that some of the learners' pre-instructional ideas might constitute a stumbling block to the acquisition of the scientific concepts which they are expected to learn. Consequently these pre-instructional ideas held by learners have been the subject of much research since they play such a key role in the learning of new science concepts.

Science education researchers have used different names for learners' pre-instructional conceptions. Some of these names found in literature include: alternative conceptions (Grayson, 2004; Leite & Afonso, 2000; Tsai & Chou, 2002), misconceptions (Vosniadou, 2002; Slotta, Chi & Joram, 1995), students' mental models (Chiu, Chou & Liu, 2002; Hrepic, Zollman & Rebello, 2002), students' preconceptions (Eschach & Schwartz, 2006), alternative frameworks, Aristotelian physics (diSessa, 1982), ontological misclassifications (Chi, 2008; Slotta, Chi & Joram, 1995), naïve knowledge (Lautrey & Mazens, 2004), naïve physics (Vosniadou, 1994) and so on. With the different appellations are also associated differences in meanings of what pre-instructional conceptions are.

Different meanings are reflected in the definitions by different authors. For example, Vosniadou (2002) views misconceptions as 'Student conceptions that produce systematic patterns of error' (p. 62). Other researchers define them as 'ontological miscategorizations of concepts' (Chi & Roscoe, 2002). In this study, I will use the expression 'alternative conceptions' to refer to the learners' ideas with regard to different sound concepts. The word 'misconceptions' when used will mean 'all incorrect descriptions, misinterpretations, or inaccurate explanations of a scientific concept created by the learner during the learning process' (Yip, Chung & Mak, 1998, p. 320).

Most science educators agree that learners' prior conceptions that differ significantly from the scientific concepts could be very resistant to change. Following normal instructional methods, many learners may still prefer to retain their pre-instructional ideas. Since pre-instructional conceptions played such a vital role in the learning of new knowledge by the learners, the study of learners' pre-conceptions became a prominent topic for research by science educators in the 1980s and 1990s (diSessa, 1993, Posner *et al.*, 1982; Slotta, Chi & Joram, 1995).

However, the persistent failure to achieve conceptual change as expected through instructional strategies hinged on creating cognitive conflict galvanized some science education researchers into searching for more satisfactory methods of teaching science to learners. An important question to consider is how the pre-instructional conceptions of sound come about in the first place.

2.1.1 How do alternative conceptions of sound come about?

It is not very clear from literature how exactly pre-instructional conceptions arise. However, there are indications that several factors in the learner's home or classroom environment might be responsible for many of them. Yip, Chung and Mak (1998) have put it as follows:

Misconceptions often have a diversity of causes. These include a partial understanding of a concept due to an inadequate prerequisite knowledge, or negligence of the conditions and assumptions behind a rule, or an over-generalization of principles from inadequate evidence. Misconceptions may also be resulted from an interference of learnt materials, an uncritical acceptance of incorrect information, or a wrong deduction due to fallacious reasoning (p.320).

Some of these factors include pre-instructional beliefs about the given concept, confusing language of science as well as the unintentional use of poor analogies and illustrations. In addition, teachers themselves might pass on their own misconceptions to their learners.

Some science education researchers have attributed alternative conceptions to flawed mental models (Vosniadou, 1994; Vosniadou & Brewer, 1992). According to Vosniadou (1994), learners come to the science class with their own presuppositions of the way the world works. When they encounter scientific concepts which contradict what they hold, they might try to assimilate them into their conceptual structures, creating hybrid models of the concepts they hold. As a result, the learners develop misconceptions of the concept. The study of Hrepic, Zollmann and Rebello (2002) typifies this view. In this study, Hrepic and colleagues noted that at pre-test, most learners were of the view that sound was made of material entities (particles). After instruction most learners shifted from the entity model to an entity-waves model by combining aspects of the pre-instructional particle model with the terminology of waves acquired as a result of instruction.

Hrepic and colleagues concluded that many learners often pass through the hybrid model before ending with the scientific version of the concept (Hrepic, Zollmann & Rebello, 2002).

In the ontological perspective of conceptual change, alternative conceptions are caused by a learner classifying the concept in a wrong ontological category (Chi, 2008; Chi & Roscoe, 2002). If the concept is misclassified into a different branch of the same ontological tree, the misconceptions are less resistant to change. However, if misclassified into a different ontological tree altogether, it is more resistant to change. Therefore in the view of this group of researchers, if sound is construed as being made of particles, it would be treated as matter. Hence sound will be assigned attributes of mass and volume, since these are attributes of all matter.

The different meanings of the same word used in science and everyday language may lead to misconceptions in the mind of learners. For instance, in everyday language, we can speak of increasing the volume of sound to mean increasing its loudness or intensity. However, Eshach and Schwartz (2006) have pointed out that such an expression may lead to the wrong notion of attributing dimensionality to sound since the word 'volume' in everyday language involves dimensions. The result is that learners might tend to construe sound as an entity having dimensions. Similarly, speed and velocity are synonyms in everyday language and can be used interchangeably. However, in science these two words mean quite different things. Speed is a scalar quantity whereas velocity is a vector quantity.

Linder (1992) has pointed out that teachers' use of slinky coils, ripple tanks or water waves to demonstrate wave properties to learners might not serve the intended purpose as expected. In his view, these activities could have the negative effect of making the learners believe that waves are material entities. This type of flawed reasoning would be difficult to undo. Thus, the use of analogies and illustrations in physics, if not well thought out, could possibly result in greater confusion or a reinforcement of students' alternative conceptions.

In a similar view, Leite and Afonso (2000) identified poor analogies, misleading illustrations and diagrams used by textbooks or teachers as a potential cause of learners' misconceptions. They argued that sound waves which are often represented in the same manner as transverse waves in textbook diagrams might make it difficult

for learners to construe them as longitudinal waves. In that study, Leite and Afonso (2000) surveyed many textbooks used in teaching secondary school physics in Portuguese schools. They concluded that many of the textbook illustrations and diagrams had the potential of causing or reinforcing learners' alternative conceptions.

One potential source of misconceptions found in literature is that of science teachers themselves. Several studies (Gonen, 2008; Kallery & Psillos, 2001) have established that many science teachers do have many of these misconceptions, and that they eventually pass some of these misconceptions to their learners. In one study, Gonen (2008) wanted to find out the knowledge of pre-service science teachers about the concept of mass and gravity. He discovered that these teachers held many misconceptions about inertia, gravity and weight concepts.

In another study, Kallery and Psillos (2001) carried out a study involving 103 in-service kindergarten teachers to determine their understanding of elementary science concepts. The results showed that only 21.9% of the teachers' answers were scientifically correct, while 57.3% were alternative conceptions. In the second phase of the same study 11 of the teachers were observed for a period of one year to evaluate the way they taught science. More than 60% of the science taught by these teachers was made of alternative conceptions, and only 7% was valid science.

In teaching science, it is not just sufficient to know the learners' pre-instructional conceptions in the topic. A very important step is also to know the teaching strategies that could be most helpful in enabling learners to accept the scientific explanation as plausible and fruitful in explaining experience (Posner et al., 1982). Hence in the next section I will elaborate on this point.

2.1.2 Teaching methods for conceptual change

Posner et al. (1982) posited that for a learner to accommodate a new concept that significantly differed from the present conception held by the learner, four conditions must be met.

Firstly, the learner must become dissatisfied with the current conception's ability to explain experience. This might occur after exposing the learner to dilemmas which

the held conception would fail to adequately explain, thus causing the learner to lose faith in its explanatory capacity.

Secondly, the new conception should be intelligible to the learner. Thirdly the new conception should be initially plausible. This means that it should appear more consistent in solving the anomalous situation that has rendered the learner dissatisfied with the current conception, and should also be consistent with what the learner believes to be true. Lastly, the new conception should hold promise of being fruitful. That is, it should have the potential of being useful in further enquiry.

In order to teach learners to accommodate the scientific concepts, Posner and colleagues proposed that teacher should first diagnose learners' pre-conceptions. Secondly they should use various strategies such as the use of anomalies to create cognitive conflict in the learners. This, in their view was going to cause the learners to become dissatisfied with the existing conception. In this strategy, the teacher played the role of 'an adversary in the sense of a Socratic tutor' (Posner *et al.*, 1982, p. 226).

After causing dissatisfaction in the learners, the teacher was then required to present the scientific concept in multiple ways in order to convince the learners that the scientific conception was more plausible than his/her present pre-conception in explaining experience. To Posner and colleagues, the cognitive conflict strategy of teaching was going to result in the learners abandoning their pre-conceptions for the scientific concept. Hewson (1992) goes further to suggest the type of environment that would likely foster conceptual change.

Hewson (1992) identified some key elements that should be present during conceptual change teaching. These include: 1) a metacognitive stage whereby learners step back and reflect about their ideas or those of others, 2) a classroom climate where there is respect by both the teacher and learners for the ideas of others, even when they seem to be contradictory, 3) a classroom environment where the teacher provides opportunities for learners to express themselves without fear of ridicule, and finally, 4) a classroom environment where learners take responsibility for their learning, respect the ideas of others and where the learners are free to change their ideas when they find others better than theirs.

Therefore according to Hewson's criteria, the argumentation instructional strategy which was used in this study would be a good instructional strategy for conceptual change since it has all these elements present. In the next section I will present some empirical studies involving the sound concepts considered in this study. Such studies serve a useful purpose in that one can be able to compare the findings of the present study with earlier ones to see the similarities and differences.

2.1.3 Empirical Studies on Conceptions of Sound

Many studies have been carried out to investigate students' conceptions of sound speed, sound propagation, and sound produced from stringed instruments. The first of these studies involved the way pre-service science students conceptualised the factors that affected the speed of sound.

Linder (1993b) studied the way some Canadian and South African physics graduates conceptualized the factors affecting the speed of sound. The data was obtained from interviews of fourteen students who had completed a physics course and were involved in physics teaching - either as tutors of undergraduate physics courses or teacher education programmes. He classified the way students conceptualize these factors affecting the speed of sound into three categories.

The first idea was that the speed of sound depended on the amount of obstruction offered by the particles of the medium as sound moved through it. According to this view, the less the opposition, the greater the speed of sound propagation; implying that sound would travel with maximum speed in a vacuum. The second conception was that the speed of sound depended on the distance separating the molecules in the medium. In this case the students reasoned that a molecule could carry sound and transmit it to its neighbour by travelling and colliding with it. Therefore in this conceptualization, the shorter the distance separating the molecules, the faster sound would travel. The third manner of reasoning was that the speed of sound depended on the compressibility of the medium. Here, sound was believed to propagate faster in more compressible mediums, which is scientifically correct. These studies show that students have many conceptions about the nature and speed of sound which are carried all along to the university level. In the next study the concept of the nature of sound was investigated.

Linder and Erickson (1989) carried out this study involving ten pre-service physics teachers' conceptualizations of the nature of sound. According to Linder and Erickson, the pre-service teachers conceptualized sound in two ways – at a molecular and at a macroscopic level. At the molecular level sound was conceptualized as an entity which could be carried by individual molecules from the source to the observer through the medium. In another form of this perspective, sound was believed to be made up of discrete entities or things which could be transferred from one molecule to the next through the medium of transmission. The molecules of the medium were assumed to be somehow stationary or moving randomly, but taking up a sound motion in the presence of the sound.

At the macroscopic level, sound was conceptualized as a type of wind or force which could 'push' or exert a force on objects. The pre-service teachers also had the tendency of using a lot of terminology learnt in physics without any clear conceptual understanding of the concepts. The next study involved an investigation of the ways junior secondary school learners conceptualised sound propagation.

Tongchai, Arayathanitkul & Soankwan (2007) investigated students' alternative conceptions on sound propagation. A grade 10 class which had not done the topic and a grade 12 class that had treated the topic formed the two comparative groups. The results showed that alternate conceptions held by students of the two groups were approximately identical and remained largely unchanged after traditional instruction in the topic.

The most commonly held misconceptions were that: 1) Sound waves of higher frequency move faster. 2) The louder the sound, the greater the speed. 3) Sounds with greater amplitudes move faster. 4) The movement of the experimenters hand determines how fast the wave in a string moves. In the next study sound propagation was investigated with a group of undergraduate students.

Wittmann *et al.* (2003) carried out a study involving undergraduate students taking a physics course on waves, with an additional time of one hour a week used for a tutorial in sound waves. The conceptions of 137 students were captured before, during and after the instructional period of ten weeks through conceptual tests and in-depth interviews.

In the first task, students were asked to describe the motion of a stationary dust particle suspended in front of a previously silent loudspeaker after it was turned on, emitting sound of varying frequency and loudness. In the second task, the dust particle was replaced with a candle flame, and the students were required to predict the behaviour of the flame as the loudspeaker was emitting sound.

Most students had difficulties differentiating between the motion of the sound wave and that of the medium through which the sound was propagated. Many of them exhibited a mixture of conceptions of sound waves as an object and as event. This hybridized model was present even after traditional instruction and problem-solving, and failed to interpret the even-like properties of waves. After working through tutorial material which was designed using the students' pre-instructional ideas as resources (building blocks of reasoning), a significantly larger number of students were able describe the motion correctly. In the next study we see of a study involving engineering students the results of the conceptualisation of sound propagation by a group of engineering students.

The study of Periago *et al.* (2009) was carried out with a group of 65 undergraduate chemical engineering students in Barcelona, Spain. The aim of the study was to evaluate and analyse students' alternative conceptions with respect to sound propagation. Three questions that focused on sound propagation were used to probe the students' conceptual understanding. The results showed that the students had a good understanding of sound propagation in air. However, they encountered significant difficulties conceptualizing sound propagation through a solid wall. In the next study the account of a study involving the concepts of loudness and other characteristics of sound is presented.

Merino (1998) studied some difficulties encountered in the teaching of the concepts of the loudness and intensity of sound. She argues that loudness, pitch and timbre are sensory properties, and hence very subjective. She proceeds to assert that assigning numerical values to them is an error. To Merino, associating loudness only to the amplitude is too simplistic misleading. This holds true associating timbre to multiples of the fundamental as well as associating pitch to frequency. She is opposed to most approaches of teaching sound concepts at the secondary level where, for example, students are made to believe that loudness, pitch and timbre are

independent of each other, and that timbre is just a combination of several overlapping of multiples of fundamentals. She points out that sound intensity levels which are expressed in decibels are often mistakenly identified with loudness which is a subjective sound quality.

The issues raised in this paper are profound but however, considering the fact that junior secondary school learners may not be in a position to understand the complexities involved in the way she suggests, it is necessary to start with the conventional way of simplifying the teaching of these concepts in order to enable the learners to grasp the basics of these concepts. Such simplification is often useful in teaching physics concepts. For example, it is sufficient to teach learners that an atom is made of a nucleus and electrons orbiting it. However, at another level students are made to understand that the nucleus contains some sub nuclear particles. To bring everything to a learner from the beginning might simply be too overwhelming for the learner to bear. I will proceed to present the next study involving the several concepts of sound by undergraduate literature students.

Takashi (2011)'s investigation was on the manner in which Japanese university literature students understood the content of sound taught at high school. Thirty students were interviewed on the concepts of medium of sound transmission, sound propagation, speed of sound in air, and the relation of amplitude and frequency with pitch and volume of sound. Out of the thirty students interviewed, six correctly answered that sound could be transmitted through all substances except outer space, and ten thought that sound could be transmitted through iron, paper and wood.

Twenty-two of the students thought that a dust particle suspended in front of a loudspeaker would move away as opposed to five who answered that the dust particle would only move slightly on the same spot. Eighteen of the students held that sound would move faster when descending than when ascending while twelve thought that the speed would be the same. Several students believed that a change in the properties of a string will not affect the pitch and volume of the sound while many of them thought the change would affect both pitch and volume simultaneously. To end this section on conceptual change, some critical views against conceptual change will next be examined.

2.1.4 Dissatisfaction with conceptual change strategies

Many studies based on Posner *et al.* (1982)'s model of teaching for conceptual change ended with the agreement that learners' pre-conceptions were very difficult to change (Chinn & Brewer, 1993; Vosniadou & Brewer, 1994). In their study, Chinn and Brewer (1993) found that when learners are confronted with anomalous data that contradicts their beliefs, they could completely change their pre-instructional beliefs only in one out of seven possibilities. Five times out of seven, they would choose to ignore, reject, exclude, hold in abeyance, or reinterpret the data without changing their beliefs in relation to the concept in question.

This study showed how difficult it is for learners to change their pre-conceptions even when through cognitive conflict strategies, they are presented anomalous data. Due to the failure of conceptual change strategies based on creating cognitive conflict to induce learners to abandon their pre-instructional conceptions for the scientific ones, several science educators began expressing dissatisfaction with this approach as an instructional strategy.

Linder (1993a) argued that conceptions were context-dependent and not static or invariable as depicted by many conceptual change theorists. He then suggested that instead of representing meaningful learning in terms of conceptual change, science educators should depict it in terms of conceptual appreciation.

DiSessa (1993), on his own part, thought that pre-instructional conceptions were not in the form of theories but small, intuitive chunks formed on the spot to explain experience. He called these intuitive thought phenomenological primitive (p-prims). He proposed that the process of learning in science classrooms should be one that enables learners to collect and systematize the phenomenological primitives (p-prims) into larger wholes, and by so doing they become 'a larger system of complex knowledge structures that can explain physical phenomena' (p. 114).

The above science education researchers and others have argued that the stress on misconceptions and the call for teachers to confront and replace them with scientific concepts is an over-emphasis which itself ignores the fundamental principle of constructivism that learners construct more knowledge from prior knowledge.

They provide learning theory based on using learners' prior conceptions as resources from productive learning in science classrooms, emphasizing the refinement and reorganization of basic knowledge elements rather than seeking to replace them.

Other researchers who have argued against the cognitive conflict approach of teaching include Clement (1993), Grayson (2004) and Hammer (2000). All of them have argued that instructional methods based on creating cognitive conflict in learners neglect the potential usefulness of some of the learners' pre-instructional conceptions which are not totally wrong. These researchers have proposed that learners' misconceptions which are in line with the scientific views could be used as anchors on which to construct valid scientific knowledge. These researchers are of the view that carefully constructed bridging analogies could be used to help the learners appropriate the correct scientific concept through belief revision of their conceptual structures.

To other researchers (Sinatra, Southerland, MaConaughy & Demastes, 2003), the conceptual change strategy based on cognitive conflict is faulty because it ignores the learners' affective factors. Sinatra and colleagues argue that learners' affective factors such as interest and motivation play an important role in the learning process and therefore need to be taken into consideration. They also hold that learners are intentional beings and have an active role to play in the learning process; hence, their motivational factors which influence their willingness to engage in meaningful learning or otherwise need not be ignored as the conceptual change theorists have done. They propose that besides inducing cognitive conflict, conceptual change should also enable learners to get actively involved in the process of learning by including meta-cognitive, motivational and affective processes.

Other researchers have argued for a multi-dimensional perspective of conceptual change (Duit, 1998, Duit & Treagust, 2003, Treagust & Duit, 2008). Their argument being that the learning process involves many complex issues and can therefore not be addressed by any particular method alone. Hence, they believe that teaching for conceptual change should involve affective, epistemological, ontological and socio-cultural issues. This view is in line with the socio-cultural constructivist position on learning as espoused by Vygotsky (1978). Vygotsky believes that cognitive development has its origin in socio-cultural setting.

A great number of science educators have embraced this view that meaningful science learning in non-western contexts should necessarily include aspects of the learners' cultural backgrounds (Aikenhead, 1996; Cobern, 1994; Ogunniyi, 1988, 2011). In the next section, the cultural views of science teaching and learning will be examined.

2.2 Cultural Perspective of science education

The preceding studies based on conceptual change theories have been criticized for not involving the learners' backgrounds which play an important part in every learner's interpretation of the world. Consequently, some science education researchers are of the view that learners' socio-cultural background knowledge should be included in the science classroom discourses (Aikenhead, 1996; Atwater, 1996; Cobern, 1996; Ogunniyi, 1988, 2005, Ogunniyi & Ogawa, 2008). Such an inclusion would enable the learners to feel more at ease in the science classroom.

From a constructivist perspective, learners' prior knowledge forms the foundation of any further learning; hence learners' indigenous knowledge should not be ignored as this would deprive them of the necessary raw material for knowledge construction. Some authors have argued for integration of science and IK as a means of redressing colonial improprieties committed against indigenous African people for centuries. Following this argument, Emeagwali (as cited in Ogunniyi, 2008) has articulated: "The recognition and appreciation of IKS is a source of healing of therapeutic import in the context of unhealthy imbalances, distortion, trivialization and neglect as inflicted by the Eurocentric education and governance." (p. 64).

2.2.1 Science and culture

Many studies have shown that the home cultures of learners from non-western backgrounds play a significant role in the extent to which these learners appropriate science concepts (Jegede & Okebukela, 1991; Aikenhead, 1996, 1997; Ogunniyi, 1988, 2011). School science which is dominantly a subculture of western culture (Aikenhead, 1996) and IK which is due predominantly to non-western cultures and they have been viewed as opposing worldviews for a long time.

However, several studies have argued that they need not be construed as polar opposites. This is because they do have areas of convergence, though they differ on

others; both seeking to explain nature from various angles. The dichotomy between the two is highlighted by 'scientism' which is construed as western, the truth, objective, value-free, universal, and the only way of knowing and explaining nature and experience. On the other hand, IK is considered unfit to be classified as science because it is viewed as falling below the bench mark of empirical science to qualify as such. However, one might argue that these assumptions are not necessarily true, considering the fact that indigenous people's ways were based on concepts and knowledge of nature and natural elements, which western science later documented and organized into regimes of knowledge.

2.2.2 Knowledge of sound by indigenous people

Several studies have shown that indigenous people's knowledge is not devoid of scientifically valid ideas (Emereole & Ontse, 2003; Ogunniyi, 1988). Emereole and Ontse (1995) investigated the knowledge of sound concepts held by illiterate Batswana people. Twenty-three elderly men, each over 45 years old were interviewed on sound concepts which included sound propagation, pitch, echoes, and so forth. It was found that in 63% of the cases, some of the subjects gave scientifically valid explanation. The percentages were higher for those concepts that directly involved practical uses of sound such as pitch. As regards the more abstract concepts such as speed, the percentages were much lower or most of them simply admitted that they did not know.

In this case, it could be argued that the lack of knowledge in these more abstract concepts of sound was not an indication of dullness or ignorance but probably a result of their different worldviews. In the scientific worldview, the researcher looks for patterns or generalizations while in the African and many indigenous people, science and technology are not separated from community survival and daily life. Hence, science and technology are studied in a holistic manner for survival (Kawagley, *et al.*, 1998; Ogunniyi, 1988); and not for abstraction with the aim of manipulating nature. The rich variety of indigenous musical instruments found in many parts of Africa bear testimony to the technological prowess of indigenous people in sound related technologies.

2.2.3 Differences between science and IK worldviews

Science and IK are not mutually exclusive. Some similarities and differences between the two knowledge corpuses are summarized in the table below.

Table 2.1 Assumptions underlying science and IKS (Ogunniyi, 2004; p. 292–293).

Assumptions underlying science	Assumptions underlying indigenous systems
Nature is real, observable and testable	Nature is real, and partly observable and testable
Space is real and has definite dimensions	Space is real, has definite dimensions but ultimately incommensurable
Time is real and has a continuous, irreversible series of durations	Time is real, continuous and cyclical
Matter is real and exists within time and space	Matter is real and exists within time, space and the ethereal realm
All events have natural causes	The universe is orderly, metaphysical, partly predictable and partly unpredictable
The universe is orderly and predictable i.e. nature is not capricious.	The universe is orderly, metaphysical, partly predictable and partly unpredictable
Scientific laws and/generalization are causal, logical, rational, impersonal and universal.	Indigenous generalizations have causal, personal, rational/non-rational, logical/non logical dimensions.
Language is not important to the workings of the natural world.	Language is important as a creative force in the workings of both the natural and the unnatural worlds.
Science is culture free	Indigenous knowledge is a critical part of culture
Science is concerned with 'what' not, 'what ought to be'.	Indigenous knowledge is concerned with 'what', 'what ought to be' and 'why'
Scientific facts are tested observations	Facts within indigenous knowledge corpus are both tested and experiential observations
Science is based on a dualistic worldview	Indigenous knowledge is based on a monistic, dualistic and pluralistic worldview.
Humans are capable of understanding nature	Humans are capable of understanding only part of nature

The difference between western science and IKS has been described by many researchers. Cobern (1994) has put these differences thus:

The scientific worldview is materialistic, aesthetic and religious. Science classification is in the natural only while that of IKS is natural, social and supernatural. Whereas science views causality as universal, mechanistic, functional, IKS views it as context-bound, mystical and teleological (p. 12).

There also exist many differences in the methodologies of research in the systems. Whereas science believes in a passive, objective researcher, indigenous knowledge is subjective, with the researcher's intuition, emotion and creativity contributing to shape the results. The next section point discusses some theories in the domain of culture and science.

2.2.4 Some theories in the domain of culture and science

Several theories have been advanced in relation to the studying of science by learners from non-western communities, most prominent among which are those of worldviews (Cobern, 1996), border-crossing (Aikenhead, 1996) collateral learning (Jedgede, 1995), and contiguity argumentation theory (Ogunniyi, 1997). A common denominator to all these theories is the attention paid to the learner's home background culture in the science classroom. When this is significantly different from that of the school science, more effort needs to be made by the science teacher to facilitate any meaningful learning. Some of these theories will be discussed below except the CAT since it was discussed under the theoretical framework in chapter one.

1.Border crossing

Akenhead (1996) views the learning and teaching of school science in terms of cultural transmission and cultural acquisition. In his view, science is a subculture of western culture, and learners from western and non-western backgrounds need to traverse four types of invisible cultural borders as they attempt to learn school science by attempting to move from their world of everyday experiences and home cultures to that of school science.

The transitions can be smooth, manageable, hazardous or virtually impossible. When the home subculture is congruent with that of school science, the learners experience a smooth transition. When the home subculture differs from that of school science, the transition has to be managed; if the home subculture is much different from that

of school science, the transition into the school science subculture is hazardous; and when the two subcultures are highly discordant, the transition is virtually impossible.

To deal with the problem faced by learners with cultural backgrounds that are very different from the scientific worldview, Aikenhead has proposed that the teacher should anticipate and explicitly facilitate their border crossings into the subculture of science. He has suggested that border crossing should be facilitated in the classroom by studying the subculture of students' life-worlds. He further proposes that a critical analysis of the learners' cultural worldview should be carried out alongside the science worldview in the science classroom. The dialogical argumentation instructional model is quite congruent with this proposition.

2. Collateral learning

Collateral learning refers to a situation whereby science learners from non-western culture “construct their scientific concepts side by side, and with minimal interference and interaction with their indigenous concepts (related to the same physical event)” (Aikenhead & Jegede, 1999, p.276). The collateral learning theory is a cognitive theory explaining why learners from western and non-western backgrounds experience cognitive dissonance in their science classrooms. It involves a situation whereby a learner holds two or more conflicting schema in the long term memory simultaneously. Collateral learning can be dependent, parallel or simultaneous.

In parallel collateral learning, the conflicting schemata are in separate compartments and hence do not interact at all. Each compartment is assessed independently, depending on the context. Secured collateral learning involves the situation whereby the conflicting schemata interact consciously, with the conflict resolved to a fair degree. According to Aikenhead and Jegede, dependent collateral learning occurs when one schema from one worldview challenges another from a different worldview, causing the learner to unconsciously modify the existing schema but without radically restructuring the existing worldview. Finally, simultaneous collateral learning occurs where learning a concept in one domain of knowledge facilitates the learning of a similar concept in another domain or culture.

3. The Cognitive Border Crossing Learning Model (CBCLM)

The CBCLM (Fakudze, 2004) is derived from the three learning theories of border crossing, collateral learning and the CAT. This theory seeks to unite Aikenhead's border crossing theory with Jegede's collateral learning theory and the CAT. The CBCLM uses the information-processing model of cognitive activity as its basic framework to propose a synthesis of the three constructs. The mental structures that function during information processing are the sensory register which receives stimuli from the environment, the working (or short term) memory which processes incoming information, and the long term memory which stores encoded information. According to Fakudze (2004), the contiguity learning hypothesis explains how information is processed in the working memory, the border crossing theory explains how information processed in the working memory traverses the boundary between the working memory and the long term memory while the collateral learning theory explains the various ways in which encoded information is stored in the long term memory.

3. Problem with border crossing theories

The three main theories mentioned above namely, the border crossing theory, the collateral learning theory and the CAT seek to explain how learning of science by non-western learners takes place. However, these theories approach the central issue from different perspectives. Aikenhead's theory approaches it from cultural anthropology (Aikenhead, 1996) while Jegede approaches from cognitive psychology (Aikenhead & Jegede, 1999). On the other hand, Ogunniyi approaches the problem from a philosophical perspective (Ogunniyi & Hewson, 2008).

Although these theories are helpful, they nevertheless seem to have the drawback of dichotomizing knowledge into science and IK. These knowledge systems are portrayed as being static while the learner has to cross back and forth between the two distinct worlds. Such construction leaves the learner in a position of helplessness, needing someone to guide him/her to cross into the other territory, and being guided by a tour guide.

However, experience tells us that the ideas in the two distinct worlds of science and home background exist simultaneously in the learner's mind, though not understood

or valued to the same degree. As Ogunniyi (2006) has pointed out there seems to be a fallacy in the mental construction of border crossing. Comparing the border crossing theories with the contiguity theory, he argues that "... within the contiguity framework the notion of cognitive border crossing from the home to the school or vice versa is rather specious. Everyone (the learner inclusive) carries his/her world around and lives nothing behind!" (p. 119).

Following this latter view expressed above, one may suggest that a more empowering picture would be to think of the learner as an artisan; for example, as a carpenter who uses different tools to accomplish different tasks, depending on the need. The carpenter would need to learn the strengths and limitations of each tool in order to be able to decide which of them is most appropriate to use in any specific context. In this case, the focus is on the goal or task (Svennbeck, 2001), and the carpenter remains the master.

Viewed from this perspective, science and IK would need to be mastered not with the aim of emphasizing differences but with the aim of using whichever of the two is more appropriate in a given context, the other tool not being downgraded because it is not in use. In the line of this argument, the contiguity argumentation theory would seem to provide that context where both science and IK can be used as tools in finding solutions to life's problems without necessarily resorting to ideological conflicts between the two thought systems. When this happens, both science and IK mutually reinforce each other in a win-win situation where "both gain and none is redundant" (Brown-Acquaye, 2001, p. 70).

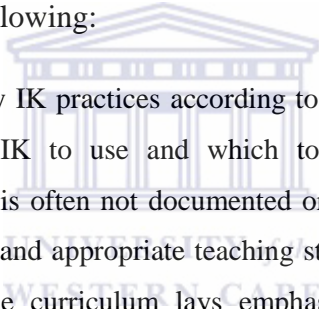
2.2.5 Challenges faced in integrating science and IK

There have been many challenges militating against the implementation of a science-**IK** curriculum in South African classrooms. Firstly, the policy document did not explicitly say how the integration of the two systems would take place, nor did it consult the teachers who were to implement the integration (Ogunniyi, 2007a, 2007b; Onwu & Mosimege, 2004). Consequently there was a rift between policy on the one hand, and practical implementation on the other. Another major challenge was the fact that most of the science teachers who were to implement such a curriculum had been exposed to the school science worldview to the exclusion of **IK**.

Consequently, they had little idea of how such integration could be possible since IK was emergent or suppressed in their worldviews.

In fact, most of the teachers had been assimilated by the Western worldview as Ogunniyi (2004) has noted it, “they are hardly more than chroniclers of the scientific knowledge” (p. 292). A third major challenge faced was the fact that higher education programs aimed at training science teachers needed to be changed in order to produce teachers with knowledge of the nature of science and the nature of IKS. In other words, the teacher training programmes need to produce teachers conversant with the epistemological and methodological similarities as well as differences between science and IK (Ogunniyi, 2004; Onwu & Ogunniyi, 2006).

The teachers in the field who dare to implement integration face some practical challenges such as those expressed by some in-service teachers (Onwu, 2009) in the following:



There are too many IK practices according to different cultures making difficulties to choose which IK to use and which to leave out. IK is time-consuming; information on IK is often not documented or not readily available. Teachers lack models to emulate and appropriate teaching strategies to effectively handle science IK integration. The curriculum lays emphasis on scientific content knowledge coverage, leaving no room for IK. Some teachers believe that certain IK issues should not form part of the science curriculum. Some teachers have the perception that IK is outdated, degenerated, demeaning, and not in synch with modern or current thinking (p. 25-26).

The integration of school science and IK faces several challenges, most notably are scientism or ‘the belief in science in itself as the sole authority to explain reality; misconceptions held by some science educators about IK, the fact that most science teachers had been trained in the predominantly western worldview and tend to have poor perceptions of IK, and so on. The accumulated success of western science and technology has given science a dominant position in most societies. This in turn has led to some people believing that science alone can explain, predict and interpret all natural phenomena.

Those who hold this view believe in the myth that science is objective, culture-free, value-neutral and universal; and that since the laws of science are generalizable and

testable, they can explain and predict natural phenomena, and so on. On the other hand, any system like IK, which does not conform to the canon of science, is dismissed as non-scientific. On the contrary, IK is deemed to be non-scientific, metaphysical, illogical superstitious, backward, non-empirical, and so forth.

2.2.6 Arguments for and against integration of science and IK

There have been heated debates as to whether or not IK should be integrated with science. Researchers who argue for integration draw support for their arguments from scientific literacy, science technology and society (STS), social constructivism, sustainability, and from the view that science itself has a culture. Scientific literacy and STS require that the greatest number of people possible should become scientifically and technologically literate in order to be able to make scientifically informed decisions in the modern information society and be able to use technology.

Following this view, the underlying argument is that more learners from non-western backgrounds need to be taught science; and since some of their cultural beliefs have been found to hinder the learning of science, (Jegede & Okebukola 1991; Kesamang & Taiwo, 2002), science instruction should be made more meaningful and relevant to them by including aspects of their cultures and methods.

Others argue that IKS has knowledge that science lacks (Snively & Cosiglia, 2001) in managing the environment sustainably. They argue that the present environment crisis and climate change that constitute a grave danger to life and earth have largely been caused by western technology, and in contrast many indigenous people have learned to live for millennia sustainably with their environment. Hence, science can learn from IKS, how to live sustainably with the environment.

Dzama and Osborne (1999) have argued that the integration of science and IKS would not necessarily lead to an improvement in the science results of African learners. They are of the opinion that the observed poor performance is caused not by a cultural disparity, but by a lack of vocational (technological) infrastructure. They argue that technological advancement acts as motivation for learners to choose science careers. Citing as examples Britain, India and Japan, they argue that technology had always preceded science and not the other way round; and that any

attempt to enable learners to achieve better in science without the preceding technological infrastructure is to ‘put the cart before the horse’ (p. 387).

However, one might argue that the example on which their conclusions and subsequent deductions were based is electricity, which in terms of the CAT is emergent as far as IKS is concerned (and they acknowledged this fact). Had they included some natural phenomena in relation to static electricity, lightning for instance, they would have most probably arrived at a different conclusion since several studies have shown that many cultures hold different worldviews on this topic (Emearole *et al.* 2009; Hlazo, Ogunniyi & Langenhoven, 2012; Kesamang & Taiwo, 2002; Liphoto, 2004, 2008).

Secondly, technological advancement alone might not be sufficient to motivate people to learn science. Many studies have come to the conclusion that despite economic and technological developments as well as available scientists and technologists to serve as role models to youth people, attrition in science poses a serious threat to many developed countries (AAAS, 1993, Millar & Osborne, 1998; Osborne & Dillon, 2008).

These countries include some of the most developed nations like America, Britain and Sweden. On the other hand, it can be argued that technological advancement in the absence of moral and spiritual values (which science can borrow from IKS) seems to be part of the fundamental cause of this attrition. In this regard, Cobern (2000) has argued that the main cause of loss of interest in science in America is the loss of meaning due to the continued pursuit of technological advancement devoid of the human element. He puts it as follows:

The economic factor in science is not sufficient to maintain interest in science given the incessant reductionist pressure of the three imperatives of naturalism, scientism, and technicism which wear away at our views of reality that give meaning to life. The principle problem in science education today is not lower test scores than the Japanese. It is the loss of meaning – an economic gain at the cost of meaningful life is Faustian bargain (p. 20).

Cobern and Loving (2001) oppose the integration of science and IKS on the grounds of the hegemony of science. They argue that any integration of the two systems

would mean science automatically dominating IKS, making the latter to become unnoticeable. To them, IKS is better off alone as a different kind of knowledge to check the excesses of science.

Other researchers such as Carter (2004) and Mackinley (2001) have objected to the integration of science and IK on the grounds of the postcolonial theory. They argue that since western science is in a dominant position, any integration with IK without an a priori resolution of the actual tensions that exist between the two – the power relations – is a mask that only benefits the dominant science position.

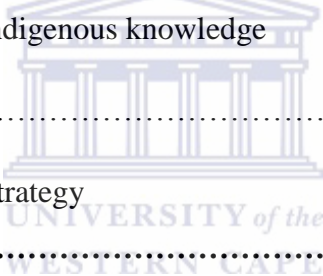
However, they do not seem to present a viable, practical alternative to the science – IKs integration which they oppose. Therefore, if knowledge as a whole has to advance, then integration of science and IKs provides a better option. The focus should not be on the dichotomies of science versus IKs, but rather, on the goal of advancing knowledge as Svennbeck (2001) has argued. Green (2008) has argued that knowledge should not be construed in terms of universalism or relativism, but that the focus should be on knowledge diversity. Drawing on the work of Goodman and Elgin, Green (2008) argues that diverse epistemologies should be evaluated on their abilities to advance understanding rather than on their capacity to express a strict realism. Such an approach would permit the evaluation of the advancement of understanding without necessarily resorting to divisive debates about ‘beliefs’ and ‘knowledge’.

From the preceding examples, one learns that a method which can likely succeed to integrate science and IK should make the science relevant to the learners by including their context, and employing methods that closely resemble those of the cultures of the learners. Such a system should for instance, begin by placing equal value to scientific and IK views of the same phenomenon instead of taking science as the reference point. It should not attribute science to the physical and IKs to the metaphysical realms. Also, it should include methods of enquiry prevalent in indigenous systems such as group discussions, apprenticeship, learning through story-telling, going outdoors to learn in the communities, and so on (Oguniyi, 2004).

2.2.7 How should science and IK be integrated?

Many science educators have argued that one of the main hindrances to the implementation of a science-IKs curriculum in the classroom has been the lack of a recommended method of implementation as the policy statement in the RCS did not make this explicit (Ogunniyi, 2007a, 2007b; Onwu & Mosimege, 2004; Onwu & Ogunniyi, 2006). Consequently many educators and teacher trainers have attempted several methods of integration. For example, a study of the best methods to integrate science–IKS in the classroom revealed that many of the teachers were not really conversant with a main method of doing so. The table below shows the rankings by 42 science pre-service science teachers of selected methods of instruction for science – IKs integration. The teachers selected the methods from 16 methods and ranked the selected choices.

Table 2.2 Teachers’ rankings of seven most critical instructional methods for integrating science and indigenous knowledge



Instructional method or strategy
1 Involving learners in problem solving
2 Providing learners with an opportunity to investigate and to present findings
3 Using a holistic or an integrated approach
4 Emphasizing showing or modeling rather than lecturing
5 Emphasizing cooperative learning rather than competitive learning
6 Frequently using provocative, argumentative or inquiry based questions
7 Using concrete materials to illustrate concepts or principles (1= most critical, 7 = least critical). (Source: Onwu & Ogunniyi, 2006, p.131).

While some of the methods hold promise for such an endeavour, others are just indicative of the extent to which the teachers’ minds are dominated by the school science worldview.

For example, when they talk of the methods of ‘problem solving’, ‘showing or modeling’ they are talking of typical school science methods which may not be effective in integrating science and IK. Any method that can be used ought to take into consideration the nature of discourse in both systems of thought. For example, the indigenous ways of learning often involve group learning in informal settings such as in rural communities.

2.2.8 What methods succeed to integrate science and IK?

Not all attempts to integrate school science and IK have been successful. It is therefore relevant to understand what makes one method succeed and another to fail. Ogunniyi (2005) asserts that for a course to be successful in integrating science and IK: (1) it should give equal status to the assumptions underpinning both science and indigenous systems. (2) It should not show science as working in the physical realm while an indigenous system works only in the spiritual or ethereal realms. (3) it should not use science as a frame of reference for judging the authenticity of indigenous knowledge systems or vice versa. (4) It should present both thought systems as essentially concerned with similar functions, namely, to describe, explain and predict natural phenomena. (5) It should emphasise pedagogical methods which focused on community related tasks rather than on individual tasks. (6) It should give preference to essays and continuous assessment over a once off, end of course examination. (7) It should direct questions to the whole class rather than to individuals, that is, everyone must be free to make comments without feeling intimidated as is usually the case in many traditional communities. (8) It should seek for communal consensus rather than individual viewpoints. (9) It should stress the need to evaluate knowledge claims according to the assumptions and standards appropriate for a particular thought system. (10) It should not present traditional thought as a prototype of science awaiting empirical testability. And finally (11) it should explore as many indigenous knowledge systems as possible (Ogunniyi, 2005, p. 3).

In view of the above suggestions, the dialogical argumentation platform provides a space where different ideas such as those of the two worldviews – science and IK are valued, debated, and accepted or rejected on the basis of evidence.

In a similar manner, Solomon (1992) as cited in Jegede and Aikenhead (1999), suggests several strategies that can be employed by a teacher to help learners of non-western backgrounds to cross from their home cultures to the culture of school science. These include the use of many resources and materials from different cultures while eliminating racially biased materials, the recognition and use of oral narratives and heritage as valid methods of teaching in the science class, the articulation and exploration of the differences and similarities, strengths and weaknesses of both science and IK in the science classroom, the inclusion of socio-cultural, political, moral and spiritual issues in science classrooms, the design of activities to help learners recognize the likelihood of continual change, conflict, ambiguity and increasing interdependence, and the encouragement of learners to express their own ideas and beliefs in a free and interactive environment, and so on (p. 57-58).

To sum it all, any method that hopes to succeed in integrating science and IK should give equal recognition to both the school science worldview as well as the IK worldview in the science classroom, value and allow the free expression of all ideas, and provide opportunities for argumentation discourses in the science class.

2.2.9 Integration of school science and IK- some examples

Several studies of integration of science and IK have been reported. In all of these studies, definite attempts were made to value the indigenous worldviews of interpreting experience, incorporating indigenous materials, contexts and ways of knowing, as well as presenting school science as one way of interpreting nature (among others, as opposed to the view that school science is the only way of knowing).

In a study reported by Aikenhead (2001), the cultural values of aboriginal learners (in North America) were integrated into the school science curriculum. Through what the author calls the ‘Rekindling Traditions Project’ school science was brought into the learners’ world rather than the contrary, and the teaching strategies adopted some aboriginal methods such as teaching ‘outdoors’ the natural world, and going to learn from leaders and other knowledgeable people in the community. This approach of presenting science did not pose any threat of assimilation, nor did it present school science as ‘the way’, hence the impact was greater motivation in the learners

to do science. The following section discusses the issue of dialogical argumentation in science education.

2.3 Dialogical argumentation in Science education

Many reasons have been adduced for the need to use argumentation as a teaching and learning strategy in science education. First, argumentation is the way scientists think (Kuhn, 1993) and it is argued that the use of argumentation in the science class is justifiably initiating learners into the practices of the scientific community.

Secondly, argumentation is thought to have cognitive value since it enables learners to externalize their views and organize their thoughts. As learners engage in the process of justifying their claims or re-examining the validity of claims in the face of new evidence or counter-claims and rebuttals, they process information at relatively high cognitive levels than the case when argumentation is absent. Kuhn (1993) also regards argumentation as the strategy by which a large number of people can be enabled to acquire scientific literacy as they engage in scientific discourses.

2.3.1 Argumentation and knowledge construction

Argumentation is valued as a key component of learning and teaching science (Driver *et al.*, 2000; Erduran *et al.*, 2004; Kuhn, 1993, 2010). Within the constructivist paradigm, knowledge acquisition is not seen as the continual accumulation of facts but as an active process involving the active interaction of learners as they engage in meaning-making. In this way, argumentation is seen as having central role “as a learning process as an outcome associated with the appropriation of scientific discourse, and as a window onto the epistemic work of science” (Bricker & Bell, 2008, p. 475). Berland and Reiser (2009) have identified the three goals of sense-making, articulation and persuading as crucial in the construction of scientific explanations and participation in argumentation discourses.

In the process of arguing to persuade others, learners are obliged to make use of evidence, articulating it to support their claims. This action can be very useful in knowledge building as many cognitive and meta-cognitive processes are involved. In this respect, Cavagnetto (2010) has observed that: “student participation in argument develops communication skills, meta-cognitive awareness, critical

thinking, an understanding of the culture and practice of science, and scientific literacy” (p. 336).

Consequently, if learners are provided with an environment that permits them to freely express their views on scientific, socio-scientific, environmental or cultural issues, they have high possibilities of gaining knowledge in the course of their group discussions. Von Aufschnaiter *et al.* (2008) have posited that as learners draw from their prior knowledge and experiences, their present knowledge is consolidated and their science understanding is elaborated at ‘relatively high levels of abstraction’ (p. 101).

However, not all arguments or group discussions may lead to scientific knowledge construction. As Covagnetto (2010) has suggested, group discussions that result in scientific knowledge construction must include the aspect of science in the argumentation activity. In this regard, the teacher needs to play the critical role of structuring suitable tasks and including necessary scientific concepts (Osborne *et al.*, 2004).

In order to have learners engage fully in argumentation, the familiarity of learners with the topic for argumentation, the specific prior knowledge of learners, and good knowledge of the structure of argumentation seem to play a crucial role (Sadler & Fowler, 2006). Similarly, Sandoval and Millwood (2005) are of the view that the quality of an argument depends on knowledge of the structure of argument as well as the conceptual understanding of the relevant content: ‘Constructing explanations requires both conceptual understanding of relevant theories and their application to a specific problem, and the epistemic understanding of the criteria for a good explanation’ (p.32). When learners have the necessary prior knowledge, they are bold and can express their opinions more confidently or rebut others’ claims, but when they lack the prior knowledge in the topic, many of the concepts would be emergent to them and they cannot boldly engage in any meaningful argumentation. This view is in agreement with that expressed by Von Aufschnaiter *et al.* (2008) who conclude that the attainment of high levels of argument largely depend on students’ familiarity and understanding of the content of the task. In their view, teachers should therefore consider the specific content knowledge and experiences before engaging in argumentation.

2.3.2 Argumentation and content knowledge

Several studies have linked argumentation quality to content knowledge (Sandoval & Millwood, 2005; Sadler & Fowler, 2006; McNeil, 2011). This implies that before engaging in argumentation the teacher should first make sure that the learners have some content knowledge. This prior knowledge might be given through instruction or through activities such as reading tasks that can provide the necessary content knowledge from which the learner may draw.

Some science educators have proposed that argumentation should start with socio-scientific topics (Kuhn, 2010). In this way, the learners would feel confident to express their views, and to challenge the views of others since there is no specific content knowledge on which to base arguments. Kuhn suggests that discussing and arguing in social contexts has the advantage of making participants feel qualified to have an opinion and to defend it. This situation is unlike in science where warrants need to conform to specific theories which the learner might not feel confident with. Kuhn further suggests that argumentation skills acquired in the social domain transferable to the science domain since “argument skills in the scientific domains are amenable to similar directions and in a similar way as skills in social domains” (Kuhn, 2010, p. 820).

2.3.3 Explicit or practical teaching of argumentation skills

Many science education researchers are of the opinion that argumentation does not come naturally to the learner (Kuhn, 1993; Erduran *et al*, 2004) and consequently, it has to be explicitly taught to learners. Osborne *et al* (2004) reiterate that argumentation is a form of discourse that needs to be appropriated by learners and explicitly taught through suitable instruction, task structuring and modeling. The authors argue that ‘just giving children scientific or controversial socio-scientific issues to discuss is not sufficient to ensure the practice of valid argumentation’ (p. 996-997). Explicit teaching of argumentation involves teaching the structure of arguments such as the TAP and criteria used to distinguish between good and bad arguments. McDonald (2008) puts it as follows:

Explicit instruction in this context refers to the direct teaching of the various parts of argumentation; including instruction pertaining to the various definitions, structure,

function, and application of arguments, and criteria used to assess the validity of arguments (p. 6).

More explicitly, teaching argumentation would mean for example that the teacher should first teach the elements of Toulmin (1958)'s argumentation pattern or the stages of the contiguity argumentation theory in a generic way before applying it later to a specific topic.

Research has shown that well-structured argumentation lessons result in greater learning (Choresch, Mevarech & Frank, 2008). On the other hand poor task structuring or poor knowledge of group dynamics in structuring group discussions results in a waste of time and little learning. Choresch and colleagues carried out a study to investigate the effects of three instructional methods on learners' technological literacy and argumentation ability. In that study, 285 seventh grade learners were taught technology using structured argumentation, unstructured argumentation and traditional lecture-demonstration method with no argumentation. At the end of the instruction, the group of learners who were taught using structured argumentation significantly outperformed the other two groups with regard to knowledge of technology and argumentation.

However, different strategies of teaching argumentation have been recommended by science education researchers. Cavagnetto (2011) in a review of argumentation interventions concluded that there were three basic approaches used to teach argumentation: 1) by immersion, 2) through argument structure, and 3) through science-and society. The researcher who used the immersion approach used arguments as an integrated component to study. Researchers who used the structured approach taught the structure of the argument separately from the investigations, and then asked the learners to apply it across the activities.

On the other hand, science-and-society approaches used controversial socio-scientific issues to provide the context for argumentation. The argumentation strategy used in this research was of the second type, that is, by first teaching the structure of the argumentation framework. The experimental group's teacher had taught the learners argumentation structure using Toulmin's argumentation pattern as well as the Contiguity argumentation theory earlier as part of the Science and

Indigenous Knowledge Systems Project (SIKSP) teacher professional development activities.

In order to scaffold argumentation, many researchers recommend that the teacher should ask open-ended as well as follow up questions during the argumentation process (McNeil & Pimentel, 2010). On the other hand, others believe that learners would construct better arguments in the absence of a teacher than when s/he is present (Keogh & Downing, 2007). In this study, the E group's teacher used leading questions, argumentation prompts, and open-ended questions to scaffold the argumentation.

The degree to which argumentation as an instructional strategy succeeds or fails in the science class depends largely on the teacher. She or he needs to structure the groups for effective learning to take place, provide help to the learners during group discussions by providing relevant prompts, asking leading questions, and allowing sufficient time for learner-learner interactions to occur. Moreover, the teacher also determines the extent to which discussions should go so that the general focus of the lesson is not lost, and so on.

Teachers do structure and scaffold argumentation in unique ways. For example, in the study cited earlier by Osborne *et al.* (2004), twelve science teachers in the London area were involved in a teacher and material development programme during which they learned to teach science through argumentation for one year. Audio and video tapes were used to capture teachers' lessons at the beginning and at the end of the year to find out how they implemented argumentation in the classroom. The findings revealed that there was a significant increase in the use of argumentation by each teacher, and that the pattern of argumentation during classroom discourse was similar for each teacher, but different between any two teachers (Osborne *et al.*, 2004).

Argumentation is also influenced by the nature of the task in which learners are engaged. Research shows that learners find it easier to engage in arguments in socio-scientific topics which have relevance to their personal lives than in purely scientific contexts (Angama, Ogunniyi & Langenhoven, 2012; Kuhn, 2010; Osborne *et al.* 2004).

It is therefore necessary for the teacher to design instructional activities for argumentation to start in socio-scientific topics before extending it to the purely scientific and more abstract contexts.

One important issue that can make or mar argumentation instruction is the manner in which argumentation groups are structured since the social dynamics of group activities can vary from highly effective to disruptive. Keogh *et al.* (2007) recommend that each group be made of four to six learners of mixed ability, gender and race. In their view, a group needs to be large enough to provide learners who can scaffold the learning of peers, but also small enough to permit each learner to have the opportunity to participate in the discussions. Also, group leaders should be chosen to help in the organization and good functioning of the group during group discussions in order to avert disruptive activities.

Although argumentation is highly commendable in science education, there exist several constraints with respect to learners, teachers and curricula which have to be overcome or at least acknowledged. It has already been said earlier that learners need to be explicitly taught argumentation because it cannot be acquired 'naturally' (Kuhn, 1993). This poses a big problem because many science teachers were not taught argumentation, and therefore cannot teach something they do not know. Besides, argumentation lessons are more demanding on the teacher in terms of task structuring and modeling. Teachers who are used to quiet classrooms during their transmission of facts to learners might become very uncomfortable with an argumentation class. This is because an argumentation class is usually full of activities as the learners engage in discussions and argumentation.

Another problem is that argumentation lessons take longer to accomplish given the daunting task of curricular exigencies on the teacher to cover as much content as possible within the shortest time possible. Some teachers might be obliged to stick to the old lecture-demonstration method in order to cover the examination syllabus. This issue is more pronounced since the performance of schools is measured mostly in the percentage of learners who pass the final year examination (for example, the Matric), and not on the quality of learning taking place in the science classroom. In some cases, parents rate teachers based on the quantity of notes they find in their children's books.

2.3.4 Argumentation and conceptual change

Many studies have suggested that dialogical argumentation is a useful tool to effect conceptual change in science. In the light of this suggestion, Leita0 (2000) argues “It is a matter of quasi-consensus among theorists and researchers that engaging in argumentation sets the scene for the building of new knowledge and for changes in people’s views” (p. 332).

It can be argued that the process of building new knowledge and inducing change in people’s views in the face of convincing evidence that occurs in argumentation classrooms is what the cognitive conflict approaches of conceptual change set out to achieve. The issue here is that the social interaction context of peers and freedom to accept or reject a view on the basis of convincing evidence or the lack of it makes it easier for a learner to give up his/her view than in other situations.

If for example, a science perspective is put side by side with an IK perspective on the same natural phenomenon, the learner would be able (depending on the context) to accept the science or IK explanation, depending on how convincing the evidence is. Therefore learners would be capable of attaining higher cognitive gains when they engage in arguments in the science class. Erduran et al. (2004) believe that: “When children engage in such a process, and support each other in high quality arguments, the interaction between the personal and social dimensions promotes reflexivity, appropriation, and the development of knowledge, beliefs and values” (p.3).

2.3.5 Argumentation and integration of science and indigenous knowledge

Several studies have reported instances where teachers have been trained in argumentation in South Africa, and others report instances of argument as instructional strategy in school science classrooms. Many studies have been carried out in the area of using dialogical argumentation to practically implement a science – IK curriculum. Some of these studies of integration of science and IK pertain to fermentation (Diwu & Ogunniyi, 2010); the conceptualization of lightning (Hlazo, Ogunniyi & Afonso, 2012); and chemical reactions (Van der Linde, Ogunniyi & Langenhoven, 2012); just to name a few. The present study follows in the same vein.

2.4 Summary

Science teaching and learning is a whole complex issue involving teachers, learners, the learning environment, learner's home background, the school curriculum, government policy and so many others that one can hardly complete in a single study. Hence I have limited myself to those issues that were considered most relevant.

The main issue was how to enable learners from non-western backgrounds to construct scientifically valid knowledge in the topic of sound which is very problematic. From the early 80s, the most popular method of science teaching was that of conceptual change strategies through cognitive conflict. As time went on, many science educators found that learners' alternative conceptions were so resistant to change that the anticipated change from unscientific to scientific thinking was not as expected.

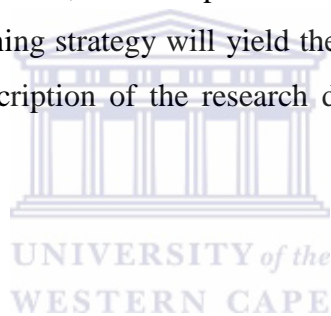
As criticisms of the conceptual change strategies mounted, many science educators seemed to move away from the Piagetian construct of personal or individual knowledge construction to social constructivist methods as advocated by Vygotsky. Thus many science educators came to the conclusion that scientific knowledge ought to be socially constructed (Kuhn, 1993, 2010). Consequently, learners' environments and home cultures were seen to play a very crucial role in determining how science is learned and appreciated by the learners.

In this regard, science learning came to be equated to cultural acquisition or enculturation into the culture of science (Aikenhead, 1996; Aikenhead & Jegede, 1999). In this perspective, the observed poor performance in science by learners from non-western backgrounds was blamed on the wide cultural gap between their home cultures and that of science which is predominantly a sub-culture of Euro-American culture. The solution to this problem of poor performance (or at least part of the solution) as proposed by many science educators was to value the learners' cultures and to integrate aspects of these cultures with science.

However, there have been various arguments against such integration from some science educators who would like to maintain the standard account of pure science in the positivist sense. Finally, it seems that most science educators are of the

opinion that science and IK should be integrated. Those who want integration believe that both science and IK can gain from each other when integrated. They also argue that if the dream of STS for all has to be achieved, then integration remains the best option to enable the millions of non-western learners of science to learn science meaningfully and to identify with it. One of the main problems that have to be solved is how to effect such integration of science and IK.

In this regard, the DAIM holds promise as a possible tool for integrating science and IK. Many science educators have endorsed argumentation as a valuable methodological tool in the construction and consolidation of scientific knowledge (Bricker & Bell, 2008; Driver *et al.*, 2000; Von Aufschnaiter *et al.*, 2008). The two main theories involved, namely the TAP and the CAT, which are based on argumentation, have been used to effect such science-*IK* integration programmes with positive results. Hence, it is hoped that this study which makes use of argumentation as a teaching strategy will yield the desired results. The next chapter is a presentation or description of the research design and implementation of the study.



CHAPTER THREE

METHODOLOGY

3.0 Introduction

In chapter two I reviewed the literature of relevant concepts pertaining to the study. In this chapter I will describe the procedures that were followed in order to generate and collect the necessary data to answer the research questions. Following good research procedures is very important because the credibility of the data and inferences of the study depends on the design and procedures. The research design and the procedures followed to obtain the data need to ensure as much as possible that the inferences drawn from the data are as a result of changes in the independent variables and not due to some extraneous variables.

Graziano and Raulin (2007) have recommended that “before any data are collected, the researcher must determine which observations to make and under what conditions, how to record the observations, what statistical methods to use to analyze the data, and so on” (p.43). In this study therefore, it was necessary to take into consideration the conditions under which the data should be collected and processed in order to provide credible answers to the research questions.

In order to enable the reader have a good knowledge of the research procedures, De Vos, Strydom, Fouche and Delport (2005) are of the view that:

The research methodology is described comprehensively, so that the reader develops confidence in the methods used. The context in which, and the purpose for which, the collection of the data took place should also be clearly spelt out ... It is suggested that descriptions of the participants, the research design, the sampling plan, data collection, data collection procedures and also the apparatus and measuring instruments be included (p.252-253).

In consonance with the recommendations of the above researchers, I will, in this chapter, proceed to describe the methods and procedures of sampling, instrument development, ethical procedures, as well as the methods of data collection and analysis.

3.1 Research setting

The research setting is the environment within which a study is conducted. This research took place in the North Education District of the Western Cape Education Department (WCED). Even though there are seven education districts in the Western Cape Province, the North Education District was chosen for the main study. Some of the reasons for this choice are the following: this district lies within close proximity to the university, hence the researcher could visit the schools more conveniently and with minimal cost; the limited time and funds available warranted a prudent choice; and also the researcher found teachers and school authorities who were willing to take part in the research.

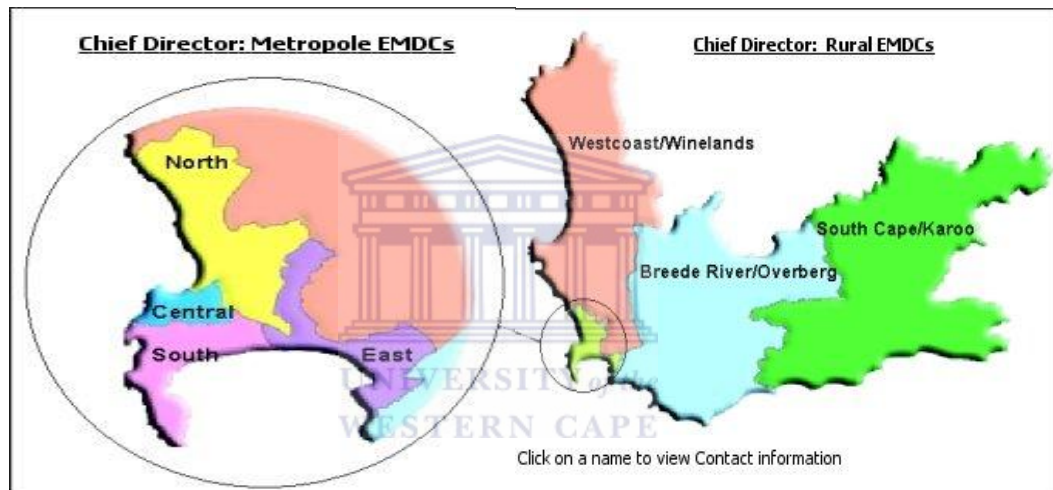


Figure 3.1 Education Management and Development Centres (EMDCs).

(Source: <http://wced.pgwc.gov.za/branchIDC/introemdc.html>).

The sample was purposively chosen, taking into consideration a number of factors thought to be necessary in the research process. These factors include costs, availability, capability and willingness of teachers who could do the teaching, schools administrators who were willing to permit the study in their schools, comparability of the schools in terms of demographics, socio-economic status of learners, educational resources, and past performance in official examinations, others.

The experimental (E) group was situated in a school in the Parow area while the control (C) group was situated in another school in Bellville South area. The

dominant population around the E group is Indian while that around the C group is 'coloured' (mixed race). However, both schools were multicultural as there were other learners of African descent also. In both schools, English and Afrikaans were spoken either as first or second language.

3.1.1 The research sample

Researchers often choose to undertake studies in smaller settings or representative samples because certain factors such as cost, time, accessibility, for example, make it impossible for the research to involve the whole of the target population. The sample for any study should be representative of the intended or target population to which the research results can be applicable; else they cannot be generalized beyond the sample. This is in accord with Cohen, Manion and Morrison (2007) who are of the view that 'the sample size, representativeness and parameters of the sample, access to sample, and the sampling strategy used' are four key factors to be considered by the researcher in every sampling strategy (p. 100).

The sample size required depends on the purpose of the study, the nature and size of the population and the type of research. Many researchers agree that a large sample is better than a smaller one. Some researchers recommend that for experimental and causal comparative studies that require more rigorous statistical procedures, the sample size should be made of a minimum of 30 subjects (Cohen *et al.*, 2007; Fraenkel & Wallen, 2008) who are randomly assigned to the experimental and control groups in order to minimize many potential sources of bias.

However, many constraints such as cost, time, administrative support, immutability of learners in school settings, among others, often prevent these ideal situations taking place in educational research. Consequently, the researcher is obliged to consider the design strategies that only approximate to these ideal situations. In this study for example, a quasi-experimental design was the most appropriate.

This study sample was made of two intact grade 11 physical science classes in two high schools situated in Cape Town, purposively chosen. Cohen *et al.* (2007) have suggested that in purposive sampling, researchers handpick the cases to be included in the sample based on their judgment that the cases possess the necessary characteristics applicable to the study. In this study, the sample was chosen on the

basis of similarities in learner characteristics. These include factors such as learners' socio-economic backgrounds, past performance of the schools in official examinations. One very significant factor to the choice of the sample was the researcher's personal knowledge of, and confidence in the two physical science teachers involved in the study.

Table 3.1 Distribution of learners by age, gender and home language

Group	E group (N=24)	C group (N=24)	Total (N=48)
Gender male	13	14	27
female	11	10	21
Age 16 & below	6	2	8
17	18	16	34
18 & above	0	6	6
Home language English	24	13	37
Afrikaans	0	11	11

3.1.2 The C group

The control group was located at Kossala High (not the real name) in Bellville South, Cape Town. Kossala High has 1200 learners and 41 teachers, giving a student-teacher ratio of 1:29. The learners came from a wide range of socio-economic backgrounds- domestic workers, middle class, professionals, and so forth. Most learners came from geographical locations well beyond the immediate area of Bellville South where the school is located - an area formerly assigned to people of mixed race (Coloureds) under the apartheid system; hence the learners demographically reflect this history. Sixty percent of the learners were Christian "Coloureds", 25% Muslim Coloureds and 15% Blacks. Of the 41 educators, 38 were "Coloureds" (28 Christians, and 10 Muslims) while 3 were Blacks. The dominant language spoken by both learners and teachers was Afrikaans, followed by English which was spoken mostly in the classroom. Most classes were taught in Afrikaans, while there were parallel classes taught in English.

During the apartheid era, the school fell under the House of Representatives (Coloured schools). At the moment, it is classified as a Quintile 3 school. (The

quintile level is an index of the degree of modern resources available at the school, with quintile one schools most resourced and quintile six least resourced). There was one security guard, and six strategically located cameras to monitor the school. It also had laboratory equipment for simple experiments in science. The academic performance of the school as indicated by the matriculation results had shown an upward path-56% in 2010 and 86% in 2011. However, the performance in physical science had been far below expectation-45% in 2010 and 32% in 2011.

The C group was taught by Mr. Francis, a quiet, focused and purpose-driven gentleman in his early forties and very skilful in using ICTs in teaching. He had a degree in physics, a postgraduate teaching diploma, a B Ed Honours degree and 18years of teaching experience. At the time of investigation, he was currently pursuing his master's programme towards the M Ed in Science Education.

3.1.3 The E group

The E group was a grade 11 physical science class at Menda Secondary School (MSS) (a fictitious name). MSS is a school with about 800 learners and 25 teachers, giving a student-teacher ratio of 1:32. There were five science teachers in the school. It was classified as an Indian school under the apartheid system. The student population was largely Indian with half being Muslims and the other half Christians. Although English is the medium of instruction, most learners also speak Afrikaans. Most learners were from very poor to middle class backgrounds.

The results of the official examination-the matriculation examination for the past few years showed that MSS had been doing well - having between 88 and 92% in the overall examination, while performance in physical science ranged from 65-82%. The school had an alarm system to ensure security. In terms of resources, this school was less endowed than the former one. There was no ICT infrastructure (neither whiteboard nor computers in the science classroom), but there was minimal science laboratory equipment available for all learners. It was a quintile 5 school in terms of availability of resources.

The E group was taught by Mr. Pieter, a former chemical engineer who joined the teaching profession six years ago as a mathematics, physical science and technology teacher. He was in his early sixties and very energetic, humorous, outspoken and

creative. He had always displayed a lot of insight during the SIKSP workshops, and had used the DAIM during his master’s programme. At the time of investigation, he was currently pursuing studies for a doctorate degree in science education.

3.2 Research design

The research design is the researcher’s overall design strategy of how he or she would generate valid data to answer the research questions. Johnson and Christensen (2012) put it succinctly that the “Research design refers to the outline, plan, or strategy you are going to use to seek an answer to your research question (s) ... planning a research design means that you must specify how the participants are to be assigned to their comparison groups, how you are going to control for potentially confounding extraneous variable, and how you are going to collect and analyze the data” (p. 296).

The design that was judged as most appropriate for this study was the quasi-experimental pretest-posttest control-group design. The quasi experimental design resembles the true experimental design in that one group is used as the experimental group and the other as a control but differs from the latter in that the subjects are not randomly assigned to the experimental and control groups.

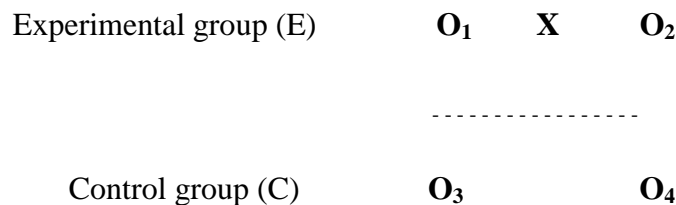


Figure 3.2 A quasi-experimental control-group design

O₁ and O₃, represent the pre-test while O₂ and O₄ represent the post-test observations. The vertical observations, O₁ and O₃ were assessed simultaneously one week before the commencement of the intervention while O₂ and O₄ were assessed simultaneously during the last week of the intervention. ‘X’, was the treatment condition, (the DAIM in this case).

Table 3.2 An outline of the research approach taken in this study

Aspects of the Research Process	Approach Taken in this Study
Research Paradigm	Constructivism
Theoretical framework	Dialogical argumentation /Conceptual change
Research Design	Quasi-experimental
Data collection	Sound achievement test (SAT) Sound and IKS questionnaire (SIKSQ) Learner interviews Teacher interviews Argumentation worksheets
Data interpretation	Analysis of SAT and learner worksheet Analysis of SIKSQ Analysis of learner and teacher interviews Classification of status of conceptions
Trustworthiness	Credibility Triangulation
Ethical issues	Informed consent Confidentiality



3.3 Pilot test results

Pilot tests are useful in that they provide useful information to the researcher as to what to expect in the actual study. They also help to expose certain flaws in the instruments or methods so that necessary steps could be taken to correct them before engaging the main study. The pilot study was undertaken in a school similar to the schools in the sample in terms of relevant characteristics such as the multicultural context of learners, the level of equipment, and past performance in official examinations.

Some lessons learned from the pilot test were that the learners complained of lack of time. Consequently they disliked answering long questionnaires, especially when they had to do the same thing again at post-test. From this feedback and the relatively reduced rate of completion of the instruments at post-test, I decided to reduce the number of items. The number of SAT items was reduced from 15 to 10

while the SIKSQ items were reduced from 13 to 8. Secondly many learners chose the alternative “Don’t know” in the SIKSQ, seemingly because they did not want to bother giving reasons. As a solution to the above situation, I decided to remove this option of “Don’t know” in the main study. Although it looked like forcing a choice on learners, it did not cause any change in the overall results. In this regard, Johnson and Christensen (2012) assert that “omitting the middle alternative (e. g. neutral ...) does not appreciably affect the overall pattern of the results” (p. 174). Secondly, the number of items was reduced from fifteen to ten in the SAT and thirteen to eight in the SIKSQ. A report of some aspects of argumentation during the pilot study is reported elsewhere (Anga’ama, Ogunniyi & Langenhoven, 2011).

3.4 How the main study took place

Pre-instructional meetings took place between the two teachers involved in the research and the researcher. The three often met at the bi-weekly SIKSP workshops at the University of the Western Cape. During their pre-instructional arrangements, it was agreed that since the topics of this research formed part of the teaching programme as prescribed by the curriculum, each teacher would use the time allocated on their time tables to teach the topic. The content was that prescribed by the grade 11 physical science syllabus on the topic ‘longitudinal waves and sound’. The sequential arrangement of the lessons was left to the discretion of the individual teacher. This was done to allow each teacher enough flexibility to adjust to the specific challenges faced in their classrooms.

The researcher gave each of the teachers some materials that had been developed earlier for this study during the pilot phase such as extra notes and exercises for discussion. In addition, the E group teacher was given argumentation worksheets, which the C group colleague did not have.

Research in Western Cape schools as a whole, just as in other places, involves many variables and challenges. Having obtained permission from the Western Cape Department of Education to carry out this research in the specified schools, the next step was to meet the principals for concrete arrangements to be put in place. Both principals had to be assured that the use of musical instruments would not disrupt the classes, and that the research as a whole would not put the school at any disadvantage with regard to syllabus coverage by the teachers. In addition, it was

made clear that the number of visits to the schools by the researcher should be kept to the barest minimum in order not to cause any disruption to the school programme.

The researcher met with the teachers of the E and C groups during bi-weekly joint workshops on science and IKS that they jointly attended at the university to discuss the implementation plan. During these meetings, the researcher and the two participating teachers agreed that the target content was that prescribed in the syllabus for grade 11 under the topic of “longitudinal waves and sound” and that each teacher would follow the lesson sequence as he deemed fit.

The plan for administering the instruments, and days for classroom observation by the researcher were agreed upon. The researcher gave some materials which he had developed and used during the pilot phase to both teachers so that they could extract whatever they needed to supplement their own material. In addition, the E group teacher obtained argumentation worksheets which the C teacher did not. There were four argumentation tasks. Three were drawn from socio-scientific and socio-cultural domains while one was in the purely scientific domain. Many researchers recommend that argumentation should begin in the social domain (Kuhn,2010; Walker & Zeidler, 2007) so that the learners should feel confident to express their opinions and to defend them.

Table 3. 3 An exemplar argumentation lesson plan for the E group

(For each lesson, the learners need to use the worksheets provided in appendix H).

Time	Activity	Learner activities	Teacher activities
10 min	Introduction	Listen and respond to teacher’s instructions.	Introduces argumentation tasks, arranges learners into small groups (of 4-6 per group).
15 min	Individual tasks	Work individually on argumentation tasks.	Moves round to give assistance to learners who need it.
20 min	Small group tasks	Learners discuss in small groups.	Moves round to help learners in different groups by giving prompts, asking leading questions.
20 min	Whole class discussions.	Group representatives present group results to the whole class. Other learners ask questions or express rebuttals.	Mediates the whole class arguments. Helps learners to reach a consensus if possible or to accept the absence of a consensus.
10 min	Conclusion	Write down the conclusion of the argumentation process.	Writes down the conclusion of the argument for learners to copy.

Time: 40x2mins = 80 min

After procedures of ethical clearance from the university ethics committee, and the WCED, the researcher obtained permission from the learners' parents and the two principals, personally explaining the purpose, process and usefulness of the study before the process could actually begin.

3.4.1 Classroom observation schedule

In order to have a feel of the actual classroom situation, the researcher planned to do observations in both C and E groups. The principals permitted a limited number of visits as they wanted to keep any interference with the school system to the barest minimum. Consequently, I was permitted to do observations once a week. The researcher was introduced to the two groups of learners- English and Afrikaans speaking- on the first day, after which he explained to the learners what the research was all about, and the role each of them could play. Ethical issues such as the anonymity of subjects, confidentiality of information, the right of subjects to withdraw from the study at any time, and so on were also explained to the learners by the researcher.

The classroom observations took place as planned in the C group, with the researcher playing the role of what Johnson and Christensen (2012) call the "observer-as-participant" (p.209). In this method, the subjects are fully aware that they are part of the study; but the researcher does not spend much time with them. Although the researcher might lose some details, Johnson and Christensen believe that this method has the advantage of the researcher being able to maintain objectivity and neutrality. The researcher did the observations once a week as permitted by the principal and took field notes.

Unlike the C group, it was not possible to carry out classroom observations in the E group as the E group's teacher expressed reservations. In order to get an idea of how teaching took place in the E group, some of the lessons were audio recorded by the E group's teacher, with the knowledge and approval of the learners. These were then transcribed and used in the study.

3.4.2 Why the Afrikaans class formed part of the C group

Initially, Afrikaans-speaking learners were included in the study mainly for the ethical reasons. It was considered that since the same teacher taught both English-

speaking and Afrikaans-speaking learners the same content, and they always wrote the same tests and examinations, it would be unethical to teach only the English speaking learners using indigenous musical instruments. The teacher and the researcher consequently agreed that the two classes should take part in all intended activities fully, although their results might be ignored in the end.

Later on, the researcher saw from the pretest scores on the SAT that there was no significant difference between the performances of the two groups. Moreover, most of the Afrikaans speaking learners could express themselves confidently in English, as they wrote their responses in English. At the pretest, only six of them answered in Afrikaans. Their teacher, who was fluent in both languages, did the translation into English. Therefore Afrikaans-speaking learners were considered equally in the C group as their English-speaking counterparts.

Table 3.4 SAT pretest-scores of learners in C group by home language.

Home language	N	Mean scores	Std Dev	df	Sig.
English	13	57.2	8.2	22	.312
Afrikaans	11	60.9	4.4		

The difference in the language of instruction did not seem to have any effect in this situation, as literature has evidenced it. This might be because most of the learners were bilingual and secondly, the same teacher taught each of the groups in their home language. Also, items of the SAT and SIKSQ were translated into Afrikaans by the teacher and read out for the benefit of those learners who had difficulties, before the learners completed the tasks therein.

3.5 Instrumentation

In order to explore the effects of the dialogical argumentation instruction model on grade 11 learners' conceptions of sound, a total of five instruments were developed. These instruments which were used to collect the data were developed by the researcher because there were none available which could be used to collect data to answer the research questions. Two of the instruments-the sound achievement test and the science-IKS questionnaire-were designed to gather data for both quantitative

and qualitative analyses. Three other instruments were designed to be used for qualitative data collection. These included learner argumentation worksheets, focus group interviews, and a classroom observation schedule.

The following instruments were used to collect data:

- A pre-test and post-test sound achievement test (SAT) comprising ten multiple choice options followed by explanations;
- A sound and indigenous knowledge systems questionnaire (SIKSQ) to probe learners' opinions about science/IKS worldviews as well as argumentation skills;
- Focus group interviews to gain an insight into learners' beliefs about science/IKS;
- Teacher interviews;
- Argumentation worksheets/audiotapes to capture group activities in the E group.

Table 3.5 Instruments used in the study

Instrument	Group	Measurement scales used	Analytical interpretation method
pre/post test SAT scale	C/E	1) 5 point strength of argumentation scale	Quantitative Qualitative
Pre/post-test SIKSQ scale	C/E	1) 5 point CAT categories 2) 5 point worldview response classification.	Qualitative
Focus group interviews	C/E	Learner response excerpts.	Qualitative
Argumentation worksheets/audiotapes	E	1) 5 point strength TAP scale 2) 5 point strength of CAT categories	Qualitative
Teacher interviews	E/C	Teacher responses	Qualitative
Classroom observation schedule	C	Researcher field notes	Qualitative

(Adapted from Diwu, 2010)

3.5.1 Validity and Reliability

Validity and reliability are very important issues in any study. Without an assurance that the results obtained in any study are valid and reliable, they cannot be depended upon.

Validity

Many researchers agree that a valid instrument is one that measures what it purports to measure. Some researchers stress on the appropriateness of the inferences made as a result of using the instrument. Fraenkel and Wallen (2008) elaborate this as follows: “validity has been defined as referring to the appropriateness, and correctness, meaningfulness and usefulness of the specific inferences researchers make based on the data they collect” (p. 148). Whatever the focus of the definition of validity, one thing stands clear - one cannot obtain correct inferences unless the data from which the inferences were based are both valid and reliable. Therefore, the process of ensuring that the instruments used to collect data are valid is very important in any research. In fact, to Cohen, Manion and Morrison (2007), “if a piece of research is invalid, then it is worthless” (p.133). According to Creswell (2005),

invalid scores may be as a result of a poorly designed study, poorly designed research questions, poor understanding of questions by subjects, irrelevant and confusing information in the questions, poorly administered instruments, subject fatigue, and so on (p. 164).

Although the threats to validity cannot be completely eliminated, many measures may be taken in the research design and procedures to reduce most of the threats to a minimum. In the research process, many threats to validity may be reduced through the method of the sample selection, instrument development and administration, data collection and processing, and so on.

With this in mind, a rigorous process was followed to ensure the validity and reliability of the instruments used in this study. Many researchers recommend that novice researchers should make use of existing instruments whose reliability and validity has been established (Fraenkel & Wallen, 2008). However in my own case I could not find any instruments that could give the desired results. That is, I could

not find any existing instruments that could be used to generate data necessary to answer my research questions. Hence I had to go through the process of designing mine. Before I go into details of how the issue of instrument validation was tackled in the design process, I wish to highlight some important constructs with regard to validation of the instruments. These are face, content and construct validity.

Three types of validity that a good research instrument should address include the face, content and construct validity. Creswell (2005) asserts that content validity is the extent to which the items in an instrument and the scores obtained from administering it are representative of the research objectives. Cohen *et al.* (2007) go further to suggest that content validity is assured if an instrument fairly and comprehensively covers the domain it purports to cover.

Face validity on the other hand is a judgment that the items in an instrument appear to be relevant. This is usually determined by experts in the field of the study. According to Creswell (2005) “construct validity is established by determining if the scores from an instrument are significant, meaningful, useful, and have a purpose” (p. 165). Again this is determined by expert opinion. In order to ensure construct, face and content validity in this study, a number of measures were taken as I will explain below.

The initial versions of the SAT and SIKSQ, together with the research questions were emailed to members of the Science and Indigenous Knowledge Systems Project (SIKSP) for peer review. The items were to be graded from 1-5, for relevance and appropriateness, and comments made for adjustments. Any item scoring less than 3 on average was immediately eliminated. After working with the items again, they were presented to four science education experts for appraisal. Each of them independently graded the items on a scale of 1-5, with one representing a poor item and five, a very good one. Any item with an average of 2 or 1 was immediately eliminated. Items with scores of 3 were modified as recommended by the experts.

In the final versions, the number of items reduced from 22 to 15 for the SAT and from 19 to 13 for the SIKSQ. The instruments were then presented to 5 experienced high school science teachers for appraisal of the appropriateness, relevance and

suitability of the items for the intended grade. Their comments led to further adjustments in the language to ensure clarity.

Reliability

Reliability refers to the consistency of scores obtained from an instrument over time or space (Cohen *et al.*, 2007). Reliability is usually established through methods such as the test-retest method, inter-rater agreement, and internal consistency methods among others. To establish reliability, the CAT and SIKSQ were rated by five science educators independently on a scale of 1-5. The inter-rater reliability stood 0.92 for the SAT and 0.93 for the SIKSQ using the Spearman-Brown formula. Reliability coefficients of 0.78 and 0.81 respectively were obtained using the split-half method. Fraenkel and Wallen (2008) recommend a reliability coefficient of .70 for an instrument to be considered reliable. Thus the instruments were deemed valid and reliable for use in data collection.

Trustworthiness

Qualitative researchers use the term trustworthiness to refer to the degree to which inferences made from a study make sense or are credible. Credibility was to a great extent achieved in this study through triangulation which is the use of different strategies and instruments in gathering and analysing both qualitative and quantitative data (Cohen, *et al.*, 2007).

3.5.2 The SIKSQ

The SIKSQ (see appendix D) consisted of 8 items, structured in three formats. In items 1-5 the learners first had to choose from a Likert scale one option out of four (strongly agree, agree, disagree, and strongly disagree). They were next asked to give a reason for their choice, and finally to indicate the source that influenced them the most.

The choices were restricted to three possibilities - science, religion/culture and personal experience. This set of items was aimed at inducing the learners to express their opinions about various aspects of science-IKS integration.

Items 6 and 7 described scenarios involving some indigenous/cultural beliefs about sound-related phenomena. The scenarios were followed by three statements with

which the learner had to agree or disagree. Finally an opportunity was provided for the learners to express their beliefs as far as the scenario was concerned. The aim of these items was to permit learners to externalize their beliefs so that one could probably have an idea of their worldviews.

The last item was on a socio-scientific issue- whether *vuvuzelas* should be banned during soccer matches or not. This question, which had been one for public debate during the 2010 Soccer World Cup, was meant to act as a stimulus for argumentation. Learners were asked to state their positions, and then give reasons to support their claims.

3.5.3 The SAT

The final version of the SAT (see Appendix C) comprised ten 2-tier items designed to test learners' knowledge of selected sound concepts in relation to: 1) the nature of sound propagation; 2) the factors that affect or do not affect the velocity of sound, and 3) the factors that affect the pitch and volume of sound produced by a string. The items were determined from extant literature on alternative conceptions held by students as well as some science teachers (as elaborated in chapter two), and the content of grade 11 physical science as indicated in the school science syllabus.

The concepts tested by these items could be articulated as follows: 1.5) Is it possible to hear sound out of a room with the door closed? 1.7) Can sound produced inside a double-walled glass container be heard outside the container? 1.9) Can the sound be heard if there is a vacuum between the double glass walls? Items 1.5, 1.7, and 1.9 were aimed at gaining an insight into the learners' conceptions about the effect of enclosures and a vacuum on sound propagation.

Items 1.1, 1.3, 2.1 and 2.3 concerned the concept of the speed of sound in air. Item 1.1 was used to probe learners' conceptions on the relationship between the speed of sound and the force of playing a drum. Item 1.3 was aimed at probing the learners' conceptions on the effect of frequency of hitting the drum on the speed of sound. On the other hand, item 2.1 was aimed at examining learners' conceptions on the effect of height or altitude on the speed of sound while 2.3 was aimed at learners' conceptions as regards the effect of a *vuvuzela's* direction on the speed of sound. Items 3.1 was on use of the sound box, item 3.3 and 3.5 was used to test the learners'

understanding of the relation between the pitch of sound from a string as a function of the string length and tension respectively.

The first part of each item was a multiple choice question, while the second part asked for an explanation as to why the learner made the choice in part one. The 2-tier test method has been used to diagnose learners' alternative conceptions in science (Tsai & Chou, 2002). Since the alternative answers provided in the multiple choice section contained learners' alternative conceptions from existing literature, it was easy to diagnose from the choices made by these learners by way of comparison with the results found in the literature.

3.6 Data collection procedures

It was thought that a mixed methods approach would be the most suitable method for this study. Johnson and Christensen (2012) define a mixed methods research approach as one in which “the researcher uses a mixture or combination of quantitative and qualitative methods, approaches, or concepts in a single research study or in a set of related studies” (p. 50). The quantitative methods alone could not fully capture the data needed to answer the research questions. Hence, it was felt that the qualitative elements would add more flesh or give a fuller meaning to the quantitative data. This corroborates the views of many researchers who are of the opinion that mixed methods have more advantages over the erstwhile dichotomous quantitative versus qualitative positions (Johnson & Christenson, 2012; Johnson & Onwuegbuzie, 2004; Johnson, 2009).

Johnson and Onwuegbuzie (2004) have outlined some advantages of mixed methods. These include the following: narrative descriptions of qualitative methods can be used to add meaning to numbers obtained through the quantitative; the researcher can answer a broader range of research questions when using mixed methods; the strength of one method can overcome the weaknesses of the other method; and the two methods can add insights and understanding that might be missed when only a single method is used. However, this does not mean that mixed methods approaches to research do not have any disadvantages.

In as much as mixed methods approaches provide richer data than either quantitative or qualitative methods alone, they also have some weaknesses (Johnson &

Onwuegbuzie, 2004). Some of these weaknesses are the following: it is difficult for a single researcher to carry out both qualitative and quantitative research; most researchers tend to master either the quantitative or qualitative method, but not both; mixed methods are more expensive and time-consuming than a single method. Despite these difficulties of the mixed methods designs, it was felt that a richer, more meaningful data was worth the sacrifice. Hence the researcher opted for mixed methods procedures instead of just the quantitative or qualitative alone.

The main instruments used in this study were the SAT and the SIKSQ. These instruments were designed in such a way that responses could provide data for both quantitative and qualitative analyses. The first part of the responses provided a choice which was used for quantitative analyses while the reasons provided in the second part provided the qualitative data. Focus group interviews, teacher interviews, classroom observations, researcher field notes and audiotape-recorded material also constituted useful sources of qualitative data.

3.7 Ethical issues

Any research in social science must be guided by ethical standards since it is dealing with human beings in order not to permit any research that may be harmful to individuals. Dowling and Brown (2010) also note that there exists a collegiate or institutional dimension of educational research which seeks to avoid any researcher in the institution bringing the educational research into disrepute through his or her research practices (p. 34).

Furthermore, the Research Ethics Framework published by the Economic and Social Research Council in the U.K, as cited in Dowling and Brown (2010, p. 35) has set out a framework of ethical principles for educational research which institutions of higher learning seem to be applying to a fair degree. These principles require that:

- Research should be designed, reviewed and undertaken to ensure integrity and quality;
- Research staff and subjects must be informed fully about the purpose, methods and intended possible used of the research, what their participation in the research entails, and what risks, if any, are involved;

- The confidentiality of information supplied by research subjects and the anonymity of respondents must be respected;
- Research participants must participate in a voluntary way, free from any coercion;
- Harm to research participants must be avoided;
- The independence of research must be clear, and any conflicts of interest or partiality must be explicit (p. 35).

In line with the above ethical considerations, the researcher made ethical commitments to the university Ethics Committee which has an ethics code to which everyone doing research in schools must abide before permission is granted by the university.

Before carrying out research in schools, the Western Cape Education Department Research Ethics Committee Standards had to be met and permission obtained by the researcher (see appendix A). Permission was also sought from the University of Western Cape's Senate Ethics Research Committee (see appendix B).

Basically the ethics code of the university and the WCED required assurances of the following ethical concerns by the researcher:

- 1) Anonymity of subjects.
- 2) The respect of subjects' individual rights to take part in the study and to withdraw whenever they choose.
- 3) Confidentiality of research information.

In order to abide by the above-mentioned ethical concerns the researcher took the following steps:

- Permission was sought from the principals of the schools in which the research was done (see appendices E and F).
- Since the learners were minors, the informed consent of their parents was sought in writing (see appendix G).
- The purpose of the research was explained to the learners and the ethical commitments made known before the commencement of the study.

- Interviews were strictly confidential.
- To ensure anonymity, the schools were given fictitious names and also, the learners used codes instead of their names in the worksheets.
- The researcher made a commitment that at the end of the study, a summary of the main findings would be sent to each of the schools involved, and to the WCED.

3.8 Focus group interviews

Focus group interviews were conducted with one group of learners, from each of the E and C groups by the teachers. The interviews were audio-recorded with the knowledge and permission of the learners. The interview questions followed a semi-structured open-ended format. With regard to the advantages of semi-structured interviews, Hobson and Townsend (2010) have asserted that

One of the main profits of part-structured-interviews is that they can help to ensure coverage of the researcher's agenda, while also providing opportunities for interviewees to talk about what is significant to them, in their own words. Related to this, researchers employing part-structured interviews can achieve both breadth and depth in their datasets (p. 231).

Focus group interviews have certain advantages over individual interviews, for example,

- They are more economical in terms of money and time;
- There is more group dynamic discussion, and less influence of the researcher on the outcomes;
- Participants may be stimulated to think more deeply and critically as other group members can question their stances, in a way that the interviewer might feel reluctant to do;
- In the school setting, the learners might feel bolder in a focus group than when interviewed on a one-to-one basis.

3.9 Data analysis

This section provides a description of the procedures followed by the researcher to collect and analyse research data. The responses to the sound achievement test (SAT) and the science and indigenous knowledge systems questionnaire (SIKSQ) were collected from the teachers of the C and E groups soon after administration. The researcher constructed a memorandum to be used for scoring the learners' responses to the SAT questions. Two lecturers went through the marking guide to determine whether or not it was appropriate. The inter-rater agreement stood at .96. The differences were resolved through discussion. Hence, the memorandum was considered valid for use by the researcher.

The researcher did the scoring of the responses. To minimize researcher bias, the scripts from the C and E groups were reshuffled. Scoring was done on all the scripts as a single group, and the scripts separated afterwards into the two groups. Also, one of the physics lecturers moderated the researcher's marking by randomly selecting 5 scripts and scoring in accordance with the marking guide established earlier. The agreement between the scores was high, ranging between 94% and 98%.

Each of the questions was scored out of a maximum of 5 points; the first part out of 3 points and the explanation out of 2 points. A scientifically correct choice in the first part earned 3 points while the choice which was in line with common sense reasoning earned 1 point. Any choice that was totally unrelated to the question as well as any unanswered question was given a zero. Similarly for the second part of each question, a scientifically correct explanation of the sound concept earned 2 points while a wrong explanation based on common sense knowledge earned 1 point. An unrelated explanation or a blank space earned zero.

Using the marking guide, each response to the SAT was coded as follows: AA =5pts; AB=4, AC=3, BB=2, BC=1 and CC= 0. Thus the total score for each question was the sum of the two parts, with a range of 0-5.

Table 3.6 Marking guide used in scoring the SAT items

Applicable to each question	Description	Code	Points
Choice made in part 1	The correct scientific concept	A	3
	An alternative conception	B	1
	An irrelevant answer or no choice	C	0
Explanation given in part 2	Scientifically correct	A	2
	Common-sense knowledge	B	1
	Unrelated response or none at all	C	0

The marking did not follow a right-versus-wrong approach. Instead, the scores were divided along a continuous scale from 0–5. It was thought that some of the alternatives provided in the first part of each question were right using common-sense reasoning. Such alternatives were given some credit (1 point) while the scientifically correct choice in part one obtained 3 points. The reasoning behind this distribution of scores was that even though the common-sense alternatives merited some credit, the learners should become aware that the conceptions were not good enough to receive full credit in a science class, and therefore they needed to know the scientific version to obtain full scores. A choice that was not related to the question as well as the cases where no alternative was chosen earned no point. In the second part of each question, a scientifically correct explanation was given 2 points while common-sense reasoning earned one point. An irrelevant explanation or a blank space earned no point.

The items on the science-IKS questionnaire (SIKSQ) were coded as follow: Any choice of 'strongly agree' was scored 4 and 'strongly disagree' was scored 1 for items in favour of IK. For negatively worded items, the scores were reversed; that is 'strongly agree' was scored 1, 'agree' 2, 'disagree' 3 and 'strongly disagree' 4. Finally the results of the SAT and SIKSQ were compiled and emailed to a statistician. This was done by entering the data on an excel spread sheet at two different times independently. This was done to detect any errors in entering the data. Discrepancies between the two sets of data were resolved by consulting the scripts and getting the correct scores.

3.9.1 Quantitative data analysis

Quantitative data is analysed in terms of numbers. The data can fall in any of these categories: categorical data, ordinal data, interval or ratio (Field, 2009, Ogunniyi, 1992). In categorical data, the variables are distinct categories or groups, for example, brands of cars or subjects studied at school; and so on. Ordinal data, on the other hand, are data that can be ranked; for example, choices made in an attitude scale (e.g. strongly disagree, disagree, agree, and strongly agree). For interval variables, equal intervals represent equal differences in the property being measured (Field, 2009). Examples of interval variables include test scores. Ratio variables are similar to interval variables, but with the additional condition that there is a true zero. Since different statistical procedures are used in analysing the various types of data, it was essential to categorize the data. The SAT results were classified as interval while the SIKSQ scores were treated as ordinal data.

Before proceeding with the statistical analysis of the SAT data, it was essential to determine whether or not the data were going to be analysed using parametric or non-parametric statistical procedures. Field (2009) asserts that four conditions or assumptions need to be fulfilled before any data can be analysed parametrically. These assumptions are that: (1) the data should be normally distributed; (2) the variances of all the groups involved should be approximately equal; (3) the data should be measured at least at the interval level; and (4) the data of the different groups should be independent of each other. That is, data generated in each group should be independent of what goes on in the other groups.

The condition of independence of data was met for the C and E groups since tests were administered almost simultaneously, and the two schools virtually have no interaction between them. The pre-to-post conditions failed to satisfy this assumption for each group. However, there are specific tests to be applied in such cases.

The SAT data were clearly at the interval level because the mean scores are continuous variables. In order to determine whether the data were normal or non-normal, the pre-and post-tests for both C and E groups were subjected to the Kolmogorov-Smirnov (K-S) test. The K-S test compares scores in a sample to a standardized normally distributed set of scores with the same mean and standard

deviation as the sample being tested (Field, 2009). If the test is non-significant, that is, if $p > .05$, then the sample distribution is not significantly different from the standard normal distribution (Field, 2009).

In such a case, the data in the sample are approximately normally distributed. If, on the other hand, the K-S is significant, that is, $p < .05$, then the sample distribution is significantly different from a normal distribution. In other words, such a sample distribution is non-normal, and the analysis must be done using non-parametric statistical procedures. The K-S test for normality was applied to the SAT results. The results were as shown below:

Table 3.7 K-S Test of normality for SAT data

Group	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
E pre-test	.135	24	.200*	.946	24	.216
E post-test	.128	24	.200*	.954	24	.334
C pre-test	.131	24	.200*	.952	24	.294
C post-test	.117	24	.200*	.955	24	.340

* This is a lower bound of the true significance.

As seen in table 3.7, the p-value for each test was .200 which implies that the K-S test showed non-significant results for all pre-and post-test mean scores for both C and E groups. Hence all the SAT scores were approximately normally distributed.

In order to determine the equality of variances, the SAT test scores were subject to Levine's test on the SPSS. The results of this test are shown in the next table (table 3.7).

Table 3.8 Levine's test for equality of variance for the SAT scores

Group	Levine's statistic based on means	df1	df2	Sig.
E pre- test	.296	1	22	.592
E post- test	.231	1	22	.635
C pre-test	.618	1	22	.440
C post-test	2.641	1	22	.118

From the table 3.8, significance values were at least .118. This means that no value was less than .05. Hence all the variances were approximately equal.

Since the SAT results satisfied all conditions of parametric data, they were analysed using parametric statistical procedures. To compare pre-post differences for each of the C and E groups, the dependent or paired-sample t-test was considered suitable. The dependent t-test uses the difference between two sets of scores (such as the pre- and post-test scores of the same group). It is this difference that is tested for normality (Field, 2009). On the other hand, the independent t-test was used to compare the pre- and post-test scores between the C and E groups. The results obtained are given in the relevant sections in chapter four.

The scores in the SIKSQ were ordinal data. According to Field (2009), ordinal data should be analysed using non-parametric statistical procedures. Non-parametric procedures (tests) are preferable because they do not need that data fulfil the type of assumptions or pre-conditions required by parametric tests. In non-parametric tests, the data are first arranged in order of increasing magnitude, irrespective of the group from which the data originate. After the ranking, the lowest number is assigned the rank 1, and the next 2 until the one with the greatest magnitude is assigned the highest rank. The manipulations are consequently carried out using the assigned ranks instead of the original values.

In this study, the pre-post results of each group were analysed using the Wilcoxon sign-rank test. According to Field (2009) “this test is used in situations in which there are two sets of scores to compare, but these scores come from the same participants” (p. 552).

To compare SIKSQ results across the C and E groups, the Mann-Whitney-U test was used. According to Runyon, Coleman and Pittenger (2000) researchers use this test when the data in the two groups is ordinal or when the assumptions of normality and homogeneity of variances are violated. The results obtained from the above non-parametric tests are reported in chapter four.

3.9.2 Qualitative data analysis

Qualitative data were obtained from various sources. These include the SAT, the SIKSQ, interviews, argumentation worksheets and researcher field notes from

classroom observations. The audio-recorded data comprising argumentation sessions in the E group, focus group interviews in both C and E groups, and teacher interviews were transcribed. While the data from the SAT were analysed using Toulmin's argumentation pattern (TAP) and Reiner *et al.*'s substance schema, that from the SIKSQ were analysed using the Contiguity argumentation theory (CAT) after classification into discernible themes or categories. Due to the massive amount of qualitative data involved, only a reasonable quantity would be used in the analysis in the relevant questions in chapter four.



CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.0 Introduction

The results of the study will be presented and discussed in this chapter. For the sake of coherence, the presentation will be done according to the questions. Some questions will be broken down into more manageable sub-questions. In each question or sub-question, the quantitative data will be presented first, followed by the qualitative part at appropriate positions to add meaning to the quantitative data. Finally the discussion would follow in each subsection, based on relevant literature and the theoretical framework used in the study.

4.1 Research Question One

What conceptions of sound do grade 11 learners hold before and after exposure to instruction involving the use of indigenous musical instruments?

This questions will be answered with respect to a) Conceptions with regard to speed of sound in air; b) Conceptions with regard to sound propagation; c) Conceptions with regard to stringed instruments.

Only 7 learners out of 48 (14.6%) at pre-test and 20 (41.7%) at post-test thought that the speed of sound in air would remain constant (atmospheric conditions are constant). At post-test, this number increased to 20 (41.7%). Although the increase was commendable when compared to the pre-test figure, it nevertheless fell below the 50% mark. This implies that this concept was still problematic after instruction. A closer observation of the reasons given by the learners who indicated that the speed of sound would remain constant reveals that some of these learners believed so with the wrong reasons. Some examples include the following:

E4 “He’s playing the drum with more force not at a faster pace”; E16 “There will be no change in speed because the drummer will only be hitting harder not faster.”

The above learners believe that the speed of sound is constant and that playing the drum harder would not cause an increase in the speed of sound produced. However, they also believe that hitting the drum faster would result in an increase in the speed

of sound now produced. This reveals the underlying erroneous belief that an increase in the frequency would result in an increase in the speed of sound. This belief seems to be held strongly by most of the learners as the next question reveals.

Table 4.1 Frequencies of learners' responses to items involving the speed of sound in air (N=48)

Questions	Responses	f pre	%	f post	%
1.1) When the drum is played with more force than before, the speed of sound	will be less than before	7	14.6	1	2.1
	will remain the same as before *	7	14.6	20	41.7
	will be greater than before #	34	70.8	26	54.2
	cannot be measured	0	0.0	2	4.2
1.3) When the drummer plays faster , the speed of sound	will decrease	1	2.1	4	8.3
	will increase #	37	77.1	28	58.3
	will be the same as before *	9	18.8	15	31.3
	cannot be measured	1	2.1	1	2.1
2.1 Thabo is at the same level as Thandi and Kele, Bongani is higher up and Chris lower. The four are at equal distances from Thabo. If Thabo plays a bass drum,	All four will hear at same time *	23	47.9	24	50.0
	Chris will hear first and Bongani last	5	10.4	2	4.2
	Only Thandi and Kele will hear at the same time #	17	35.4	19	39.6
	Bongani will hear first and Chris last	2	4.2	2	4.2
2.3 If Thabo points the vuvuzela in the direction of Chris and blows it,	Bongani will hear first and Chris last	0	0.0	1	2.1
	Chris will hear first and Bongani last #	27	56.3	18	37.5
	Only Thandi and Kele will hear at the same time	5	10.4	7	14.6
	All four will hear at same time *	16	33.3	22	45.8

Note: In the table above the scientifically accepted right alternative is indicated by an asterisk (*) while the most prevalent alternative conception is denoted by (#).

The majority of learners 34 (70.8%) at pre-test believed that the speed of sound in air would be greater when the drum is played with more force. This belief was still held by 26 (54.2%) learners at post-test. This is an indication that the concept needs

a great effort on the part of both learners and the teacher to change. There seem to be three underlying reasons as to why the learners think that playing the drum with more force would result in an increase of the speed of sound produced.

Some learners believed that using a greater force will result in more sound being produced and that it is this 'more sound' that causes the speed to increase. However, the meaning of the 'more sound' does not seem to be quite clear. It seems that this expression may mean 'a larger quantity of sound'. For example, E6 says: "The more force you exert on the drum the more sound will be produced." Similarly, E15 says "The force creates sound waves and the more force there is, the more sound waves will be produced."

Some of the learners believed that the increase in the speed of sound would come about as a result of an increase in the energy of the sound waves. For example, E21 says "There would be an increase in the energy produced of the sound waves." The third reason given was that the speed of sound has to be greater because the sound is louder when more force is used. For example, E13 says "The more force applied to the drum, the louder the sound will come out." Similarly E22 says "The force that the drummer exerts on the drum would create a much faster speed and would create more volume." To summarize, the learners seem to believe that using more force would result in greater speed of sound because 1) more sound is produced, 2) the sound produced is now louder, or 3) the sound produced possesses greater energy.

Only 9 learners at pre-test and 15 at post-test rightly believed that the frequency of hitting the drum would not affect the speed of the sound produced. However, some of the reasons given by these learners still indicate underlying alternative conceptions. For example, E19 says "You are not playing harder therefore it will stay the same." Similarly, E21 says "The speed will remain the same because same energy is used which will result in same speed." Although these learners believe that the speed of sound would remain constant when the drum is played at a faster rate, they however seem to believe that playing the drum harder means that more energy is being used in doing so, and consequently the sound now produced will travel with a higher speed. In the minds of these, learners the speed of sound is directly related with the energy used in producing the sound.

At pre-test, 37 (77.1%) of the learners believed that the speed of sound would increase if one played the drum faster. This view was still held by 28 learners (i.e. 58.3 %) at posttest. This seems to be indicative of the belief that the frequency of vibration of the source influences the speed of the ensuing sound. More specifically, most of the learners seemed to hold the view that the higher the frequency, the higher the speed of sound produced. Some of the excerpts seem to indicate the thinking that an increase in the speed of sound at a higher frequency is trivial and so needs no explanation. For example, “The sound will of course travel faster” (E18).

In a similar way, E16 just re-echoes the statement: “The faster the drummer plays, the faster the speed of the sound.” And E4 “Playing the drum faster, sound waves move faster and the speed increases.” Another set of learners seem to hold the notion that there would be an increase in the speed of sound because more sound would be produced as one plays the drum faster. Some examples of such reasoning come from E13 who says “The faster the drum is played the more sound will come of it.” And similarly, E15 says “The faster force also creates more sound waves.”

In question 2.1, almost half of the learners (23 or 47.9%) at pretest had the right conception that the speed of sound is the same irrespective of the height. The numbers did not change much with instruction as 24 (50%) out of the 48 learners held the same view at post-test. These learners seemed to have understood that the speed of sound in a uniform medium is constant (unless atmospheric conditions change). For example, E16 says “The height does not have any effect. They are all at the same distance away from Thabo so they will all hear sound at the same time.”

On the other hand, half of learners (24 learners or 50%) at pre-test believed that sound would move faster when descending to a lower altitude than when moving to a point situated at a relatively higher altitude, and that the speed at the same altitude would have a value between the two speeds in the up-down direction. After instruction, the numbers reduced to 19 (39.6%) at post-test. Most of the learners who chose B or C in response to question 2.1 gave reasons such as the following:

E2: “Sound waves will travel faster downwards and therefore reach Chris first and Bongani last. It will reach Thandi and Kele at the same time since they are at equal distance away from Thabo and on the same level”; E6: “Thandi and Kele are at the same level as Thabo so they would receive the sounds at the same time.”

To many learners (32 at pre- and 24 post-test), pointing and blowing a horn (vuvuzela) in the direction of Chris causes the speed of sound to be greater in that direction. The speed of sound is thought to be less in the opposite direction, while remaining unchanged along the same contour line. E2 gave this as the reason: “Sound waves will take longer to move upward than downward since it is pointed down. Thandi and Kele will once again hear the sound” and similarly, E3 says “Thabo is blowing the horn in Chris’ way and Bongani is in the totally opposite direction” while E13 puts it this way: “With the sound being directed at him it should reach him first and Kele and Thandi should hear it at the same time.” After the results on learners’ conceptions with regard to the speed of sound in air have been presented, the following section provides a discussion to these results.

4.1.1 Discussion of conceptions with regard to the speed of sound in air

A discussion of the above results is hereby presented. For the sake of clarity, the discussions will follow the sub-questions as the results. These discussions will be done in the light of extant literature and the theoretical framework.

a) Speed of sound and amplitude

There were few learners who chose the option that the speed of sound would be constant when the drum is played with more force. Among this group of learners, some of them still showed some incorrect reasoning for believing so. For example, E4 and E16 gave the following reasons for believing that the speed of sound would remain constant: “He is playing the drum with more force not at a faster pace. There will be no change in speed because the drummer will only be hitting harder, not faster.”

These learners believe that a greater force, which means greater amplitude of vibration, would not alter the speed of sound, but also express the alternative conception that an increase in the frequency would result in an increase in the speed of sound. This is an indication that it is not just enough to ask learners to choose the right answer as in a multiple choice test because the learners might make the right choice with the wrong reasons. Therefore, it is necessary to ask why learners make their choices as in argumentation-based instructional methods in order to uncover

underlying misconceptions held by the learners, and then devise instructional strategies to help the learners overcome them.

The results of question 1.1 show that many of the learners associated a change in the speed of sound with the force used to produce it. For example, E6 says ‘The more force you exert on the drum the more sound will be produced.’ (This learner does not seem to see the difference between ‘more sound’ and ‘more speed’). And E9 says ‘The harder you hit, the more speed there is.’ This corroborates the findings of earlier research (e.g. Eshach & Schwartz, 2006; Linder, 1993b) where students have erroneously associated the speed of sound with amplitude. They seem to reason that a larger force would result in larger amplitude of the sound wave (which is true), but fail to understand that the velocity of sound is determined by the properties of the medium in which it propagates, not by the manner in which the sound is produced.

This reasoning of associating the properties of the sound to the instrument producing it has also been reported by Driver *et al.* (1994) among middle school learners. The reasons given seem to suggest that most learners who hold this view reason that using more force implies more energy given to the sound waves; hence the sound would acquire greater speed.

The underlying reasoning seems to point to an analogy from the physical world where, from Newton’s second law, an increase in the force causes a given mass to accelerate or where more energy is used to provide greater kinetic energy to a moving object. So by applying the same reasoning to sound, those learners believe that the greater the force, the greater the speed of the sound produced. Therefore, the reasoning seems to be the consequence of a substance attribute to sound.

Using Reiner *et al.* (2000)’s substance schema, one sees that the learners believe that sound needs a force to move faster or accelerate. This confirms that the *inertial schema* of substances is present.

Literature is replete with examples of learners attributing properties of physical objects to sound (Linder, 1992, Linder & Erickson, 1989; Hrepic *et al.*, 2002, 2007; Mazens & Lautrey, 2003; Eschach & Schwartz, 2006; Wittmann *et al.*, 2003), and sometimes this is done in a confused manner when the learners inappropriately try to

integrate the material or substance conceptions with the accepted scientific abstract concept, resulting in hybrid models of sound understanding (Hrepic *et al.*, 2002; 2007).

Another source of this alternative conception may stem from everyday usage and interconnection between ‘force’, ‘energy’, motion’. For example E21 says the increase in the speed of sound will be the result of more energy: ‘There would be an increase in the energy produced of the sound waves.’ It is normal in everyday language to say that the more force or energy a soccer player uses, the faster the ball will move; so some learners seem to have translated this reasoning wholesale into the context of the force on the drum and the subsequent speed of sound. This reasoning again is an indication that the learners have the impression that sound is inertial (requires a force to accelerate). The reasoning of the learners confirmed the substantiality attribute of Reiner *et al.*’s substance schema (Reiner *et al.*, 2000; p.5).

b) Speed of sound and frequency

Most learners (77.1% at pre-test and 58.3% at post-test) believed that the speed of sound would increase if the frequency of playing the drum were to increase. This belief was justified by one learner on the basis of the wave equation: velocity = frequency x wavelength ($V = f \lambda$) which is in the textbook. This is a rather more difficult situation to resolve because it demands that the learner understand that the velocity of the sound wave depends on the properties of the medium, but not on the wave properties nor on the manner in which the sound waves are produced. The scientific concept here is based on the more theoretical underpinning and much against intuitive reasoning which learners often use at the first encounter with science concepts.

This was probably the most difficult of the alternative conceptions encountered with regard to the speed of sound. As mentioned earlier, learners like E9 who chose the right answer to question 1.1 still expressed the belief that the speed of sound would be higher if the frequency of hitting the drum were higher. This misconception has been reportedly found with grade 10 and 12 high school learners in Thailand (Tongchaiet *et al.*, 2007) as well as pre-service science teachers in Turkey (Bolat & Sozen, 2009).

One of the main causes of this alternative conception may be the association of the speed of sound with the object producing it as reported by Driver *et al.* (1994). One way to possibly help learners in this regard might be to enable them to come to understand that the speed of sound depends only on the properties of the medium, and is independent of the source. Another issue of which learners need to become aware is that the frequency of vibration depends on the properties of the membrane of string (such as the tension), and not the rate of striking the instrument.

With regard to the influence of the wave equation: $V=f\lambda$, it might be useful to make the learners come to understand that the frequency and wavelength vary covariantly, while velocity is unaffected if the properties of the medium remain constant. In the case where a teacher is using dialogical argumentation as the instructional strategy, these concepts would need to be carefully crafted into argumentation tasks. For example, the learners of the E group had an activity that was structured to enable them reflect on the relationship between the force of playing the drum and the velocity of the sound produced. This task probably helped some of these learners to change their views as the posttest scores for this question improved much more than in the second question which demanded them to find the relationship between the speed of sound and the frequency of hitting the drum.

c) Speed of sound and altitude

Many of the learners thought that the speed of sound is greater when sound descends than when it ascends, but constant along the same level. This corroborates the findings of Takashi (2011) where 18 undergraduate students out of 30 (that is, 60%) interviewed believed that sound would travel faster when descending than when ascending. Although these students might have been constrained to choose only between these two alternatives (since the third option of equal speed in both directions was not provided by the researcher), the results are indicative of intuitive ways of reasoning out physics concepts.

A possible underlying cause of this misconception is an attempt to reason from everyday understanding of 'motion' under the influence of 'gravity' in mechanics. A ball thrown upwards decelerates until at maximum height, the speed is zero. When the same ball is thrown from a high tower, the textbooks show snapshots of the falling ball gaining speed. A similar kind of reasoning can be erroneously inferred

from the fact that a moving object such as a bicycle can speed up when descending, but tends to slow down when ascending. In other words, this alternative conception may come up as a result of the learner treating sound as a material object or substance that has weight, and whose velocity can thus be influenced by gravity. The substance schema of Reiner *et al.* (2000) is again evident here (*substances are gravity sensitive*).

d) Speed of sound and direction of *vuvuzela*

More than half (56.3%) of the learners at pre-test and 37.5% at post-test thought that sound would travel faster in the direction in which the *vuvuzela* is facing and slower in the opposite direction; with the speed at the same level having a value between these two. I could not find any study with similar results in the literature consulted. While the explanations may be similar to the previous situation above, an additional conception here is that some learners believe that ‘concentrating’ the sound by using a *vuvuzela*, which could focus the sound waves like a megaphone, can increase the speed of the sound in that direction. For example, these learners below give their arguments as to why they believe that Chris should hear first and Bongani last as follows:

E3 “Thabo is blowing the horn in Chris’ way and Bongani is in the total opposite direction”; E4 “The sound is traveling in Chris’ direction so he will hear it first”; E13 “With the sound being directed at him it should reach him first and Kele and Thandi should hear it at the same time.”

A possible underlying intuitive reasoning here may be that sound is more concentrated in the direction of the horn and therefore has more energy, hence more speed. A further investigation may be needed to arrive at a more definite conclusion.

4.1.2 Learners’ pre-post-test conceptions with regard to sound propagation

Sound propagation refers to the manner in which sound moves within a medium or across the boundaries of different media. Many learners have had different views of how they conceptualize sound propagation. In this study the learners’ conceptions on sound propagation were captured through three questions (1.5, 1.7, & 1.9). The results are summarized in the next table (table 4.2).

Table 4.2 Learners' responses to items involving sound propagation (N=48)

Questions on sound propagation	Options	F pre	% pre	F post	% post
Q1.5 Is it possible to hear the sound of the marimba outside the room?	No	2	4	5	10
	Yes *	23	48	17	35
	Yes, if only very close to window#	21	44	14	29
	Yes, only if a loudspeaker is used	2	4	2	4
Q1.7 If a CD player is playing music between a sealed double-wall glass container	It is possible for all dancers to hear*	7	15	15	31
	Only some dancers can ever hear	6	13	6	13
	Only a few can ever hear#	12	25	6	13
	None of the dancers will hear #	22	46	20	42
Q1.9 If the air between the glass walls is removed completely	It is possible for all dancers to hear	6	13	11	23
	Most of the dancers will hear #	11	23	6	13
	Only a few of the dancers will hear	2	4	3	6
	None of the dancers will hear *	26	54	24	50
	Blank	4	8	4	8

Many learners (23 at pretest and 27 at post-test) rightly thought that sound can propagate out of a room with doors and windows closed. However, different explanations were given as to how sound gets outside the walls of the room. While some learners made mention of vibrations, many of them seemed to believe that sound can only go out of the room through openings. The following excerpts are indicative of what many of the learners hold:

“Some of the sound waves could have escaped through openings, e.g. the cracks in the wall.” “Sound waves can travel through the slightest openings; sound waves that hit the wall can also create a sort of sound.” “Under the doors there is space that sound can go through. There are spaces and particles which we may not see in walls that sound can travel through.” “The sound of the marimba will send vibrations through the doors and windows, a faint sound will be heard. The sound waves can travel through the tiniest space, so it will be heard from a distance, if it is loud enough.”

While the vibratory concept is scientifically correct, the idea of sound leaving the room through apertures is an indication of an alternative conception that many learners often harbour (Chang *et al.* 2007; Driver *et al.* 1994; Mazens &

Lautrey,2003). This alternative conception regards sound as an entity or substance which is containable and locational (Reiner *et al.*, 2000, p. 4-5).

Only 7 (14.6%) learners and 15 (31.3%) learners of pre-and post-test, respectively thought that sound could be heard outside a double-walled glass container. While some learners thought that sound of a lower intensity could be heard outside the glass container, others thought that a loudspeaker was required for the sound to be heard. The reasons given for believing that sound could be heard across the double-walled glass container varied, however.

Some learners thought that the sound could be heard as a result of vibrations caused by collisions of the sound given off by the record player and the walls of the glass container. On the other hand, other learners thought that the sound would be heard outside the double-walled glass container after escaping through microscopic holes in the glass walls. As an example, the reason given by E4 was: "Because sound waves can travel through the small microscopic holes in glass." Similarly E5 said: "The sound given off from the record player will hit against the glass causing it to vibrate and give off a sound."

Twenty-two learners (45.8%) at pre-test said that sound would not be heard out of the double-walled glass container because the double-walled glass would totally block all sound. According to these learners, the sound would remain trapped inside the container. A few of the learners made allusion to the hardness of glass as a contributing factor to the blocking of the sound in the interior of the glass container.

Some of the opinions expressed include the following: E9 "Sound is trapped inside the glass wall." E8 "Even though the record player is playing louder, the double walled glass container will block out all the sound and the sound will only stay in the area he/she is playing." E13 "Because the glass walls are completely sealed and it is doubled walled, it would block the sound and none of the dancers would hear it." E23 "Well, this depends on the thickness of the glass. Sound is being trapped and compressed."

Some of the learners were of the opinion that even though the sound would be blocked inside the glass container, some of the sound would eventually manage to get through the first glass wall of the container, at least. Some of the learners'

expressions are as follows: E3 “The sound will maybe penetrate the 1st wall but it’s highly unlikely that it will do so to the second one.” E11 “Glass blocks out some of the music being played, while others are able to hear it. Not all the sound is blocked.”

Approximately half of the learners (25 at pre-test and 24 at post-test) said that sound could not pass through the glass container when there was no air between the double walls. This is scientifically correct. Although some of the learners gave the right reason that sound needed a medium for propagation, others showed that their reasons were still based on inappropriate conceptions. Many of these learners thought, for example, that the sound would not pass through the vacuum because there would be no air to ‘carry’ the sound.

Other learners argued that there would be nothing for sound to ‘travel on’. This gives the impression that these learners might be conceptualizing sound as a separate entity that is carried by air molecules or that needs air to move on, just as a car might need a road. Some of the examples in this category include the following: E1 “Sound waves moves with the help of oxygen/air but if there’s none, the sound will not move.” E4 “Nothing to carry the sound waves (no air).” E16 “If there is no air, there will be nothing for the sound waves to travel on.” E20 “Air is a vacuum that carries sound in space. You have nothing because no air.”

Nineteen learners at pre-test and twenty learners at post-test said that sound would be heard, either partially or completely, despite the vacuum between the glass walls. Some of these learners believed that the situation was even better for sound propagation. Examples of learners who expressed this view are E9 “The sound can be heard better now because of the less air” and E25 “Sound can go through the tiny spaces between glass”.

Discussion

The dominant alternative conception of sound propagation was that sound can only propagate through openings - either macroscopic ones as holes in the doors and windows, or microscopic holes on the glass; presumably, invisible to the naked eye. This misconception has been found in many learners (Linder & Erikson, 1989; Mazens & Lautrey, 2003; Reiner *et al.*, 2000; Wittmann *et al.*, 2003). Thus, to

some learners, sound cannot move out of a container unless there are holes through which it can do so, for example, E5 says ‘There are spaces and particles which we may not see in walls that sound can travel through’.

The underlying assumption here is probably that the learners were regarding sound as an entity or material substance that occupies space and hence needs an opening to be able to pass through. In terms of the analytical framework, this notion fits into Reiner *et al.*’s category of ‘containability’ (*substances are containable*).

The main reason given by learners who thought that sound could not be heard outside the double-walled glass container was that the sound was blocked or trapped between the walls. The underlying reasoning here seems to be similar to the same - that sound is made of entities or microscopic substances which can be ‘blocked’ by containers. Following the same line of reasoning, sound would move easily in a vacuum than in air or solids as E9 expressed: “Sound can be heard better now because of the less air”.

Some learners in attempting to explain why sound would not move through an airless gap between the glass walls said there would be no air to carry the sound. For example E4 said: “Nothing to carry the sound. No air.” This also indicates a flawed understanding of sound propagation as a self-standing entity or something that can be carried by air molecules (Linder & Erickson, 1989).

Literature is full of alternative conceptions about sound propagation in air (Linder & Erickson, 1989; Mazens & Lautrey, 2003; Takashi, 2011). Linder and Erickson (1989) have identified the conceptualization of obstruction to the movement of a sound entity in university students. According to this view, sound would move faster in a vacuum because the vacuum offers the least obstruction to the movement of sound. This study seems to confirm similar beliefs in grade 11 learners. In terms of Reiner *et al.* (2000)’s substance schema, the learners seem to show the belief that sound is *containable, locational, stable and corpuscular*.

4.1.3 Conceptions with regard to sound produced by stringed instruments

The pitch of sound produced by a vibrating string is directly related to the frequency. For any string, the frequency depends on the tension, length and mass per unit length of the string. Learners’ ideas on stringed instruments are shown in the next table.

Table 4.3 Learners' responses to items involving stringed instruments (N=48)

Questions on stringed instruments	Options	Freq pre	Freq post
Q3.1 The round part at the base of figure 3.1a (gourd) is hollow. What important role does it play in the sound produced?	It increases the frequency #	6	12
	Used to put on the floor easily	0	2
	Used to amplify the sound *	41	33
	Used to make it look beautiful	1	1
Q3.3 If the strings are all of the same size (diameter) and having the same tension (i.e. pulled equally tight); which of them will produce the sharpest sound (the sound with the highest note) when plucked?	String number 1 * (shortest string)	15	22
	String number 2	2	0
	String number 3	5	3
	String number 6 # (longest string)	20	17
	Blank	6	6
Q3.5 If the musician in fig 3.1b wants to produce a sharper sound, which of these actions can accomplish it?	Increase the length of the string	4	1
	Increase the size (thickness) of string	2	0
	Increase the tension in the string *	33	43
	Increase force of playing #	9	4

Many learners hold scientifically valid reasoning about two of the concepts in relation to stringed instruments. Forty-one (85.4%) of the learners at pre-test and 33 (68.8%) of the learners at post-test knew that the sound box would amplify the sound from the string. On the other hand, 33(68.8%) of the learners at pre-test and 43(89.6%) of the learners at post-test knew that the pitch of the sound could be increased by increasing the tension in the string. However, some learners (6 at pre- and 12 at post-test) thought that the function of the sound box was to increase the frequency.

Also, many of the learners (20 at pretest and 17 at posttest) believed that the uppermost string of the harp, which is the longest, would have the highest pitch. Many learners reasoned that the hollow part of the harp amplifies sound by reflection or that 'hollowness' makes a loud noise.

The sharpness of the sound from a string was attributed more to its location on the instrument rather than to its length, which would alter the frequency. A good number of the learners (20 at pre-test and 17 at post-test) thought that the longest string would produce the sharpest sound. This is equivalent to attributing the highest frequency to the string with the greatest length, which is just the opposite of the reality.

Discussion

The learners made much use of their everyday experience in this question. For example E3 said “Everyone is starting to do that to the sound speakers in the car as well so it does amplify the strings.” And another learner said that he believed increasing the tension would increase the pitch of the sound from a string because he knew how to play the guitar. These examples show that practical materials learners are more familiar with could make more sense in teaching science than those learners are less familiar with.

Although most learners knew that the hollow box of the harp amplifies the sound produced by the string, many seem to have many alternative conceptions as to how the amplification actually happens. Several learners seemed to believe that hollow objects produce sound. For example, E11 said “The hollow part of the instrument helps with the increase in volume. The emptiness makes a louder sound.” while E12 said similarly that “Hollow objects give off greater sound.” It is possible that this conception might have been taken from the everyday expression that ‘an empty vessel makes the loudest noise’. Another frequent explanation encountered in this question was that the amplification is caused by echoes. Some of the learners made statements such as the following: E13 “Being hollow the sound will echo louder.” E15 “This happens because echo is taking place inside the hollowness of the base.”

Many explanations by learners as to why they thought a chosen string would produce the sharpest sound tended to rely on the position of the string rather than on its properties. The general impression given was that the last string always produces the sharpest sound. For example, E11 “It is number 6 because it is the highest.” E15 “String number 6 because it is the last string and the last string always has the sharpest sound.” E22 “It would be string no. 6. The way it is tuned in or tightened it would be the last string and is thus the sharpest.” Some learners thought that a

longer string would produce a sharper sound, for example, E13 who said “The longer the string is the more sound will flow from it, creating more sound the more sound created the shaper it will become.”

Practical experience seemed to have influenced some learners in this question. For example, E20 “The tighter the string the more tension is provided like that of a guitar.” Some learners associated a sharper sound with more energy being used, for example, E21 said ‘more energy would be exerted and the more energy the more force and more force would make a sharper sound.’ This means that E21 thinks that the pitch and amplitude of vibration affect each other. More specifically, the learner thinks that a greater amplitude of vibration would lead to a higher pitch (and by implication, a higher frequency). This corroborates the findings of Takashi (2011) where students associated a change of volume with frequency. However, these findings differ from the former case in that volume and frequency were thought to vary directly rather than in a covariant manner as in the former case.

4.2 Research Question Two

4.2a) Is there a difference between the gains in conceptual understanding of sound by learners exposed to DAIM as compared to those not exposed to it?

4.2b) Are the learners’ conceptual understanding of sound related to gender or age?

4.2a) Is there a difference between the gains in conceptual understanding of sound by learners exposed to DAIM as compared to those not exposed to it?

The aim of this question was to find out if there was a difference between the changes in conceptual understanding of sound by learners exposed to DAIM as compared with those not exposed to it. The null hypothesis (H_0) was that there was no difference between the gains in conceptual understanding of sound by the E and C group learners – those exposed to the DAIM and those not exposed to; while the alternative hypothesis (H_1) was that there would be a difference. In order to effectively compare the E and C groups, I used the pre-posttest results of the SAT which tested the learners’ conceptual understanding of sound.

Table 4.4 below shows the pre-post-test results of the SAT for both E and C groups obtained using two-group t-test for independent samples. The t-test was considered

appropriate since the distribution of learners' total scores (pre-post) for each of the groups was normally distributed using the Kolmogorov-Smirnov test; and the variances were approximately equal as they were found to be non-significant difference using Levine's test on the SPSS. Hence the conditions for using the t-test were fulfilled (Field, 2009).

Table 4.4 Comparison of E & C performances on the SAT

Sound concept	Grp	Mean	SD	mean diff.	SD Error	t value	Sig.(2-tailed)
Speed (pre-)	E	12.00	1.911	-0.417	.477	-0.873	.387
	C	12.42	1.349				
Propagation (pre-)	E	8.92	1.742	0.917	.430	2.134	.038*
	C	8.00	1.180				
Strings (pre-)	E	8.75	2.152	-0.292	.653	-0.447	.657
	C	9.04	2.368				
Total (pre-test)	E	59.33	7.287	0.417	2.073	.201	.842
	C	58.92	7.077				
Speed (post)	E	15.50	2.874	2.417	.722	3.347	.002*
	C	13.08	2.062				
Propagation (post)	E	11.17	1.857	3.042	.602	5.054	.000*
	C	8.13	2.290				
Strings (post)	E	11.21	2.226	2.292	.654	3.506	.001*
	C	8.12	2.302				
Total (post-test)	E	75.75	10.506	15.50	2.645	5.861	.000*
	C	60.25	7.585				

Alpha = .05; $t_{critical} = 2.01$; $df = 46$; (*) indicates a significant difference: E (N=24); C (N=24)

From Table 4.4, the E group had a mean pre-test score of 59.33%, with a standard deviation of 7.29 while the C group had a mean pre-test score of 58.92%, with a standard deviation of 7.08. The mean difference between the E and C pre-test scores was 0.42%, with a standard error difference of 2.07. This difference was not

significant $t(46) = .201, p > .05$. The effect size (r) was less than .10, indicating a negligible effect.

On average, the E group performed better at post-test ($M = 75.75, SD = 10.51$), than the C group ($M = 60.25, SD = 7.59$). This was highly significant $t(46) = 5.861, p < .05$; giving an effect size, $r = .65$, representing a large effect following Cohen's classification (Field, 2009).

As far as the different concepts of sound are concerned, there was no significant difference between the two groups at pre-test as far as the speed of sound and properties of sound from stringed instruments were concerned. However, the E group performed significantly better on items involving sound propagation ($M = 8.92, SD = 1.74$) than the C group ($M = 8.00, SD = 1.18$). This was significant $t(46) = 2.134, p = .038$; representing a medium sized effect, $r = .3$. At post-test, the E group performed better than the C group in all areas of sound under study.

The above results indicate that the E group obtained a significant improvement between the pre- and post-tests on the conceptual understanding of sound. The effect size ($r = .65$) means a large effect on the basis of Cohen's categorization (Field, 2009). The relevant variables in the experiment were similar (as far as possible) for both E and C groups; the main difference being the method of instruction where the C group teacher used the direct instruction method and the E group teacher used the DAIM.

Table 4.5 Pre-post differences in mean scores for E and C groups

Group	N	Mean difference	S.D	t value	Pr>/t/
E	24	16.5	8.42	9.55	< .0001
C	24	1.3	9.04	0.72	.477

$t_{critical} = 5.02; \alpha = .05$

As can be seen from Table 4.5, the mean the pre-post score of 16.5 for the E group was significantly better than for the C group. This shows that the E group learners probably learned the concepts better than their counterparts in the C group.

The frequencies and percentages of the learners who chose the scientifically correct alternatives are shown in the Table 4.6.

Table 4.6 Pre- Post percentages of learners with right scientific conception on the SAT (for each of C and E groups, N=24)

Question	Grp	Pre (%)	Post (%)	Gain (%)
1.1When the drum is played with more force than before, the speed of sound	E	17	63	46
	C	13	21	8
1.3When the drummer plays faster , the speed of sound	E	21	63	42
	C	17	63	46
1.5Is it possible to hear the sound of the marimba outside the room?	E	63	75	12
	C	33	38	5
1.7If a record player is playing music between a sealed double-wall glass container	E	25	33	8
	C	4	29	25
1.9If the air between the glass walls is removed completely	E	75	88	13
	C	29	13	-16
2.11Thabo is at same level as Thandi and Kele, Bongani is higher up and Chris lower. The four are at equal distances from Thabo plays a bass drum.	E	46	63	17
	C	50	38	-12
2.3If Thabo points the vuvuzela in the direction of Chris and blows it,	E	29	42	13
	C	38	50	12
3.1The round part at the base of figure 3.1a (gourd) is hollow. What important role does it play in the sound produced?	E	83	79	-4
	C	88	58	-30
3.3If the strings are all of the same size and having the same tension (i.e. pulled tight equally); which of them will produce the sharpest sound when plucked (i.e. pulled with the fingers)?	E	50	71	21
	C	13	21	8
3.5If the musician in fig 3.1b wants to produce a sharper sound, which of these actions can accomplish it?	E	79	96	17
	C	58	83	25

Discussion

The E group showed a significant improvement on the mean rank scores of the SAT which was used to test learners' conceptual knowledge of the sound concepts in the study, while the C group did approximately the same as at pre-test, as the mean gain was not statistically significant.

A possible contributing factor to the E group's better performance could most probably be the intervention method (the DAIM) which was used by the E group's teacher. The DAIM, being an enquiry method, involves learners actively constructing knowledge through the argumentation activities. Many studies have shown that learners who use dialogical argumentation strategies acquire higher and more permanent cognitive gains (Asterhan & Schwarz, 2007; Diwu, 2010; Skoumios & Hatzinika, 2009; van der Linde, 2012; von Aufschnaiter et al., 2008).

Why the E group might have performed better in some questions

Some of the alternative conceptions were structured into argumentation activities, for example, question 1.1. An examination of the pre- to post-test gains by the E group in this question shows a significant shift towards the scientifically accepted understanding, that the speed of sound in air is not affected by the force with which the sound is produced. A few excerpts will be taken from some learners who at pre-test believed that the speed of sound would be greater when the drum is played with more force.

E 3 (pre-): The drummer is playing the drum with more force than before

E3 (post-): The speed will not change

E 21 (pre-): There would be an increase in the energy produced of the sound waves

E 21 (post-): The loudness does not affect the speed of sound but the pitch.

These learners who took part in argumentation activities showed evidence of having made significant conceptual gains with regard to the effect or no effect of force on the speed of sound. This corroborates the findings of Skoumios and Hatzinika (2009).

While working with a group of learners on the topic of heat and temperature, they found that learners who used evidence to justify their claims in group discussions had better conceptual understanding of the school science knowledge with regard to the concepts being studied. Similarly, these learners, by taking part in an argumentation activity involving the effect of force on the speed of sound, showed that their previous conceptions had changed to the scientifically valid one. E3 and E21, for example, had learned that the speed of sound neither depends on the force of playing the drum nor on the energy used in doing so.

Dialogical argumentation tasks involving speed of sound

As mentioned above, the dialogical argumentation activities in the E group included one activity on the relation between the speed of sound and force of playing a drum. Below are some of the excerpts showing how some of the groups' argumentation took place on the question: "Does a loud sound travel faster?"

Group 1 (The Attorneys)

Individual level

E12: "The frequency of a vibration can increase resulting in a louder sound. But it cannot change the speed of sound"; E13 "The speed of sound does not change if the sound becomes louder in the same medium, the pitch would increase if the sound is louder" E15 "No, it does not change. The speed of sound does not change in the same medium; the loudness of sound depends on amplitude."

Group conclusion:

No. A louder sound does not move faster. The loudness of the sound is determined by the frequency and amplitude. But it does not change the speed of sound

Group 2 (Little Monsters)

Individual level

E17: "Yes. My opinion is that the louder sound will travel faster. The higher the frequency the faster it moves" E1 "No. The amplitude only changes but sound travels at a constant rate" E4 "No. The volume of the sound does not affect the speed."

Group conclusion:

No. The volume does not affect the speed, only the amplitude changes.

The arguments of the learners in group one are mostly made of claims and simple reasons justifying the claims. All the learners are of the opinion that a louder sound would not move faster. Most of the arguments are at level one or two of the TAP classification. That is, arguments involving simple claims against counter claims with or without grounds, and no rebuttals. In group two, the arguments seem to be at

a higher level. The claim of the first learner is rebutted by two other learners, with backings. For example, E4 objects on the grounds that 'the volume of the sound does not affect the speed.'

Some excerpts from focus group interview results in the C group

Interviewer: If I hit a drum faster, does the sound move faster, slower or stays the same?

1st Learner: "When the drum is hit fast the sound moves faster in air"

2nd Learner: "When the drum is hit fast the speed will be the same, it will only sound louder"

Interviewer: Your friends have given two different opinions. What do you say?

3rd Learner: I think that the faster the beat, the closer the wavelengths; and wavelength is directly proportional to wave speed, thus the sound will move faster.

Discussion

The first learner still holds the alternative conception that the speed of sound would increase when the frequency increases, while the second has got the right scientific concept that frequency would not affect the speed of sound. The reasoning of the third learner seems to show some confusion. He seems to start with the idea that the waves would be closer, implying that the wavelength would actually reduce.

However, his conclusion is that since the wave speed is directly proportional to the wavelength, the speed of sound would increase; thus contradicting his assertion that the waves would be closer. This seems to confirm the results of earlier findings that support that learners find argumentation in scientific contexts more difficult (Angaama *et al.*, 2012; Osborne *et al.*, 2004).

4.2b) Comparison of performance on the SAT by gender and age

Gender

The analysis of the data on the basis of gender was performed across the two groups (Table 4.7). The pre-test percentage mean scores for male learners ($N = 27$, $M = 59.89$, $SD = 5.85$) was not much different from that of the female learners ($N = 21$ ($M = 59.43$, $SD = 8.61$); the mean difference of 0.54 was not significant $t(46) = -.258$, $p = .807$, $t_{critical} = 2.01$, at $\alpha = .05$ level. The effect size was negligible (.05),

meaning no effect. Similarly, at post-test, the male learners (N = 27) obtained a mean score of (M = 68.9, SD 5.85) as compared to the female learners (M = 66.4, SD = 8.61). The mean difference of 2.03 (SD = 3.51) was again not significant [$t(46) = .579$, $p = .566$, $t_{critical} = 2.01$] at alpha level .05.

Table 4.7 Comparison of learners' performance on the SAT by Gender

Total score	Gender	N	Mean	SD Dev	mean difference	STD Error	t value	Sig. (2tail)
Speed (pre-)	male	27	12.26	1.56	0.12	.485	.240	.811
	female	21	12.14	1.80				
Propagation (pre)	male	27	8.44	1.31	-0.04	.454	-.070	.945
	female	21	8.48	1.83				
Strings (pre-)	male	27	9.52	2.33	1.42	.625	2.276	.028*
	female	21	8.10	1.90				
Total (pre-test)	male	27	59.89	5.85	+0.54	2.089	-.258	.807
	female	21	59.43	8.61				
Speed (post)	male	27	14.22	2.59	-0.16	.811	-.196	.846
	female	21	14.38	3.03				
Propagation (pst)	male	27	9.30	2.28	-0.80	.747	-1.069	.291
	female	21	10.10	2.90				
Strings (post)	male	27	10.15	2.49	0.20	.741	.264	.793
	female	21	9.95	2.62				
Total (post-test)	male	27	68.89	5.85	2.03	3.510	.579	.566
	female	21	66.43	8.61				

Alpha = .05, $t_{critical} = 2.01$; $df = 46$

In this question the learners' scores on the SAT were compared according to gender to see if there was a significant difference between the mean scores of boys and that of the girls. On all aspects of sound tested, both at pre-test and post-test, there was no significant difference between the performance of male and female learners; with the exception of the concepts involving stringed instruments at pre-test where the male learners performed better (M = 9.52, SD = 2.33) than their female counterparts

($M = 8.10$, $SD = 1.90$). Although the mean difference of 1.42 was significant at alpha level .05 [$t(46) = 2.276$, $p = .028$, $r = .32$], the effect was nevertheless moderate ($r = .32$).

Discussion

Several studies have reported differences in performance, perceptions of science, and interest in science based on gender, especially in the physical sciences (Farenga & Joyce, 1999; Greenfield, 1997; Jones, Howe & Rua, 2000; Lee & Burkam, 1996). Farenga and Joyce, found that both male and female learners believe that “certain subjects such as mathematics, physics and chemistry are considered masculine whereas subjects such as biology, language, and art are perceived as feminine” (p. 61).

Jones, Howe and Rua (2000) reported a similar perception by learners. On the other hand, Lee and Burkam (1996) reported on the performance of male and female learners in science. They found that middle school male learners performed significantly better than their female counterparts in physical science while the female learners performed modestly better than their male counterparts in life science.

In this study the results showed no difference in the performance of the male and female learners, contrary to the findings of Lee and Burkam (1996); but they corroborate the findings of Greenfield (1997) who found no difference in the attitude and participation of male and female learners in science.

Although one cannot give a definite reason for the similarity in the performance of the male and female learners in both E and C groups, I would like to suggest that a possible reason could be the context in which the learning took place. If it were largely due to the method of teaching, then the female learners of the two groups would probably have performed differently because different teaching strategies were employed in the two groups. Since both E and C groups used indigenous musical instruments to provide a familiar context, the interest of learners and familiarity of instruments might have made a significant contribution.

Lee and Burkam (1996) have reported that practical activities benefit girls more than boys in middle secondary school physical science. They have further suggested that

more practical work would be advantageous to girls. Similarly, Greenfield (1997) concluded that girls were equally competent in manipulating science equipment as boys during the early secondary years. This is perhaps the case here though more studies would need to confirm this.

Taking into consideration the results of these studies, and given that the sound equipment was familiar to the learners, the girls were probably more positively motivated to a greater degree than were the boys. The classroom observation in the C group confirmed this. As the teacher used the instruments to demonstrate some of the concepts, several learners-both boys and girls got quite excited. Several of them tried playing the instruments. Many of the learners expressed that they enjoyed learning sound using indigenous musical instruments because they were simple enough to be mastered easily.

The comparison was also done with the two groups taken separately. The results are presented below.

Table 4.8 Percentage scores on the SAT by gender

	Group	Gender	N	Mean %	SD	t value	df	Sig. 2tail	Mean diff.
Pre-	C	male	14	61.57	5.77				
		female	10	55.2	7.32	2.39*	22	0.026	6.37
	E	male	13	59.23	6.85				
		female	11	59.45	8.1	-0.07	22	0.942	-0.22
Post-	C	male	14	61.43	7.94				
		female	10	58.6	7.12	0.9	22	0.379	2.83
	E	male	13	73.69	10.86				
		female	11	78.18	10.02	-1.05	22	0.307	-4.29

$t_{crit.} = 2.07$; (*) indicates a significant difference at $p = 0.05$; $\alpha = .05$

The learners' pre- and post-test scores in the C and E groups were compared using the t-test for independent means. At pre-test, the male learners in the C group performed better ($M=61.57$, $SD=5.77$) than their female counterparts ($M=55.2$, $SD=7.32$). This was significant ($t(22) = 2.39$, $p < .05$, $r = .454$). This gave a medium effect size, $r = .454$. At post-test, there male learners still performed slightly better ($M=61.43$, $SD=7.94$) than female learners ($M=58.6$, $SD=7.12$). However, the

difference was not significant $t(22) = .9, p > .05$. In the E group, the male and female learners were at par, scoring 59.23 and 59.45 respectively. At post-test the female learners ($M=79.18, SD = 10.02$) outperformed their male counterparts ($M=73.69, SD=10.86$). The difference was however not significant $t(22) = 1.05, p > .05$.

These results show that in both the C and E groups, the performance of male and female learners did not seem to show any significant difference. That is, in the two classes that formed the sample, male and female learners performed equally on the sound conceptual test.

Age

Table 4.9 Comparison of learners' performance on the SAT by age

C group					
Age	N	Pre-test	SD	Post-test	SD
16	2	56%	8.5	50%	2.8
17	16	60%	7.5	62.7%	7
18	6	57%	6	57%	6.4
E group					
16	6	55%	8.46	78.33	13
17	18	60.78%	6.48	74.89	9.83
18	0	0	0	0	0

As with gender, the analysis of the data on the basis of age was performed across the two groups. The learners' performance on account of age is presented in Table 4.8 (see p. 112). The pre-test mean percentages are similar and are probably not likely to be significantly different from each other. The standard deviations at the pre-test are also similar. However, both statistics change considerable at the post-test. Performing inferential statistics in view of the disparity of number of learners in the age groups was not considered appropriate. Hence only the descriptive indices are presented. However, despite the disparity in terms of the number of subjects per age group the overall mean scores were similar. However, at the post-test the 16 year-olds outperformed the 17 year-olds and they in turn outperformed the 18 year-olds. Again, the actual factors responsible for this are beyond the scope of this study. One

would have expected that the reversal of what actually occurred considering increase in age implies the probability of one having more experience and greater conceptual understanding.

Due to the great variation in the number of learners in the age groups, it was not proper to use inferential statistics for the question involving learners' ages. Hence only descriptive statistics were employed, and therefore no statistical inferences could be made on the basis of the above results. However, one notices that the performance of the learners in the C group does not differ much among the age groups. However, the learners aged 17 maintain a slight lead at both pre- and post-test while the learners aged 16 trail behind the rest. On the other hand, those aged 18 maintained the same mean score as at pre-test.

In the E group the younger learners (16 years of age) performed less than their older counterparts at pre-test. However they seemed to have gained more as a result of the instruction, performing better than the older learners at post-test. However, these results in no way suggest that younger learners gain better from instruction than older learners. A further investigation would be needed to do so.

4.3 Research Question Three

a) What IKS concepts of sound do learners hold? b) What are the learners' attitudes towards the integration of IK and science? Are learners' attitudes towards the integration of science and IK affected by gender?

IKS conceptions of sound – animal sounds

As mentioned earlier, this question was answered from the responses of the learners to questions 6 and 7 of the SIKSQ. The analysis will be done using the CAT framework, as it is the most appropriate in this context. At pre-test 29 learners out of 39 believed that the cat's strange noise was a bad omen while 7 learners disagreed. But this situation changed at post-test where only 17 agreed and more learners (19) disagreed. Agreement to the statement seems to indicate an underlying IKS worldview that animal sounds can have various meanings in the affairs of human beings, while disagreement might be indicative of a dominant scientific worldview (which is strongly empirical).

a) Conceptions with regard to IKS

The purpose of this question was to find out the indigenous beliefs associated with the sound made by animals as exemplified by the cat scenario (Q. 6) and the beliefs about the effects of music on human behaviour (Q. 7).

Table 4.10 Learners' responses to items involving IKS (N=39)

Item on IKS	GP	Pre-test					Post-test				Bla nk	P value
		N	SA	A	D	SD	SA	A	D	SD		
6.1 The sound of the cat was a bad omen*	E	20	7	9	3	0	3	6	7	3	1	0.6111
	C	19	6	7	1	3	2	6	9	0	2	
6.2 The cat must have seen the snake.	E	20	5	10	3	1	3	12	4	0	1	0.7204
	C	19	3	11	2	1	3	10	4	0	2	
6.3 It was just coincidence.	E	20	4	6	8	1	4	6	5	4	1	0.6818
	C	19	4	7	4	1	0	10	6	0	3	
7.1 The music caused their son's bad behaviour.*	E	20	3	8	7	1	5	7	5	2	1	0.5266
	C	19	3	9	4	1	2	8	6	1	2	
7.2 The music contributed to moodiness*	E	20	2	11	6	1	5	12	3	0	0	0.0263
	C	19	5	7	3	1	1	8	6	1	3	
7.3 The music & strange behaviour are not related.	E	20	3	3	10	3	2	1	1	6	0	0.118
	C	19	4	1	6	5	3	2	9	2	3	

An asterisk (*) indicates a statement that is indicative of strong IKS beliefs; $\alpha = .05$

The pre-post-test change in the numbers may be an indication that many learners must have changed from an IKS-based worldview at pre-test to a more science-dominant worldview at post-test. I will take some excerpts to probe further. The learners' views will be presented, followed by the analysis in terms of the CAT.

Equipollent Category of CAT

I will consider the first learner, E1: “The cat could have cried for many reasons. The girl being bitten is just a coincidence.”

E1 agreed that the cat’s noise was an indication of a bad omen i.e. something bad was likely to happen, and strongly agreed with the statement that the cat must have seen the snake. She also agreed with the statement that the two incidents were mere coincidence. E1 seems to hold both the scientific and an IKS worldview. The view of associating the sound made by the cat to an occurrence of some impending evil about to happen the next day is typical of IKS beliefs. At the same time, she seems to base her argument on pure logic when she says “The cat could have cried for many reasons.” To this learner, the cat’s cry could have been caused by various factors, possibly including the fact of seeing the snake, but not also excluding the fact that it could have been giving a warning as a premonition; not having seen the snake beforehand.

By asserting that the snake bite and the noise made by the cat were ‘just a coincidence’, she seems to hold a strong science worldview. This suggests that she holds both science and IKS worldviews simultaneously. In terms of the CAT, this learner seems to fall in the equipollent science-IKS category. Many learners seemed to holding similar (equipollent) views. I will take a group of learners who seem to hold similar views.

E5 “The cat was crying as a warning” E6 “Nature has its own way in explaining when something bad is about to happen, there are always signs to show it” E8 “I believe that the cat making that strange noise was an indication to them that something bad is going to happen.”

The above learners agreed with the three statements made. That is, they agreed that: 1) the cat’s noise was a bad omen, 2) the cat must have seen the snake, and 3) the two situations happened by mere coincidence. In addition, all of them hold the view that the cat’s noise was a sort of warning, which is an IKS worldview. However, the fact that they also believe that the snake bite and the noise were just coincidental is indicative of a school science worldview which cannot justifiably attribute a causal relationship between the two incidents. These learners therefore seem to hold dualistic science and IKS worldviews concurrently. In terms of the CAT, they seem to hold equipollent science – IKS worldviews.

The next group of learners still seems to fall under the equipollent category of the CAT.

E18 “For some reason, animals sense when danger is near especially in nature” C5 “Yes, animals have a sense called 6th sense allowing them to behave strangely before an event.”

Both learners above did not believe that the cat’s noise was a bad omen (which is a science worldview). On the other hand, E18 believed that the cat must have seen the snake while C5 did not. Also, both of them agreed that the cat’s noise and the snake bite happened by chance, which is a science worldview. However, their statements given above concerning their views on animal foreknowledge of events indicate that they also hold the IKS worldview. This means they are holding both science and IKS worldviews simultaneously – which is an equipollent state in terms of the CAT.

Assimilated worldview

E16 “I’m not very superstitious, so I don’t believe that the cat had some sort of knowledge.”

E16 strongly agreed to the statement that the cat’s noise was a bad omen (which is an indication of the presence of an IKS worldview) and agreed that it must have seen the snake. However, the same learner disagreed with the statement that the snake bite and the cat’s noise just happened by chance – which means that to her, the two events were not completely unrelated to each other (which is again an indication of an IKS worldview). But the assertion that she was “not very superstitious” seems to indicate that this learner was either not aware of the IKS worldview which she seemed to be holding or wanted to refuse its existence in order to be seen as “scientific”. Cognizant of the fact that all the learners were from non-western backgrounds where indigenous beliefs are part of normal life, she seems to fall in the assimilated IKS worldview category. This situation is in contrast with that of the next learner below.

Dominant worldview

E19 “Animals have a special sense to detect danger.”

This learner strongly agrees that the cat’s noise was a bad omen, and disagrees that the cat had seen the snake. E19 also believes the occurrences of the snake bite and the cat’s noise are not just coincidental (meaning that to him, they are causally related) and believes that animals have a special sense to detect danger. This learner

seems to consistently hold the IKS worldview, implying that in the CAT classification, IKS worldview is dominant.

Several studies have shown that learners and science teachers from non-western background often harbour their indigenous beliefs alongside science concepts and use both worldviews in different contexts without any conflict (Ogunniyi, 2004, 2005, 2007a & b). These learners seemed to have corroborated these findings. The interest shown in seeing that science and IK be integrated (to be discussed in question 3 shows that learners are comfortable with an integrated science-IK environment than otherwise).

Table 4.11 Comparison of E and C groups on IKS integration

		N	Mean rank	U	Z	sign (2-tailed)	t critical
Pre-test	E	20	27.15				
	C	19	12.47	47.0	-4.053	< .0005	2.03
Post-test	E	20	23.68				
	C	19	16.13	116.5	-2.093	0.036	2.03

The attitude to science-IK integration was captured through the SIKSQ questions 1-5. The data were analysed using the Mann-Whitney U test on SPSS as the data were ordinal. The results are presented in table 4.10 above. The results indicate that at pre-test, the E group had a higher score (M=27.15) than the C group (M=12.47), Z=-4.053; U= 47.0, P< .0005, r =.65. At post-test the E group again obtained higher mean score (M=23.68) than the C group (M=16.13). This was significant at alpha=.05, U=116.5, Z=-2.093; p=.036, r=-.34, t_{critical} = - 2.03. Table 4.10 shows the pre-to-post-test scores by each of the groups. The increase of mean scores by the C group was significant, Z = -2.103, p < .05, r=.46 as opposed to that of the E group which was not significant Z = -0.378, p< .05; at alpha = .05.

The E group seemed to be more inclined to favour the integration of science and IK, from the pre- and post-test scores on the SIKSQ as their mean scores were significantly higher than those of the C group at both pre-test and post-test. A major contributing factor could be the influence of their teacher who had already been

using dialogical argumentation to integrate science and IK (See Van der Linde *et al.*, 2012). These learners had already learnt to appreciate and value IK in the processing of gold, and relating it to chemical reactions. Hence, they could probably see a more positive relation between the two knowledge corpuses than their counterparts of the C group who were experiencing IK in science for the first time.

The C group on the other hand, had a modest regard for science-*IK* integration, with a significant improvement on this attitude in favour of science-*IK* integration at post-test. The relatively lower interest in science-*IK* integration may be due to the fact that they had not been used to such a method before or they have the common misconception that *IK* is old-fashioned or something of the past. Another reason might be the fact that their teacher was using modern technology (computer, digital projector) to present the science lessons; so some of them might think of science-*IK* integration as regression instead of advancement in science and technology. This mentality was exhibited by the learner C9 when he said “Modern classrooms don’t need old things in it.”

Several reasons were given by learners for wanting or not wanting the integration of science and *IK*. Those in favour of integration gave the following reasons:

1. Integration would broaden knowledge;
2. Integration would give *IK* its place of value in the field of knowledge;
3. Integration should be done because science is universal;
4. Integration should be done because *IK* contains science;
5. Integration should be done to ease understanding of science;
6. Integration should be done because *IK* is interesting, and spiritually and emotionally satisfying.

Meanwhile those who were against integration of science and *IK* did so on the grounds that 1) *IK* is archaic and 2) *IK* does not help in calculations. I will take some excerpts to illustrate further, arranging them in the sections (A1 – A7) that follow.

A1 Equipollent worldview

The first group of learners are those who seem to value knowledge from a broader, all-inclusive perspective. To these learners, science and *IK* are complementary and

using the two instead of one or the other means more complete knowledge. This corroborates several arguments for integration which see knowledge as better construed in a holistic, inclusive framework rather than dichotomizing it (Brown-Acquaye, 2001; Ogunniyi, 1988; Snively & Cosiglia, 2001).

Using the CAT, these learners probably have equipollent science-IKS worldviews. Some of the learners who expressed this view asserted the following: C5 “Because it is better to have a broader knowledge of everything so all aspects can be viewed. Yes, to expose all aspects of science- new and old”; E7 “The more you know the better for you, in both science and indigenous knowledge”; E8 “It broadens your knowledge and exposes you to things you don’t come across every day”.

A2 Dominant IKS worldview

The learners in the second category seem to have a high esteem for IK and think that integration would result in science benefiting from some knowledge that IK possesses outside the domain of science. Hence, in the CAT categorisation, they seem to have dominant IKS worldviews. The excerpts below are some examples in this category:

E6 “There are a lot of things that the modern science does not know about and each and every day we discover new things”; E7 “Indigenous knowledge will forever remain important regardless of the modern science”; C13 “Music relates on the culture you come from e.g. Africans are more into instrumental sounds than Europeans.”

A3 Dominant science worldview

Some learners wanted integration because they thought that science was universal and that integration would benefit IK. These learners seemed to express a dominant science worldview in the CAT classification.

C5 “Because science is everything we do, no matter where”; E1 “Science is the matter of which everything is composed”; E2 “Everything originates from science”; E5 “There is science in everything, life is science” E8 “Science is everywhere even in culture.”

A4 Equipollent worldview

The learners below seem to like integration for the reason that IK is helpful in learning science. Thus IK can be used as a stepping stone to science. To these learners, there is no marked difference between the two, so they can be used in a complementary manner. This seems to portray an underlying equipollent worldview in the CAT classification as these excerpts show:

E2 “We see how indigenous knowledge uses science and it helps us understand the science today”; C10 “There is science in cultural music and studying sound using musical instruments makes it more interesting to learn about”; C23 “Because sound is science and all sound no matter what sound it makes it has scientific principles.”

A5 Equipollent worldview

So many learners wanted integration of science and IK because they thought that this would enable them to better understand the science, since IK is simpler to understand. Some of these learners are the following: C5 “Because it’s easier to understand”; C10 “You need the past so that you can understand the present. Without knowing different systems you won’t be able to work with indigenous knowledge. It gives you a better understanding and improves your knowledge about science.” C17 “Because you don’t need some formula for the instrument to work. You just have to blow or hit some strings. Modern (*methods*) are not always the best way to learn.”

A6 Dominant IKS worldview

Some of the learners expressed that they liked the indigenous music because they did obtain some inner satisfaction from it. These inner feelings were either emotional or metaphysical in nature, portraying a dominant IKS worldview. For example, C23 said: “When you play instruments it takes over your soul and gives you a happy and joyful feeling”; and C25 expressed: “Sound usually makes it more spiritual when you worship your father through sound. Music instruments are always fun to play.”

A7 Dominant science worldview /Assimilated IKS worldview

The last group of learners did not want any integration of science and IK. To these learners, IK was old fashioned or useless in the science classroom. In the CAT classification, these learners seem to be having dominant scientific worldviews, with the IKS worldview having been suppressed or assimilated as these excerpts indicate: C9 “Modern classrooms don’t need old things in it”; E19 “It has somehow come a thing of the past”; E1 “It does not help with calculations.”

Discussion

The discussions will be done in terms of the theoretical framework and the relevant literature. In terms of the TAP, most of the learners’ arguments can be classified at level 1 (arguments involving a simple claim against a counter claim with no grounds or rebuttals) or level 2 (arguments with claims or counter claims, with grounds, but no rebuttals). For example, the grounds used to justify the claim that IK should be integrated with school science by learners in A1 is that integration would lead to broadening of knowledge, in contrast with the case when there is no integration.

The learners in A2 continue similarly to say that IK possesses knowledge that science does not have; hence it is relevant to integrate the two. Those in A3 argue for integration on the basis that science permeates life, including IKS. To them, since science is everywhere and in everything, it does not make sense to exclude IK from it, hence integration should be the obvious thing. The learners in A4 on their part argue that both science and IK are mutually supportive of each other, hence should be integrated. On the other hand, the learners in A5 argue that IK is easier to understand, and would therefore enable learners to understand science better if the two are integrated. For the learners in A6, emotional or spiritual excitement underpins their desire for science-IK integration.

The learners who oppose integration of science and IK (A7) do so on the grounds that IK is archaic and ill-equipped to be of much use in a modern science classroom.

b) Is there a difference in the IKS beliefs between the E and C group learners?

Table 4.12 Comparison of E and C groups on IKS beliefs

	Grp	N	Mean rank	U	Z	sig.2tailed	t critical
Pretest	E	20	19.15				
	C	19	20.89	173.0	-.480	.631	2.03
Posttest	E	20	22.8				
	C	19	17.05	134.0	-1.587	.120	2.03

In order to quantify the beliefs of the learners, the scores of items 6 and 7 of the SIKSQ were used. The results indicate that at pre-test, the mean rank scores of the E and C groups were comparable ($M=19.15$ and 20.89 respectively), which was not significant, $U=173$, $Z=-.480$, $p=.631$. At post-test, there was again no significant difference between the mean rank scores of the E and C groups (22.8 and 17.05 respectively); $U=134$, $Z=-1.587$, $p=.120$, $t_{critical}=2.03$. $r=.36$ There was therefore no significant difference in the IKS conceptions of sound by the learners in the E and C groups both at pre-test and post-test. However, the C group had a modest effect between pre- and post-test, $r=.36$.

Are learners' IKS beliefs gender-related?

Table 4.13 Learners' IKS-based beliefs by gender

Group	Gender	N	Mean Rank	U	Z	Sig.(2tailed)
E pre	Male	13	10.31	43	-0.2	0.842
	Female	7	10.86			
C pre	Male	11	10.73	36	-0.664	0.507
	Female	8	9			
E post	Male	13	11.31	35	-0.841	0.4
	Female	7	9			
C post	Male	11	10.45	39	-0.417	0.717
	female	8	9.38			

Table 4.13 shows the scores on the science and indigenous knowledge systems questionnaire for male and female learners. The results show that there was no significant difference between learners' IKS beliefs based on gender. The mean rank scores on the SIKSP questionnaire that contained IK concepts showed no difference between the male and female learners. This was the case for both E and C groups and at pre- and post-test.

4.4 Summary

The findings of this study suggest that many learners hold some scientifically valid conceptions of sound even prior to formal instruction. On the other hand, a number of learners also hold many alternative conceptions of sound. A summary of the main prevalent alternative conceptions of sound will be presented below. For the sake of clarity, the summaries are arranged according to the questions.

4.4.1 Question one

The concepts tested in this question were those of the speed of sound in air, the nature of sound propagation, and the variation of the pitch of sound from stringed instruments with properties of the string.

Speed of sound: Many learners thought that the speed of sound would increase if the force of playing a sound instrument or the frequency of playing increased. Many also thought that sound would move faster when descending than when moving to a higher position, and that if one points a sound instrument in a given direction, the speed of sound would be greater in that direction.

Sound propagation: Some learners thought that sound can only 'escape' from an enclosure through apertures (doors, windows, holes), and that sound can be heard outside a sealed glass container because there are microscopic holes in the glass. Some learners also believed that when a glass container is sealed the sound would be 'trapped' inside - hence cannot be heard. Others thought that sound would propagate through a vacuum even better than in air because there is nothing to obstruct its motion.

Sound from strings: Learners thought that the pitch of the sound produced by a string depended on the relative position of the string rather than on its length. Some

learners attributed sharper sounds with longer strings while others thought that a higher pitch would result from an increase in the force of striking the string. The performance of the E and C groups was comparable at pre-test, but at post-test, the E group outperformed the C group on all aspects of sound under study.

4.4.2 Question two

The alternative conceptions of learners in the C group remained largely unchanged after instruction while those of the E group changed appreciably, but not completely. Learners seemed to overcome the alternative conceptions that were worked into structured argumentation activities better than those which were not. There was no significant difference between the performance of male and female learners at both pre-and post-test.

4.4.3 Question three

Most learners desire science-IK integration. Reasons given for this integration reveal underlying equipollent, scientific and IK worldviews as the most prevalent or dominant worldviews in the learners. Gender did not seem to have any effect on the learners' views on science-IK integration. Both argumentation and use of indigenous materials in teaching science seemed to positively influence learners' interest in science-IK integration.

Having presented and discussed the results in this chapter, the next chapter concludes the present study, outlines its implications and presents recommendations.

CHAPTER 5

CONCLUSION, IMPLICATIONS AND RECOMMENDATIONS

5.0 Introduction

The purpose of this study was to use an inquiry method, the DIAM, together with an indigenous context provided by the indigenous musical instruments to teach sound concepts to grade eleven learners. This was done in the anticipation that if successful, the method could serve as a potentially useful means of arousing learners' interest in physical science and possibly leading to increased motivation and performance in the subject by learners. The detailed results of this study were presented in chapter four. In this chapter, some conclusions will be drawn from the study followed by some implications and recommendations for curriculum advisers, policy makers and other stakeholders.

5.1 Main findings

The findings showed that the learners did not come to class tabula rasa; rather, they already held many opinions about sound concepts. However, while some of the learners' conceptions were in line with acceptable scientific knowledge, others conceptions were not.

5.1.1 Question one

What conceptions of sound do grade 11 learners hold before and after exposure to instruction involving the use of indigenous musical instruments?

The following is a summary of main findings to this question:

a) Velocity of sound

- The greater the force used in producing sound, the higher the speed of sound.
- The higher the frequency, the greater the speed of sound.
- The speed of sound is greater when the sound is moving from a higher to a lower position and lowers when it is moving from a lower to a higher position.
- The speed of sound is greater in the direction which a horn is blow, and lowers in the opposite direction.

b) Sound propagation

- Sound can only be heard outside a room if there are openings or holes through which it can escape.
- Sound cannot be heard outside a sealed glass enclosure because it would be trapped within it.
- Sound can be heard outside a sealed glass container because it escapes through tiny (microscopic) holes in the glass.
- Sound can propagate better in a vacuum since there is nothing to obstruct it.

c) Sound from strings

- A longer string produces a sharper sound (i.e. sound with a higher tone).
- The sharpness of the sound produced by a string depends on the relative position of the string.
- The sharpness of the sound from a string depends on the force of striking it.

5.1.2 Question two:

a) Is there a difference between the gains in conceptual understanding of sound by learners exposed to DAIM as compared to those not exposed to it? b) Is the learners' conceptual understanding of sound related to gender?

The following is a summary of main findings to this question:

- Learners taught using dialogical argumentation performed significantly better than their counterparts taught using the teacher-centred method.
- There was no significant difference between the performance of boys and girls in the sound achievement test.
- Although some alternative conceptions still remained after instruction, argumentation helped the learners in the E group to correct more of their alternative conceptions of sound than did the traditional method used in the C group.

5.1.3 Question three:

a) What IKS concepts of sound do learners hold? b) What are the learners' attitudes towards the integration of IK and science? Are learners' attitudes towards the integration of science and IK affected by gender or age?

The following is a summary of main findings to this question:

IK beliefs

- Animal sounds can act as warning or prediction of some future event.
- Music has an effect on human behaviour.
- Most learners in both E and C groups desire the integration of science and IK.
- This desire was similarly expressed by male and female learners.
- Both argumentation and indigenous musical instruments seemed to have had role to play in increasing learners' interest in the subject, and in desiring science- IK integration.

5.2 Limitations of the study

Since different teachers were used to teach the experimental and control groups, teacher characteristics would most likely have an influence on the results. The observed effects may therefore not solely or entirely be attributable to the instructional method alone. Also, since the whole classes were used because it was not possible to randomize the learners, subject characteristics on relevant variables could not be completely taken care of. Hence, the assumption that the two groups were initially equivalent might be disputable.

The participants of this study were learners mostly from the Coloured and Indian communities in under-resourced schools; hence, the results reported here might be slightly different in other contexts. In line with the ethical commitments signed by the researcher, the visits to the schools were limited as both principals did not want any disruptions to the learners' daily programme. Therefore, it was not possible to undertake detailed classroom observations, and this might have impacted on the generalizability of the findings.

In the analysis of the results in relation to age, most of the learners were found to be around the age of 17 and those outside this group were relatively fewer. Hence it was not possible to apply more rigorous inferential statistical methods on such questions. Hence the conclusions made on the basis of age are rather conjectural. The study also showed no differences based on gender, despite many reports of such differences. It will be necessary to undertake a more elaborate study using a much larger sample to determine if indeed gender plays a significant role.

Finally, time constraints and demands to complete syllabuses set out by the Education Department for teachers are usually so demanding on teachers that to find time to assist in such a research activity is a near miracle (Diwu, 2010; Ogunniyi & Taale, 2006).

5.3 Implications

Argumentation has been recommended by many science educators as a viable method of teaching science (Driver *et al.*, 2000; Kuhn, 1993; Ogunniyi, 2007a & b; Osborne *et al.* 2004). This notion seems to have been confirmed by the results of this study. Thus, argumentation needs to be taken seriously by curriculum planners, teacher-trainers and science teachers, because it has the potential of serving as a useful tool to achieve greater success in physical science, and effecting science-IK integration better than most other methods.

Moreover, this method can be used not only in one subject area but in others as well. Argumentation can also be applied to many subjects in the school curriculum. Besides, it does not require the financial costs that are often prohibitive to the implementation of other methods such as technology-based ones. Therefore, it can be a vital key to changing the story of poor performance in physical science if given the attention it deserves. Many researchers and educators have been concerned about the wide gap that exists between the policy of science-IK integration and what practically takes place in the classroom (e.g. Ogunniyi, 2011; Ogunniyi & Hewson, 2008; Ramorogo & Ogunniyi, 2010).

Some of the reasons for this disparity were that teachers who have been educated in the former system were not practically equipped to implement such a policy. This study seemed to point out that some science teacher training programmes could

actually equip science teachers for the implementation of science-IK integration, with no loss of content knowledge as required by the curriculum.

The use of local materials, technologies, methodologies, and epistemologies are thought to enhance learners' interest and participation in school science (Kawagley, Norris-Tull & Norris-Tull, 1998; Lesiba, 2006). Using indigenous musical instruments to teach sound seemed to have increased the learners' interest in the topic. This was probably because they could more easily relate the context with their daily experiences. Integrating science and IK in other science domains would possibly make learners see more relevance of science to their daily lives. Hence, one can say that an integration of IK with science could possibly sustain their interest and motivation to possibly pursue science-related professions later in life.

The constructivist belief of teaching science is to relate new knowledge to what the learner already knows. In line with this, many learners expressed the desire to see science and IK integrated for better understanding of school science broader knowledge and for the sake of increased interest to see the science in their culture. Therefore, it is worthwhile giving attention to what learners would find interesting and helpful to them, in their pursuit of knowledge.

5.4 Conclusions

The DAIM seemed to have been effective in

- (i) Diagnosing and changing learners' alternative conceptions on sound.
- (ii) Serving as a tool and platform for science – IK integration.

The issue of diagnosing and replacing learners' alternative conceptions with scientific ones has occupied a central position in educational research and instructional practice for several decades. Dialogical argumentation seems to be an instructional approach that can be very useful in this dimension if well-mastered by both teachers and learners. The DAIM in particular, seems to be a very useful means of integrating IK and science as it serves as a level platform in which various discourses can be accommodated, supported by evidence, and views changed on the basis of more valid evidence. By valuing indigenous materials, methods and epistemologies in the science class, there seemed to be greater possibility of

increasing the interest and performance of South African learners in physical science, as Mckinley, Brayboy and Castagno (2008) have noted: “It is generally argued that regardless of curricular area, when pedagogy and curricula are more aligned with students’ cultural norms, experiences and worldviews, that interest in school and achievement levels improve” (p. 740).

Using indigenous musical instruments to teach sound concepts seemed to have aroused interest in learners and to have helped them understand and appreciate the topic better than otherwise. This seemed to have had an influence on the learners expressing the desire for science and IK to be integrated for better understanding and arousal of interest.

The learners and teachers were mostly from the Coloured and Indian communities of Muslim, Christian and Hindu religions. Also, given that only intact classes were used, the results may not be generalizable. However, they may be clearly indicative of the trends in similar communities, especially in the under-resourced schools. Hence this method of instruction may be an economically viable means of achieving higher learner interest and performance in physical science.

5.5 Recommendations

Integrating learners’ cultural ways of knowing into science would help them to appreciate the relevance of science to them (Ogunniyi, 2011). When this happens, the learners would likely develop greater interest in science. Therefore, by including indigenous musical instruments in the teaching of sound concepts, the learners would relate better to the topic.

From the constructivist viewpoint, learners’ prior knowledge constitutes a useful raw material for the construction of further knowledge in the science classroom (Ausubel, 1968). Integration of science and IK is thus, the normally expected way of recognizing learners’ resources for scientific knowledge construction in the classroom. Conversely, rejecting or downgrading learners’ prior knowledge would be depriving them of their potential raw materials for constructing scientifically valid knowledge.

In the light of the research findings, it would be necessary to practically integrate IK into the physical science curriculum to improve learners' interest, motivation and performance in the subject.

Argumentation seems to be a cost effective, practical, versatile instructional tool and a platform that can be employed for effecting conceptual change, critical thinking and implementing a science-*IK* curriculum in physical science. Hence it would be necessary to give science teachers training in this area during their years of training or to give in-service training to those already in the field so that they can be able to use it practically.

- If science and *IK* have to be integrated, it would be necessary for an evaluation of both in official examinations, since the school system seems to be so much focused on examination results as the main means of evaluating success.
- This research was carried out in dominant Coloured and Indian communities. It would be worthwhile carrying out a similar study in other communities to compare the results.
- The learner is not greater than his teacher. If good results have to be attained in physical science, then teachers should be given adequate training in both content and knowledge and teaching strategies as dialogical argumentation that can be effective in producing such desired results as Osborne and Dillon (2008) have expressed:

Good quality teachers, with up-to-date knowledge and skills, are the foundation of any system of formal science education. Systems to ensure the recruitment, retention and continuous professional training of such individuals must be a policy priority in Europe (p.25).

Final comments

The lessons garnered from this exploratory study are worth highlighting. First, as a novel researcher, I have gained much experience about the complexity of the research process especially the unpredictability of many events or situations that arise when human beings are involved. For example, a change of the administration of my previous experimental school meant looking for another school. The new

principal in the former did not permit me to continue the study. Even after getting another school several constraints in terms of the time I could stay in the school, what I could or could not do, and so on placed enormous constraints on what I would have liked to be the case.

The issue of working with technology also brought many challenges as some of the audio as well as video-taped materials were not as good as anticipated, resulting in a lot of strenuous efforts to get the details. Hence, I could not get the details of what I would have liked to get from the E group since I was not permitted to do observations there.

Due to the pressure to cover the syllabuses, the school administrators as well as the teachers expressed great concerns over time constraints. The learners were very often stressed by the pressure of their own work that the research was seen as an added burden to bear. Hence some of the learners did not complete the post-test. Other learners needed every possible method of incentive to take part in the study, especially to complete the post-test. To enable them go on with the post-test, some of them had to be given pens or some other incentives. However, this is not unethical as some researchers recommend it if necessary (Creswell, 2005; Fraenkel & Wallen, 2009). Although the giving of incentives placed some financial burden on the meagre resources available, they did enable me to get most of the required data.

Despite the many constraints that I faced in the course of this study, it was also an exciting journey and a learning experience for me as I worked with different people - learners, teachers and school authorities. In conclusion, I learnt firsthand that working with people in a research context is fraught with many unpredictable events ranging from the frequently changing school environment, interruptions, moods of people which vary from one day to another and of course my uncertainties and anxiety as a novel researcher. I also learnt that to accomplish the object of my study I needed much patience, tolerance and wisdom to make the whole exercise a worthwhile endeavour.

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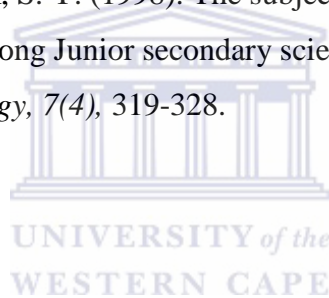
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Appendix A: Permission from the Western Cape Education Department



WESTERN CAPE
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RESEARCH

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ENQUIRIES: Dr A T Wyngaard

Mr Daniel Anga'ama
University of the Western Cape
Bellville

Dear Mr Daniel Anga'ama

RESEARCH PROPOSAL: EFFECTS OF USING A DIALOGICAL ARGUMENTATION INSTRUCTIONAL MODEL TO TEACH GRADE 11 LEARNERS THE CONCEPT OF SOUND, USING INDIGENOUS MUSICAL INSTRUMENTS (IMI)

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 **25 July 2011 till 30 September 2011**
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: Audrey T Wyngaard
for: **HEAD: EDUCATION**

DATE: 22 July 2011

Appendix B: Permission from UWC Senate Research Committee

**OFFICE OF THE DEAN
DEPARTMENT OF RESEARCH
DEVELOPMENT**

Private Bag X17, Bellville 7535
South Africa
Telegraph: UNIBELL
Telephone: +27 21 959-2948/2949
Fax: +27 21 959-3170
Website: www.uwc.ac.za

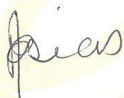
21 June 2011

To Whom It May Concern

I hereby certify that the Senate Research Committee of the University of the Western Cape has approved the methodology and ethics of the following research project by:
Mr DA Angaama (School of Science and Mathematics Education)

Research Project: Effects of using a dialogical argumentation instructional model to teach Grade 11 learners the concept of sound, using indigenous musical instruments

Registration no: 10/8/24



*Ms Patricia Josias
Research Ethics Committee Officer
University of the Western Cape*



**UNIVERSITY of the
WESTERN CAPE**

A place of quality, a place to grow, from hope to action through knowledge

Appendix C: The Sound Achievement Test (SAT)

PLEASE COMPLETE THE FOLLOWING:

SCHOOL..... CODE GROUP

HOME LANGUAGE

SECOND LANGUAGE

THIRD LANGUAGE

TICK IN THE APPROPRIATE BOX.

AGE

Under 16 years	
16 years	
17 years	
18 years	
Above 18 years	

GENDER

Male	
Female	

SECTION 1: MULTIPLE CHOICE

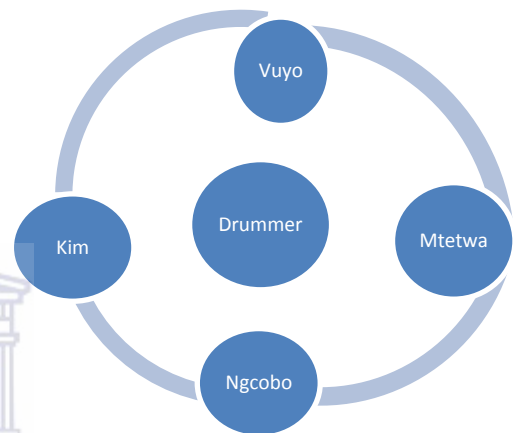
In each question, put a tick against the best answer in the box provided. The answers first part carries three marks while the reasons carry two marks each.

QUESTION 1

Fig1.1a Drum



Fig 1.1b Drummer and dancers



1.1 A drummer is playing the drum in Fig 1.1a. Vuyo, Mtetwa, Ngcobo and Kim are dancing around him in a circle. If the drummer starts playing the drum with **more force than before**, the **speed** of the sound now produced

- A) **Will be less** than before.
- B) **Will be the same** as before.
- C) **Will be greater** than before.
- D) **Cannot** be measured.

1.2 Give your reason(s) for the answer above.

.....
.....
.....

1.3 If the drummer now decides to play with the same force as at the beginning, **but much faster**, the speed of the sound

A) will **decrease**

B) will **increase**

C) will **remain the same** as before

D) Cannot be predicted.

1.4 Give your reason(s) for the answer above.

.....

.....

.....



Fig 1.5a A marimba

marimba



Fig 1.5b A musician playing a



1.5 A musician is playing a marimba in a room loudly. **All doors and windows are completely closed.** Is it possible to hear the sound of the marimba outside the room?

A) No.

B) Yes.

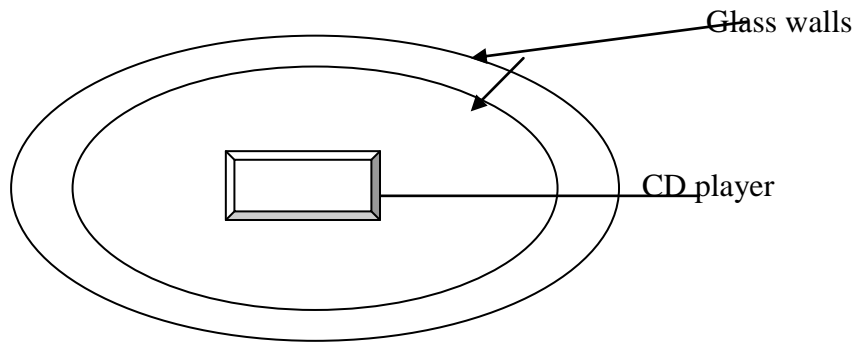
C) Yes, if only one is very close to the window.

D) Yes, but only if the musician is using a loudspeaker.

1.6 Give your reason(s) for the answer above.

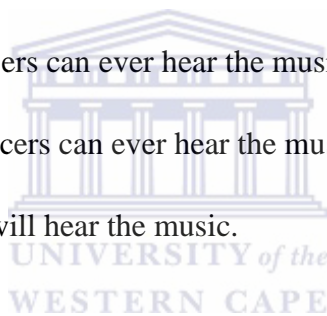
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Fig 1.7: A record player inside a double-walled glass container



1.7 A CD player is playing very loudly inside a double-walled glass container as shown above. The glass walls are completely sealed and dancers are around the glass container. Which of these statements is true?

- A) It is possible for all the dancers to hear the music.
- B) Only some of the dancers can ever hear the music.
- C) Only a few of the dancers can ever hear the music.
- D) None of the dancers will hear the music.



1.8 Give your reason(s) for the answer above.

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1.9 What will happen if all the air between the glass walls in question 1.7 above is completely removed?

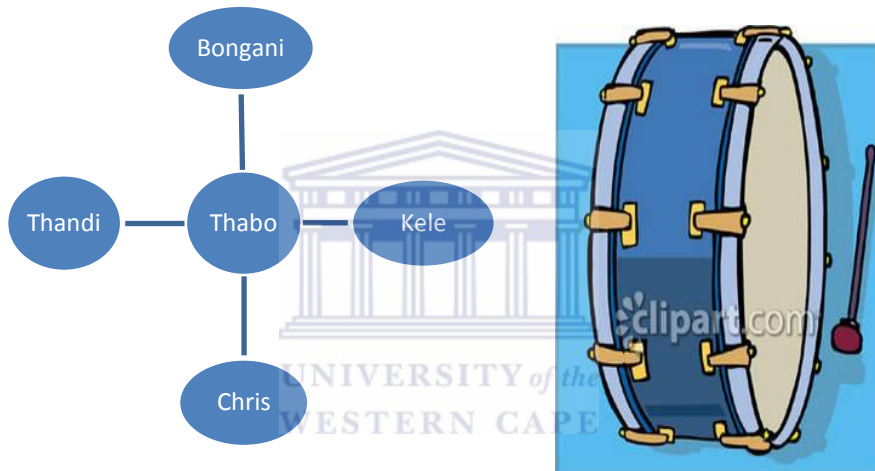
- A) It will still be possible for all the dancers to hear the music.
- B) Most of the dancers will be able to hear the music.
- C) Only a few of the dancers will be able to hear the music.
- D) None of the dancers will be able to hear the music.

1.10 Give your reason(s) for the answer above.

.....
.....
.....

QUESTION 2

Fig 2.1 Position of Thabo and friends Fig 2.1b Thabo's Bass drum



Thabo's four friends, Bongani, Kele, Chris and Thandi are at equal distances from him. Bongani is higher up on a hill and Chris is lower than Thabo. Thandi and Kele are at the same level as Thabo. Assuming the temperature and other atmospheric conditions remain constant,

2.1 If Thabo plays the bass drum from his house, which of these statements is true?

- A) All the friends will hear the sound at the same time.
- B) Chris will hear the sound first and Bongani last.
- C) Thandi and Kele will hear the sound at the same time, and the rest at different times.
- D) Bongani will hear the sound first and Chris last.

2.2 Give your reason(s) for the answer above.

.....
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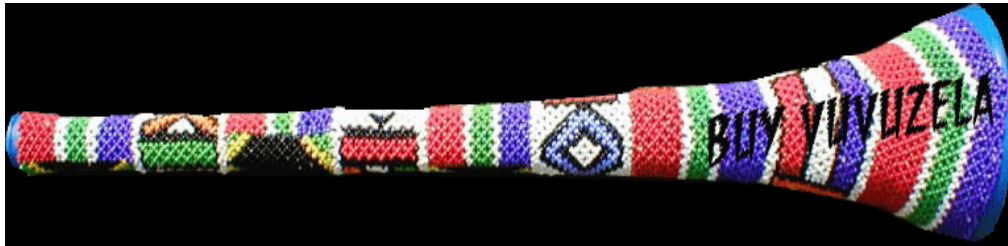


Fig 2.7 A vuvuzela

2.3 Thabo points the horn(vuvuzela) in the direction of Chris and blows it. How will the sound reach Thabo's friends?

- A) Bongani will hear first and Chris last.
- B) Chris will hear first and Bongani last.
- C) Only Thandi and Kele will hear at the same time.
- D) All of them will hear at the same time.

2.4 Give your reason(s) for the answer above.

.....
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.....

QUESTION 3

Fig3.1a



Fig3.2b



Two musicians playing African harps (Image from harpvoyages.com)

3.1 The round part at the base of figure 3.1a is hollow. What important role does it play in the sound produced?

- A) It increases the frequency of the sound from the strings.
- B) It enables the musician to put it on the floor easily.
- C) It amplifies (increases the volume of) the sound from the strings.
- D) It makes the instrument look beautiful.

3.2 Give your reason(s) for the answer above.

.....

.....

.....

3.3 In fig 3.1b, all the strings are made from the **same material**. The lowest *is string number 1* and the highest is *string number 6*.

If the strings are all of the **same size**(same diameter) and having the same tension (i.e. pulled tight equally); which of them will produce the **sharpest sound** (i.e. the highest note) when plucked (pulled with the fingers)?

A) String number 1

B) String number 2

C) String number 3

D) String number 6

3.4 Give your reason(s) for the answer above.

.....

.....

.....

3.5 If the musician in fig 3.1b wants to produce a sharper sound, which of these actions can accomplish it?

A) Increase the length of the string

B) Increase the size of the string

C) Increase the tension in (i.e. tighten) the string.

D) Increase the force with which the string is pulled.

3.6 Give your reason(s) for the answer above.

.....

.....

.....

Appendix D: The Science and indigenous knowledge questionnaire

PLEASE COMPLETE THE FOLLOWING:

SCHOOL..... CODE GROUP

HOME LANGUAGE

SECOND LANGUAGE

THIRD LANGUAGE

TICK IN THE APPROPRIATE BOX.



UNIVERSITY of the
WESTERN CAPE

AGE

Under 16 years	
16 years	
17 years	
18 years	
Above 18 years	

GENDER

Male	
Female	

For each statement below, indicate by using a tick (✓) if you:

Strongly agree (SA), agree(A), disagree (D), or strongly disagree (SD).

1. Studying sound using indigenous musical instruments makes me feel that there is science in every culture. SA A D SD

1.1 Why do you think so?

.....
.....
.....

1.2 Which of these influence(s) your reason the most? (tick)

Science religion/culture Personal experience

2. I feel excited studying some aspects of sound using indigenous musical instruments.

UNIVERSITY of the WESTERN GATE
SA A D SD

2.1 Why do you think so?

.....
.....
.....

2.2 Which of these influence(s) your reason the most? (tick)

Science religion/culture Personal experience

3. Indigenous musical instruments do not apply any scientific principles at all.

SA A D SD

2.3 Why do you think so?

.....
.....
.....

2.4 Which of these influence(s) your reason the most? (tick)

Science religion/culture Personal experience

3. There is no use studying Indigenous knowledge systems in today's modern science classrooms.

SA A D

3.1 Why do you think so?

.....
.....
.....



3.2 Which of these influence(s) your reason the most? (tick)

Science religion/culture Personal experience

4. It is necessary to study both science and indigenous knowledge in a science classroom for better understanding.

SA A D SD

4.1 Why do you think so?

.....
.....
.....

4.2 Which of these influence(s) your reason the most? (tick)

Science religion/culture Personal experience

In each of these questions, read the short story and then answer the questions that follow.

6.0 One day very late at night, a cat started making some strange noise. Gogo (grandmother) woke up the children and grandchildren and said that the noise made by the cat was an indication that something bad was about to happen. She proposed that they should visit a *sangoma* (traditional doctor) the next day, but the children refused. The next day, towards the evening, Thandi, one of her granddaughters was bitten by a big snake. She died before they could reach the hospital.

Some people believe that

6.1 The cat's noise at night was a sign that something bad was about to happen.

SA A D SD

6.2 The cat must have seen the snake that night.

SA A D SD

6.3 The cat's cry and the snake bit happened by mere coincidence (chance).

SA A D SD

6.4 What is your opinion?

.....
.....
.....

7.0 Sibanda is a teenager in grade 11. His parents came to complain about him a week ago. They said that since he started listening to some music he downloaded from the internet, his behaviour had had become strange. Sometimes, he sits alone in his room for the whole day with headphones on. Sometimes he treats his younger brothers and sisters very cruelly.

They suspect that:

7.1 The music has caused their son's bad behaviour.

SA A D

7.2 The music has contributed to his being moody, depressed or aggressive.

SA A D

7.3 The music has nothing to do with his strange behaviour.

SA A D

7.4 Can music influence a person's behaviour? Explain.

.....
.....
.....

8.0 Should the vuvuzela be banned during football matches or not?



(Above pictures adapted from *Acidcow.com*)

The *vuvuzela* made news during the last world cup in South Africa. However, there were fears that the world football governing body, FIFA, was going to ban it from football matches. Haters of the *vuvuzela* have their reasons why it should be banned; while those who like the *vuvuzela* have their arguments why it should not be banned.

Give your opinion on whether *vuvuzelas* should be banned during football matches or not, and give as many reasons as possible to support it.



UNIVERSITY *of the*
WESTERN CAPE

Appendix E: Letter to the principal of Menda Secondary School

Daniel Anga'ama

Univ. of the Western Cape,

danangaama@gmail.com

Tel.: 073 390 8242

27th July, 2011.

The Principal,

Menda Secondary School

Sir,

An Application to carry out Research in your Institution

I am a Master's student at the University of the Western Cape and wish to request your permission to carry out my research in your institution. This research entitled: *"Effects of using a Dialogical Argumentation Instructional Model (DAIM) to teach some concepts of sound to grade 11 learners by means of indigenous musical instruments"* has already been approved by the WCED (Ref. 20110722 – 0013).

DAIM is an enquiry teaching strategy developed at the School of Mathematics and Science Education at UWC to promote critical thinking in learners as they study in small groups, make claims and support them with evidence, while others make counter claims or refutations. DAIM also enables teachers to integrate science and indigenous knowledge as required by LO3 of the new curriculum. The use of indigenous musical instruments besides normal science equipment adds a context with which many learners are familiar (since music forms part of most cultures, and can help to increase their interest in physical science). It is hoped that this study will be of much benefit to learners of physical science.

The identity of the institution will not be disclosed, and learners' rights, anonymity and dignity will be respected. The research results will also be communicated to the school for the purpose of information.

Thank you in advance for your understanding.

Yours sincerely,

.....

(D.A Anga'ama)

.....

Supervisor

Appendix F: Letter to the principal of Kossala High School

Daniel Anga'ama

University of the Western Cape,

danangaama@gmail.com

Tel.: 073 390 8242

27th July, 2011.

The Principal,

Kossala High School

Sir,

An Application to carry out Research in your Institution

I am a Master's student at the University of the Western Cape and wish to request your permission to carry out my research in your institution. This research entitled: *"Effects of using a Dialogical Argumentation Instructional Model (DAIM) to teach some concepts of sound to grade 11 learners by means of indigenous musical instruments"* has already been approved by the WCED (Ref. 20110722 – 0013).

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The identity of the institution will not be disclosed, and learners' rights, anonymity and dignity will be respected. The research results will also be communicated to the school for the purpose of information.

Thank you in advance for your understanding.

Yours sincerely,

.....

(D.A Anga'ama)

.....

Supervisor

Appendix G: Letter requesting the consent of parents

Dear Parent/Guardian,

I am a master's student at the University of the Western Cape. As part of the requirements of the programme I am carrying out a study entitled "Effects of using a dialogical argumentation instructional model (DAIM) to teach grade 11 learners some concepts of sound by means of indigenous musical instruments". This study involves learners giving their opinions on some concepts of sound through filling of questionnaires and interviews.

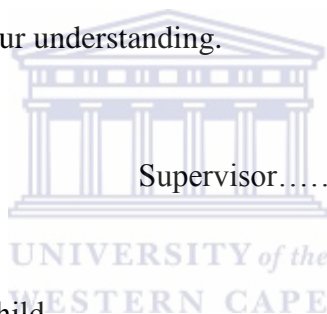
I wish to request your permission to involve your child of in the study. I wish to assure you that the rights and dignity of every learner involved will be respected; that all information will be treated as confidential and the identity of the subjects will not be disclosed to a third party. Also, your child has the right to terminate his/her participation in this study at any time he/she so desires. I therefore request you to grant me your permission by signing the consent form below.

Thank you for your understanding.

Sign

Daniel Anga'ama.

Supervisor.....



I hereby authorize my child..... of to take part in the study entitled "Effects of using a dialogical argumentation instructional model (DAIM) to teach grade 11 learners some concepts of sound by means of indigenous musical instruments".

I understand that all information will be treated with confidentiality, that the identity of the subject will not be disclosed and that my child has the right to withdraw at any time he/she so desires. I further agree to indemnify the University of the Western Cape and its employees from any liability or actions that may ensue from the study for which this consent is granted.

Witness sign.


(Parent/guardian)

Date

APPENDIX H: ARGUMENTATION WORKSHEETS

WORKSHEET FOR INDIVIDUAL TASKS

GROUP CODE

Your claim (opinion)	Your grounds (reasons)
Activity 1	
Activity 2	
Activity 3	 The logo of the University of the Western Cape, featuring a classical building facade with columns and a pediment, with the text 'UNIVERSITY of the WESTERN CAPE' below it.
Activity 4	

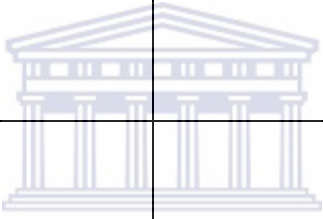
WORKSHEET FOR SMALL GROUP TASKS

ACTIVITY

LEARNER	CLAIM	GROUNDS (REASONS)
CODE		
CODE		
CODE		
CODE		
CODE		
REBUTTALS (disagreements) here →		



WORKSHEET FOR WHOLE CLASS DISCUSSIONS

GROUP	CLAIMS	GROUNDS (REASONS)
REBUTTALS (Disagreements) →	 UNIVERSITY <i>of the</i> WESTERN CAPE	
CONCLUSION →		